A leap towards SAE L4 automated driving features

Use case Sweden

D5.3 Demonstration of CCAM systems and services of goods transport in hub-to-hub

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D5.3 UC Sweden

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Terms and abbreviations

Term / Abbreviation	Description
AGV	Automated Guided Vehicle
ANPR	Automatic Number Plate Recognition
AZ	AstaZero
CCAM	Connected, Cooperative and Automated Mobility
C-ITS	Cooperative Intelligent Transport Systems
ERP	Enterprise Resource Planning
ETA	Estimated Time of Arrival
GDPR	General Data Protection Regulation
GRT	Gothenburg RoRo Terminal AB
L2	SAE level 2[1]
L4	SAE level 4[1]
LSP	Lindholmen Science Park
OEM	Original Equipment Manufacturer
RSU	Roadside-Unit
SAE	Society of Automotive Engineers
SIN	SINTEF
SPaT/MAP	Signal Phase and Timing/intersection geometry message
STA	The Swedish Transport Administration
Sub-UC	Sub-use case
TBD	To Be Determined
TNO	The Netherlands Organisation for Applied Scientific Research
UC	Use case
V2X	Vehicle-to-everything
VOLV	Volvo
VRU	Vulnerable road users
WMS	Warehouse Management System
WP	Work package
YMS	Yard Management System

Several terms are used to refer to the CCAM solutions/vehicles in the project (e.g. L4 CCAM vehicles, L4 CCAM automated vehicles, CCAM vehicles, CCAM AVs). To ensure coherence in the deliverable, the term "CCAM vehicles" (which in this project refers to either L2 or L4 automated electric vehicles) is used throughout the document. L2 and L4 is specified where needed throughout the text.

[1] https://www.sae.org/blog/sae-j3016-update

Introduction

Across Europe, the logistics sector is entering a pivotal phase as technological advances, regulatory developments, and operational needs increasingly align. Although automated freight systems are evolving quickly, the transition from controlled pilots to large-scale, real-life deployment remains challenging. The MODI project addresses this gap by demonstrating how highly automated freight vehicles can operate effectively in real-world conditions. Centred on the Rotterdam–Oslo logistics corridor, MODI brings together industry partners, authorities, and infrastructure providers to test and advance automated freight transport solutions.

Within this corridor, MODI explores five distinct use cases spanning confined terminal areas and public roads. Together, they illustrate the full spectrum of operational challenges: from access control and charging to border crossings, interactions with other traffic, driving on highways and urban environments, loading and unloading operations, and transitions between confined and public environments.

Four regional use cases are located in the Netherlands, Germany, Sweden, and Norway, while the fifth covers the full corridor from Rotterdam to Oslo:

- The Netherlands: Port operations
- Germany: Motorway to harbour
- Sweden: Hub-to-hub
- Norway: Border to port
- UC CCAM test corridor

This report focuses on use case Sweden.

Purpose of this document

The purpose of this document is to describe the demonstration activities carried out for the use case Sweden (UC Sweden). The document also provides a description of the different sub-use cases, their challenges, and the solutions demonstrated, in addition to the involvement and roles of the partners.

The document describes each sub-use case separately and provides a description of the vehicles, equipment and physical and digital infrastructure used.

This document also describes any limitations and constraints that needed to be taken into consideration when performing the demonstration activities.

Finally, the document lists how the demonstration activities have been documented in form of pictures, videos, media coverage, and links.

The document intentionally does not include a reference section due to the sensitive nature of these documents, and therefore not publicly available. The background information about the relevance of the sub-use cases and lessons learned, that was shared at the MODI UC SE final event, have been added as an appendix. Furthermore, films from the demonstrations are publicly shared. Links to the films can be found in the high-level description covering all sub-use cases, and in each sub-use case section covering that specific part.

High-level description of the Use Case overall

UC Sweden focus on hub-to-hub transport with heavy-duty vehicle. The demonstrations include:

- enhanced hub-to-hub driving through connected automation and digitalization from a logistics centre to the port of Gothenburg, and
- a transport between a warehouse and a nearby distribution centre

with the aim to demonstrate the full chain's automation, including loading and unloading, charging, access control, driving on, off and along public roads.

The demonstrations used a L2 Volvo electric truck with advanced digitalization and C-ITS functionalities in some of the demonstrations, and a L4 Einride electric autonomous vehicle with remote operation capabilities in some others.

Identified Sub-Use Cases

The following sub-use cases have been identified for the demonstration activities, as described in the MODI Description of the action:

- Automated loading and unloading: Create and demonstrate a solution for automated loading and unloading of pallets, monitored and partly operated by the remote operator.
- Gate Access: Create and demonstrate gate access services, including request, confirmation & passing based on proper "document" handling.
- Automated charging: Create and demonstrate automated electric charging, including planning, allocating, and confirming slots on premises.
- Driving on public road: Demonstrate L4 driving on and off public roads.

The location of all the demonstration sites and routes are shown in Figure 1 below.

Figure 1: The location of all demonstration sites and routes used in the Swedish UC.

In the film MODI UC SE The Movie (https://vimeo.com/1168848691) all sub-use cases and demonstrations activities are presented. As part of each sub-use case section there is also a link to a shorter film covering only the specific sub-use case.

Challenges and Solutions Demonstrated

The following challenges have been identified, as described in D2.1 Report on UC details[2], and the following solutions have been demonstrated, see Table 1.

Table 1: Challenges and solutions demonstrated for UC Sweden

UC Sweden: Hub-to-hub with heavy-duty vehicle	
Challenges:	• Driving in mixed traffic with heavy trucks at low and high speeds including merging. • Moving from the motorway to regional/local roads. • Driving automated including transitions between confined area and public road. • Interaction with VRUs. • Handover automated driving to central control unit. • Loading/unloading of trucks. • Charging of electric vehicles.
Solutions demonstrated:	• Demonstrate L4 driving on and off public roads. • Demonstrate CCAM systems and services driving L2. • Create and demonstrate gate access services, including request, confirmation and passing based on proper document handling. • Create and demonstrate a system for terminal port booking, allocation, and parking. • Create and demonstrate a solution for automated loading and unloading of pallets, monitored and partly operated by the remote operator. • Create and demonstrate automated electric charging, including planning, allocating, and confirming slots on premises. • Create a better understanding of how and when the remote and the onboard operator have to be involved.

[2] D2.1 Report on UC details, 28th September 2023, A leap towards L4 automated driving features, Simen Rostad Saether (SINTEF) et al.

Partners involved in the use case

The following partners with logo have participated in the use case as partners, associated partners or stakeholders.

Table 2: Partners involved in the Swedish use case.

	Partner	Role in the sub-UC
	Lindholmen Science Park (LSP) https://www.lindholmen.se/en/sciencepark	UC leader
	Volvo (VOLV) https://www.volvogroup.com/en/	Providing the CCAM vehicles for demonstration
	Einride (EIN/ERA) https://www.einride.tech/	Providing the CCAM vehicles for demonstration and the control tower
	Q-Free https://www.q-free.com/	Providing C-ITS systems and applications
	Gothenburg RoRo Terminal (GRT) https://gotroro.com/en/	Providing the physical infrastructure
	DFDS (DFDS) https://www.dfds.com/en/freight-ferries-and-logistics	Providing the physical infrastructure (warehouse, gate), digital infrastructure, and logistics mission
	AstaZero Proving Ground (AZ) https://astazero.ri.se/	Providing the proving ground and the gate including traffic light
	The Swedish Transport Administration https://bransch.trafikverket.se/en/startpage/	Associated partner. Responsible for long-term planning of the transport system for all types of traffic

In addition, the companies Apotea, Babyland, STILL and Rocsys have also contributed, without any formal connection to the project.

Table 3: Companies involved in the Swedish use case.

	Partner	Role in the sub-UC
	Apotea warehouse in Morgongåva (not a partner in the MODI project) https://www.apotea.se/	Providing the physical infrastructure (loading dock) where the pallets with goods from Babyland were delivered
	Babyland warehouse in Morgongåva (not a partner in the MODI project) https://www.babyland.se	Providing the physical infrastructure (loading dock) and pallets with goods that was transported to Babyland warehouse in Morgongåva
	STILL, part of the KION group (not a partner in the MODI project) https://www.still.se/	Providing the automated forklift
	Rocsys (not a partner in the MODI project) https://www.rocsys.com/	Providing the automated charging solution (the ROC-1)

Sub-use case: Automated loading and unloading

The demonstration

The Automatic Loading and Unloading (ALUL) demonstration was a collaborative effort between Einride, STILL (part of the KION Group), and DFDS. It took place at the DFDS logistics site in Viared, an industrial area outside the city of Borås, about 60 km east of Gothenburg, during the end of March and beginning of April 2025.

Figure 2: DFDS warehouse in Viared, the site for the Automated loading and unloading tests and demonstrations.

This demonstration aimed to address the operational gap created by autonomous vehicles, where the removal of the driver eliminates the role that traditionally includes performing physical loading and unloading tasks, and which in many countries is also considered responsible for cargo securing. It creates a gap in the chain that must be filled by warehouse staff or automation.

Einride partnered with STILL, who provided an automated forklift that has been developed outside the MODI project, capable of handling Euro pallets. It uses technology which allows it to navigate without requiring extensive adjustments to existing infrastructure in the warehouse. It is equipped with cameras and sensors, ensuring it stops if obstacles or debris are detected. It has a maximum load capacity of 1500 kg and operates at a speed of 2.0 m/s.

The demonstration followed these steps:

1. Dock the Einride vehicle at the DFDS loading dock
2. Restrain (secure) the vehicle at the loading/unloading dock
3. Manually open the cargo hold door as well as the DFDS port
4. Communicate that the vehicle is docked and ready to be loaded, either:
    a. Manually through the Einride Remote Interface to personnel on site, or
    b. Digitally through an integration between Einride systems and warehouse systems

5. Automatically load the vehicle in accordance with the decided loading scheme
6. Receive information that the vehicle is loaded, either:
    a. Manually through personnel on site to the Einride Remote Interface, or
    b. Digitally through an integration between Einride systems and warehouse systems
7. Manually secure the load and validate that it is secured
8. Manually close the door to the cargo hold as well as the DFDS port
9. Drive automated to loading dock for unloading
10. Repeat step 1, 2, 3 and 4
11. Automatically unload the vehicle in accordance with the decided unloading scheme
12. Receive information that the vehicle is unloaded, either:
    a. Manually through personnel on site to the Einride Remote Interface, or
    b. Digitally through an integration between Einride systems and warehouse systems

At the time for this demonstration the steps 4, 6 and 12 were conducted manually. The DFDS warehouse in Viared was not equipped with a digital system related to those steps.

The evaluation team measured the time to load and unload. Details will be available in deliverable D2.4 Impact analysis report of MODI-CCAM solutions and use cases.

Figure 3: The Einride vehicle is being loaded by STILLs automated forklift. View from warehouse and from inside of the cargo hold.

The Role of the Remote Operator

While the physical loading and unloading is automated, the Einride Remote Operator remains essential for supervising the process and bridging the gap between the autonomous vehicle and the not fully digitalised and automated loading bay. Tasks that the remote operator is conducting in this part of the logistics chain:

- Deciding which loading dock is available, and directing the vehicle there
- Ensures the vehicle is correctly docked and adjusts the vehicle's air suspension to align the cargo hold height perfectly with the loading ramp
- The operator must oversee the loading via cameras in the cargo hold to ensure that the vehicle is correctly loaded and secured

Note that the remote operator retains legal responsibility for load securing and there is no fully automated solution for securing the cargo in the market yet. The liability of cargo securing is likely something that needs to be handled in a future legal framework for automated driving.

Key learnings and findings

- Operational Speed: While automated forklifts are currently slower than manual drivers, they offer a continuous operational tempo. The automated system enables 24/7 operations without breaks, which improves overall system efficiency.
- Maintenance: Automated forklifts also reduce "wear and tear" on the interior of the vehicle's cargo hold compared to manual forklift operations due to in general more careful loading.
- Safety: Removing manual interaction from the loading dock increases safety by separating humans from heavy machinery.
- Standardization of Goods: The system requires pallets to be in good condition, unlike humans, robots are yet advanced enough to "nudge" or adjust irregular stacks to make them fit. Automated systems have stricter tolerances.
- Legal Liability: International regulations are needed to clarify the "grey area" of who is responsible for load securing and liability when no human driver is physically present to verify the cargo securing.
- Infrastructure Standardization: Physical loading dock dimensions must be harmonized, and manual wheel chocks must be replaced with automated vehicle securing mechanisms to remove the need for human intervention on the ground.
- Digital Integration: Autonomous vehicles require full digital integration with Warehouse Management Systems (WMS) or Yard management Systems (YMS) to automatically trigger dock equipment like levellers and doors without manual interventions.
- Remote Operator Role: A remote operator is currently essential to visually monitor the process and assume responsibility for load securing, as no fully automated load-securing technology currently exists and since the remote operator is legally liable for the cargo securing.
- Physical Constraints: Navigating the narrow space inside a trailer and managing the uneven transition between the dock and the vehicle remain technical challenges for automated forklifts.
- Digital Compatibility: A common communication protocol is required to allow different vehicle manufacturers and warehouse systems to communicate without custom made integrations.
- Market Immaturity: The market for automated loading is currently immature, with very few suppliers offering a product capable of automated loading and unloading, and the market for automated load secreting solutions is even more unmature.

Figure 4: The UC-SE team outside the DFDS warehouse with the Einride vehicle docked at the loading bay*, and inside the warehouse with the self-driving forklift.*

Partners involved in demonstration of the Sub-UCs

The table below lists the partners, associated partners and stakeholders actively participating in conducting the demonstration activities.

Table 4: Partners involved and their role in the sub-use case automated loading and unloading.

Partner	Role in the sub-UC
Lindholmen Science Park (LSP)	UC leader
Einride (ERA)	Providing the CCAM vehicles for demonstration
DFDS warehouse in Viared (DFDS)	Provides the warehouse loading dock
STILL, part of the KION group (not a partner in the MODI project)	Providing the automated forklift, also called Self Driving Vehicle (SDV)

Vehicles

The following vehicles have been used during the demonstration activities.

Table 5: Vehicle used in the sub-use case automated loading and unloading.

Vehicle	Owner
CCAM vehicle	Einride
Automated forklift, also called Self Driving Vehicle (SDV)	STILL

Physical and Digital Infrastructure

The following physical and digital infrastructure have been used during the demonstration activities.

Table 6: Physical and digital infrastructure components in the sub-use case automated loading and unloading.

Physical and digital infrastructure	Owner
Loading dock	DFDS warehouse in Viared
Digital communication protocol	STILL
Remote operator	Einride

Constraints and limitations

The following constraints and limitations were considered during the demonstration activities.

This demonstration was conducted inside of the warehouse, thus not affected by the weather outside. It was done without any deviations due to traffic inside the warehouse or failing equipment.

Demonstration activities

The following demonstration activities have been performed:

Table 7: Demonstration activities in the sub-use case automated loading and unloading.

Demonstration activities	Dates
Automated Loading and Unloading (ALUL) set up (preparations, mapping, calibration, tests)	24 March – 1 April 2025
Filming	2 April 2025
Public demonstration	3 April 2025

Documentation

The following documentation in the form of presentations, pictures and videos etc have been collected.

Table 8: Descriptions of demonstration documentation for the sub-use case automated loading and unloading.

Documentation description	Links
Film, recorded 2 April at DFDS in Viared.	https://vimeo.com/1168861040
Presentation at the MODI UC SE Final public event, 11 November 2025 at LSP.	Appendix 1: MODI UC SE Final Event, 2025-11-11 – extract from presentations

Sub-use case: Gate access

The demonstration

At ports and other confined areas there are usually gates and different kinds of physical and digital barriers for the vehicle to handle to enter the confined area, such as gates, and handling of documentation.

UC Sweden has conducted two demonstrators in the sub-use case “Gate access”, one for each OEM in the UC, i.e. one with Einride and one with Volvo. They will be presented separately.

Einride demonstration

Current access control methods—such as entering PIN codes on a keypad, swiping access cards, or speaking to a guard via intercom—require a physical driver. These methods are incompatible with Level 4 vehicles, which lack a cabin or a driver to perform these manual tasks.

The "Gate Access" demonstration was conducted by Einride and Q-Free at the AstaZero proving ground in the beginning of May 2025. A gate and C-ITS equipment were installed at AstaZero to conduct the demonstrations. Within the demonstration, access services such as request, confirmation, and passing based on proper document handling was conducted by Q-Free as C-ITS provider. The demonstration focused on validating a standardized, digital method for autonomous vehicles to enter secure areas without human interaction at the gate. AstaZero Proving Ground is located about 65 km east of Gothenburg and is a fenced off area.

Figure 5: The Einride vehicle demonstrating gate access at AstaZero and the UC-SE team.

The partners demonstrated automated access control using C-ITS (Cooperative Intelligent Transport Systems) technology, specifically utilizing the ITS-G5 communication standard. The demonstration validated that a standardized C-ITS message could replace manual interaction. The infrastructure (gate) communicated its status (open/closed) via the C-ITS modules to the Remote Operator, who then sent the appropriate mission to the vehicle (for example, approves or rejects the vehicles to enter).

The system treated the gate access similarly to a signalized intersection. It used standard messages typically used for traffic lights: SPaT (Signal Phase and Time) to indicate if the gate is "Green" (Open) or "Red" (Closed), and MAP messages to define the lane topology in accordance with ISO/TS 19091. This allowed the remote operator to bridge the gap between the autonomous vehicle and the site infrastructure.

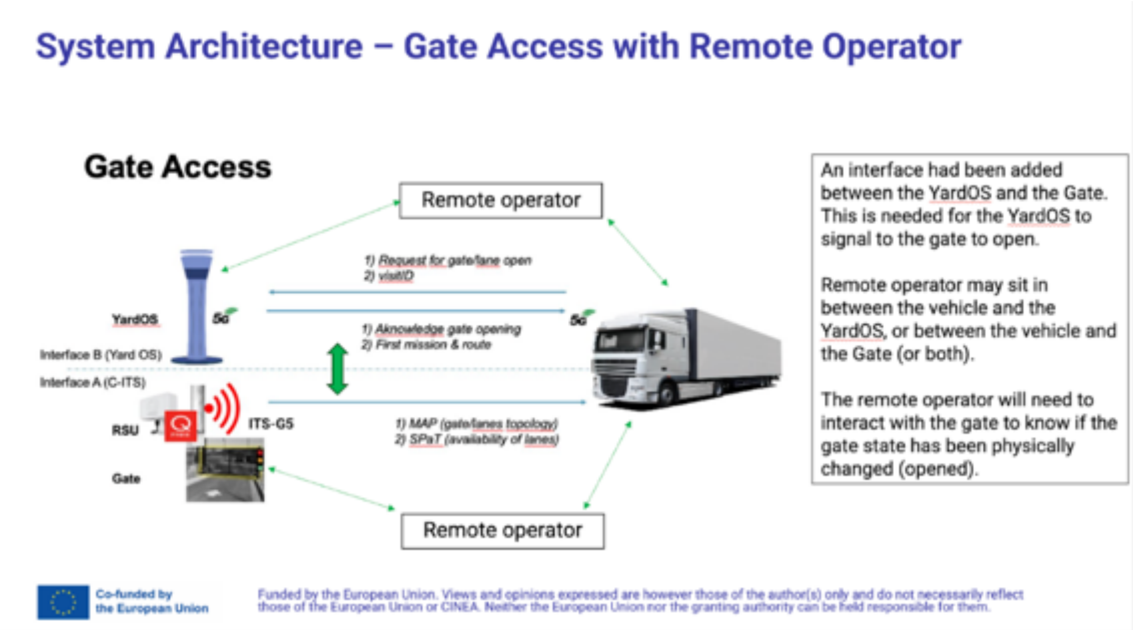


Figure 6: The picture describes the system architecture for gate access with a remote operator.

The demonstration featured a "digital handshake" between the vehicle's systems and the gate infrastructure. Two scenarios were demonstrated: one in which the Einride vehicle was given access to the site and one in which it was not.

The demonstration, when the Einride vehicle was given access to the site, followed these steps:

1. Approach and Initial Communication

   As the autonomous vehicle approached the gated area, the local infrastructure (a Roadside Unit or RSU) constantly broadcasted digital information about the road layout (MAP message) and the current status of the gate (initially set to "red light" and "closed" - SPaT message).

   - Action: The vehicle detected its position relative to the gate and identified that its destination was on the other side and recognized that the lane topology described in the MAP message corresponded to its approach.
   - Request: The vehicle sent a digital Signal Request Message (SRM) to the gate system, effectively asking for permission to enter and requesting a green light. The request included loading bay on the terminal side of the gate enabling gate controller to understand which gate was applicable.
2. Authentication and Decision

The gate system received the request and immediately processed it to ensure security and logistics coordination.

- Verification: The system evaluated the vehicle's unique digital signature (Vehicle ID) and consulted a backend database to check if this specific vehicle had a scheduled arrival slot. This process was secured using certificates issued by the European Union C-ITS Security Credential Management System (EU CCMS).
- Decision: If the vehicle was authorized, the system approved the request. It also determined specific routing instructions, giving detailed guidance to the vehicle on how it should proceed to Loading Bay 1 or Loading Bay 2.

3. Actuation and Confirmation

   Once approved, the physical infrastructure responded to the digital request.

   - Signal: The system sent a Signal Status Message (SSM) back to the vehicle confirming that access was granted.
   - Physical Action: The gate began to open (a process taking approximately 12 seconds), and the traffic light switched to green once the gate was fully open (SPaT message).

4. Execution and Entry

   With the path clear and authorization received, the vehicle executed the final steps of the entry.

   - Operator Oversight: The status (Green Light) and destination instructions were relayed to the Remote Operator (RO). The RO confirmed the mission, ensuring the vehicle proceeded safely.
   - Entry: The vehicle drove through the open gate—which remained open for a defined window (e.g., 10 seconds)—and continued autonomously to dock at the assigned loading bay.

The demonstration, when the Einride vehicle was not given access to the site, followed these steps:

1. Approach and Initial Communication

   As the autonomous vehicle approached the gated area, the local infrastructure (a Roadside Unit or RSU) constantly broadcasted digital information about the road layout (MAP message) and the current status of the gate (initially set to "red light" and "closed" - SPaT message).

   - Action: The vehicle detected its position relative to the gate and identified that its destination was on the other side and recognized that the lane topology described in the MAP message corresponded to its approach.
   - Request: The vehicle sent a digital Signal Request Message (SRM) to the gate system, effectively asking for permission to enter and requesting a green light. The request included loading bay on the terminal side of the gate enabling gate controller to understand which gate was applicable.

2. Authentication and Decision

   The gate system received the request and immediately processed it to ensure security and logistics coordination.

   - Verification: The system evaluated the vehicle's unique digital signature (Vehicle ID) and consulted a backend database to check if this specific vehicle had a scheduled arrival slot. This process was secured using certificates issued by the European Union C-ITS Security Credential Management System (EU CCMS).

- Decision: If the vehicle was not authorized, the system rejected the request.

3. Actuation and Confirmation

   Once rejected, the physical infrastructure responded to the digital request.

   - Signal: The system sent a Signal Status Message (SSM) back to the vehicle confirming that access was denied.
   - Physical Action: The gate did not open.

Figure 7: The Einride vehicle is approaching the closed gate (left). The gate has opened, the Remote Operator's view (right).

Role of the Remote Operator

While the goal is full automation, this demonstration utilized Einride's Remote Operator to bridge the gap between the new C-ITS signal and the vehicle's control system. The Remote Operator received the C-ITS message indicating the gate status (Open/Closed).

Key learnings and findings

- C-ITS Viability: The demonstration validated that C-ITS (Cooperative Intelligent Transport Systems) is a reliable technology for enabling secure, digital access control for autonomous vehicles entering private sites.
- Limitations of Current Tech: Existing methods like keypads, access cards, and cameras were found unsuitable for autonomous operations due to their reliance on manual physical interaction.
- Standardization Necessity: A unified C-ITS standard for gate access is critical to avoid integration problems and prevent manufacturers from needing specific software for every logistics facility they visit.
- Remote Operator Role: The test confirmed that a Remote Operator can safely and effectively manage the entry process by receiving digital gate status messages and commanding the vehicle to proceed.
- Digital Integration: Successful access control relies on connecting the gate's digital signal directly to backend warehouse management systems or yard management systems to verify booking and cargo data automatically.

Partners involved in demonstration of the Sub-UCs

The table below lists the partners, associated partners and stakeholders actively participating in conducting the demonstration activities.

Table 9: Partners involved and their role in the sub-use case gate access.

Partner	Role in the sub-UC
Lindholmen Science Park (LSP)	UC leader
Einride (ERA)	Providing the CCAM vehicle for demonstration and the control tower
AstaZero Proving Ground (AZ)	Providing the proving ground and the gate including traffic light
Q-Free (QFREE)	Providing C-ITS communication equipment (RSU, OBU and Central event management for V2I communication) and application software

Vehicles

The following vehicles have been used during the demonstration activities.

Table 10: Vehicle used in the sub-use case gate access.

Vehicle	Owner
CCAM vehicle	Einride

Physical and Digital Infrastructure

The following physical and digital infrastructure have been used during the demonstration activities.

Table 11: Physical and digital infrastructure components in the sub-use case gate access.

Physical and digital infrastructure	Owner
Proving ground	AstaZero
Gate	AstaZero
C-ITS communication and traffic light	Q-Free
Control tower	Einride

Constraints and limitations

The following constraints and limitations were considered during the demonstration activities.

The demonstration was conducted at the AstaZero proving ground so that the system could be properly verified. The aim of the test was to prove that the suggested solution works in practice. For this, only a few iterations of the test were needed.

The weather during the test period was varying with sun, overcast with rain and with a temperature around 10-13 degrees Celsius. At the film- and final public demonstration days, there was no rain. These demonstrations could then be conducted without any deviations due to traffic, weather or equipment failures.

Demonstration activities

The following demonstration activities have been performed:

Table 12: Demonstration activities in the sub-use case gate access.

Demonstration activities	Dates
Gate Access set up (preparations, calibration, tests)	6 May 2025
Public demonstration	7 May 2025
Filming	8 May 2025

Documentation

The following documentation in the form of presentations, pictures and videos etc have been collected.

Table 13: Descriptions of demonstration documentation for the sub-use case gate access.

Documentation description	Links
Film, recorded 8 May 2025 at DFDS at AstaZero	https://vimeo.com/1168862799
Presentation at the MODI UC SE Final public event, 11 November 2025 at LSP.	Appendix 1: MODI UC SE Final Event, 2025-11-11 – extract from presentations

Volvo demonstration

The "Gate Access" demonstration conducted by Volvo Group in partnership with DFDS and the Gothenburg RoRo Terminal focused on automating the interaction between the truck and the terminal infrastructure to increase efficiency and reduce manual administrative tasks.

Together they demonstrated gate access to a confined area at the Gothenburg RoRo Terminal, about 10 km west of Gothenburg. The demonstration validated a seamless entry and exit process through a "digital handshake" between the vehicle and the infrastructure.

Figure 8: Location for automated gate access demonstration.

The specific steps demonstrated at the Gothenburg RoRo Terminal were:

This demonstrator followed the normal gate access procedure.

1. Driver access: The vehicle was pre-registered to the port entry before reaching the gate through a digital solution including information about the transport company, including ID and name of the CCAM driver.

2. Transport booking: The vehicle booked a timeslot, to pick-up and/or drop off a trailer at Gothenburg RoRo Terminal through a digital solution.
3. Automatic authentication: As the Volvo truck approached the terminal gate, it automatically authenticated itself to the digital gate system. This created a "digital handshake" that verified the vehicle's identity without the driver needing to stop, roll down a window, or manually enter a PIN code.
4. Automated gate operation: Once the authentication was successful, the gate opened automatically.
5. Digital instructions via app: Simultaneously to the gate opening, the terminal system sent specific logistical data—such as the exact location of the trailer to be picked up—directly to the driver's DFDS transport app. This allowed the driver to proceed immediately to the loading zone without stopping for physical paperwork or verbal instructions.

The demonstration also covered the return trip to the DFDS warehouse in Viared, applying similar "Gate Access" principles to goods declarations:

1. Upon approaching the warehouse gate, the truck performed another digital handshake.
2. The system demonstrated automated goods declaration via the cellular network.
3. This allowed the driver to skip the manual check-in and form-filling process, significantly streamlining the administrative side of the transport.

Figure 9: Upon the arrivals at Gothenburg RoRo Terminal, the truck performed a "digital handshake," automatically authenticating itself. The gate opened, and the specific container location was sent directly to the driver's app.

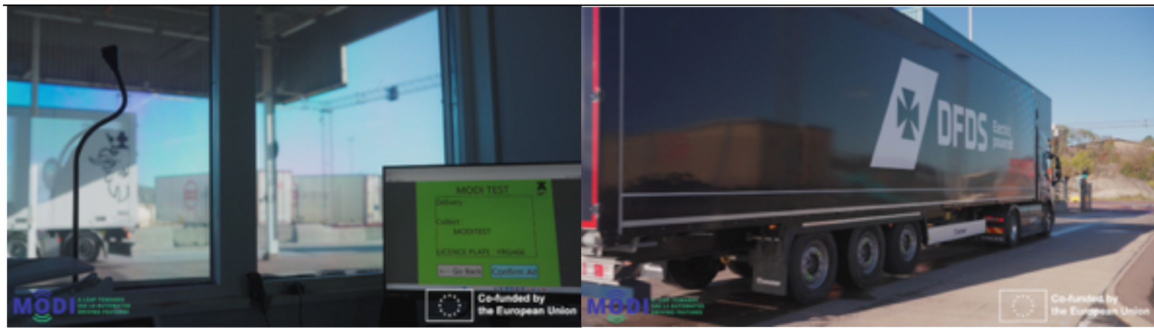


Figure 10: Digital confirmation and authorization to be able to leave the Gothenburg RoRo terminal (left). Digital confirmation and authorization finalized, and gate is open (right).

Key learnings and findings

- Digital Authentication: A secure "digital handshake" via C-ITS was found to be more reliable and secure than visual license plate recognition, which is vulnerable to dirt, theft and weather conditions.
- Operational Streamlining: Automating the gate process eliminates manual check-ins and paperwork, allowing vehicles to digitally declare goods and enter immediately upon arrival.
- Internal Routing: Granting access is insufficient; the terminal must also digitally transmit specific internal coordinates (e.g., trailer location) to guide the vehicle after it passes the gate.
- Cargo Verification: To ensure security, the vehicle must prioritize communicating hidden identification data regarding the specific cargo or trailer it is carrying, rather than relying solely on the truck's license plate.
- Logistics Integration: Integrating the vehicle's real-time Estimated Time of Arrival (ETA) with terminal systems is essential for optimizing planning and handling high-frequency gate passages.
- Mixed Traffic: Terminals must implement systems capable of managing the safe coexistence of both manual and autonomous vehicles simultaneously during the transition period.
- Infrastructure Strategy: Physical gate infrastructure should be minimized in favour of digital pre-clearance systems that allow non-stop flow for authorized vehicles, diverting only exceptions for manual checks.
- Standardization: A unified European standard for communication protocols is required to prevent manufacturers from needing different software configurations for every logistics facility they visit.

Partners involved in demonstration of the Sub-UCs

The table below lists the partners, associated partners and stakeholders actively participating in conducting the demonstration activities.

Table 14: Partners involved and their role in the sub-use case gate access.

Partner	Role in the sub-UC
Lindholmen Science Park (LSP)	UC leader
Volvo (VOLV)	Providing the CCAM vehicles for demonstration
Gothenburg RoRo Terminal (GRT)	Providing the physical infrastructure
DFDS (DFDS)	Providing the digital infrastructure and the logistics mission

Vehicles

The following vehicles have been used during the demonstration activities.

Table 15: Vehicle used in the sub-use case gate access.

Vehicle	Owner
CCAM vehicle	Volvo

Physical and Digital Infrastructure

The following physical and digital infrastructure have been used during the demonstration activities.

Table 16: Physical and digital infrastructure components in the sub-use case gate access.

Physical and digital infrastructure	Owner
Gate at the GRT and digital protocols	Gothenburg RoRo Terminal
Providing the digital infrastructure	DFDS

Constraints and limitations

The following constraints and limitations were considered during the demonstration activities.

The demonstrations were done without any deviations due to traffic, weather nor equipment failures. The terminal was in normal operation at the demonstration, i.e. the gate was used also by other trucks according to the normal procedure.

Demonstration activities

The following demonstration activities have been performed:

Table 17: Demonstration activities in the sub-use case gate access.

Demonstration activities	Dates
Hub2Hub between GRT-DFDS set up (preparations, calibration, pre-tests)	6 October – 7 October 2025
Final tests and filming	8 October 2025
Data collection	9 October – 10 October 2025

Documentation

The following documentation in the form of presentations, pictures and videos etc have been collected.

Table 18: Descriptions of demonstration documentation for the sub-use case gate access.

Documentation description	Links
Film, recorded 8 Oct 2025 at GRT.	https://vimeo.com/1168869293
Presentation at the MODI UC SE Final public event, 11 November 2025 at LSP.	Appendix 1: MODI UC SE Final Event, 2025-11-11 – extract from presentations

Sub-use case: Automated charging

The demonstration

Einride partnered with the company Rocsys to address the operational challenge of charging autonomous vehicles without any human intervention at the AstaZero proving ground in April-May 2025. AstaZero Proving Ground is located about 65 km east of Gothenburg and is a fenced off area.

In this sub-UC, project meetings, workshops, individual discussions, physical tests and demonstrations were held with the project partners involved to gain experience and learnings.

The demonstration consisted of two distinct but integrated demonstrations:

- the physical demonstration of the automated charging
- the digital demonstration of planning the charging sessions

The physical demonstration of the automated charging

The primary goal of the physical demonstration was to demonstrate one possible solution to bridge the gap between current manual charging infrastructure and a charging infrastructure that is compatible with autonomous operations. As SAE Level 4 (L4) vehicles lack a driver in the vehicle to physically plug in the cable, the process must be made digitalised and automated.

Rocsys provided a robotic arm (ROC-1), designed to act as a "hands-free" solution for automated charging. The ROC-1 is not a charger itself, but a robotic arm that moves the charging connector from the mobile charging station to the vehicle charging inlet and connects it automatically without any human interaction. For the test in the MODI project, one ROC-1 was installed at the AstaZero proving ground together with a mobile charging station.

During the test, the ROC-1 accurately detected the Einride vehicle's charging inlet and plugged in a standard CCS (Combined Charging System) connector without any human intervention, enabling fully automated charging.

The demonstration followed these steps:

1. The Remote Operator sends a mission to the Einride vehicle to go charge and park
2. The Einride vehicle parks in the right position
3. The Remote Operator opens the hatch to vehicle's charging inlet
4. The Remote Operator assesses the position of the vehicle and if it's safe to start a charging cycle
5. If everything is ok, the Remote Operator sends a mission to ROC-1 to start the charging operation
6. The ROC-1 moves the CCS connector towards the Einride vehicles charging inlet and connects it automatically
7. When charged, the Remote Operator sends a mission to ROC-1 to stop the charging operation
8. The ROC-1 returns to its starting position
9. The Remote Operator sends a mission to the Einride vehicle to continue with regular operation

During a period of two weeks in April and May 2025, this automated charging solution was used every day by the Einride test team, at the AstaZero proving ground. The tests focused on system compatibility between the ROC-1 and the Einride vehicle, robustness and reliability related to parking distance, ability to connect, charge and disconnect. While the robot solves the connection issue, safety remains paramount. The ROC-1 has sensors to ensure no humans are injured by the moving arm.

The Role of the Remote Operator

In the demonstration, the Einride Remote Operator remained essential for supporting the process and bridging the gap between the autonomous charging infrastructure and the vehicle.

Figure 11: The set up of the Einride vehicle and the Rocsys ROC-1 (left). The automated charging demonstration and part of the UC-SE team (right).

Figure 12: The Robotic arm moves a standard CCS charging connector (left) towards the Einride vehicle's charging inlet and connects (right).

The digital demonstration of planning the charging sessions

While a physical charging robot provides clear benefits, it remains ineffective if the charging slot cannot be booked or if power supply is unavailable. Therefore, Einride also conducted a demonstration of the digitalization of the charging process using their intelligent freight platform, Saga, including planning, allocation, and confirmation of slots on premises.

Einride demonstrated how transport planning and charge planning must be integrated as part of the sub-use case. When a transport mission is planned in Saga, the system automatically checks for available charging slots and power capacity.

A key innovation demonstrated was moving from simple time-slot bookings to energy-based reservations". Given limitations on grid capacity, booking a time slot does not guarantee the vehicle will get the full power it needs (e.g., if four trucks plug in simultaneously, the power might split). Einride's system reserves the specific power and energy required for the vehicle to complete its next mission, prioritizing vehicles based on their departure schedules.

Key learnings and findings

- System Robustness: The tests verified that the Rocsys robotic arm is a robust and reliable hardware solution capable of automating the physical connection between the charger and the vehicle. The parking accuracy needed from the Einride vehicle was on some occasions not fulfilled and the ROC-1 was then unable to succeed with the connection.
- Compatible hardware: The demonstration shows that the Einride autonomous vehicle, with some minor changes, is compatible with the ROC-1 hardware.
- Digital Integration: Successful automated charging requires an "all or nothing" approach where the physical robotic connection is fully supported by digitalized planning, initiation, and termination processes.
- Remote Operator: The Remote Operator could support the process until such a fully digitalised solution is implemented
- Integrated Planning: Integrating charge planning directly with transport planning software reduces charging downtime and increases infrastructure utilization compared to treating them as separate tasks.
- Energy-Based Reservations: Moving from simple time-slot bookings to energy-based reservations allows the system to prioritize power allocation to vehicles with urgent transport missions.
- Standardization Necessity: Adopting specific standards like OCPP 2.0.1 and ISO 15118 is critical to enable the seamless, app-free communication and authorization required for fully automated charging workflows.
- Operational Cost Shift: Removing the driver shifts, the optimization focuses from managing driver rest breaks to minimizing vehicle standstill opportunity costs and leveraging dynamic energy tariffs.

Partners involved in demonstration of the Sub-UCs

The table below lists the partners, associated partners and stakeholders actively participating in conducting the demonstration activities.

Table 19: Partners involved and their role in the sub-use case automated charging.

Partner	Role in the sub-UC
Lindholmen Science Park (LSP)	UC leader
Einride (ERA)	Providing the CCAM vehicle for demonstration and the control tower

AstaZero Proving Ground (AZ)	Providing the proving ground
Rocsys (not a partner in the MODI project)	Providing the automated charging solution (the ROC-1)

Vehicles

The following vehicles have been used during the demonstration activities.

Table 20: Vehicle used in the sub-use case automated charging.

Vehicle	Owner
CCAM vehicle	Einride

Physical and Digital Infrastructure

The following physical and digital infrastructure have been used during the demonstration activities.

Table 21: Physical and digital infrastructure components in the sub-use case automated charging.

Physical and digital infrastructure	Owner
Proving ground	AstaZero
Automated charger solution (ROC-1) and its web application for control	Rocsys (not a partner in the MODI project)
Mobile charger	Einride
Control tower	Einride

Constraints and limitations

The following constraints and limitations were considered during the demonstration activities.

The demonstration was conducted at the AstaZero proving ground so that the system could be properly verified. The weather during the test period varied with sun, overcast with rain and with a temperature around 10-13 degrees Celsius. The ROC-1 could operate in rain, however the mobile charger used had no weather protection, so tests had to pause when heavy rain occurred. At the film- and final public demonstration days, there was no rain. These demonstrations could then be conducted without any deviations due to traffic, weather nor failing equipment.

Demonstration activities

The following demonstration activities have been performed:

Table 22: Demonstration activities in the sub-use case automated charging.

Demonstration activities	Dates
Installation, commissioning and test phase	14 April – 6 May 2025
Public demonstration	7 May 2025
Filming	8 May 2025
Demo of the digitalisation of the charging process	15 December 2025

Documentation

The following documentation in the form of presentations, pictures and videos etc have been collected.

Table 23: Descriptions of demonstration documentation for the sub-use case automated charging.

Documentation description	Links
Film recorded 8 May 2025 at AstaZero proving ground	https://vimeo.com/1168856788
Presentation at the MODI UC SE Final public event, 11 November 2025 at LSP.	Appendix 1: MODI UC SE Final Event, 2025-11-11 – extract from presentations

Sub-use case: Driving on public roads

The demonstration

UC Sweden have conducted two demonstrators in the sub-use case “Driving on Public Roads”, one for each OEM in the UC, i.e. one with Einride and one with Volvo. They will be presented separately.

Einride demonstration

Einride demonstrated driving on a public road, conducting an automated transport flow in a live commercial environment, from Babyland’s warehouse (shipment pickup) to Apotea’s warehouse (delivery) in Morgongåva, covering a distance of approximately 750 m.

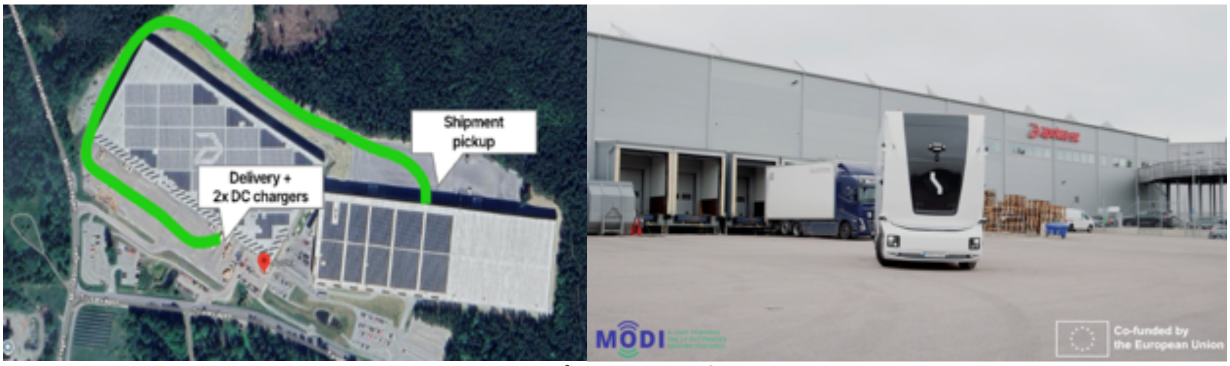


Figure 13: Apotea and Babyland site in Morgongåva, the site for the Einride Driving on public road demonstration (left). Einride vehicle in operation (right).

Although the route is located in an industrial area in Morgongåva, located about 115 km northwest of Stockholm, the Swedish Transport Administration defines it as a public road, as it is accessible to other traffic, including trucks, pedestrians, cars and emergency vehicles. Consequently, Einride had to obtain a test permit to operate there.

Previously, long-haul trucks had to visit both warehouses to pick up goods. The Einride vehicle now consolidates goods by moving them from Babyland to Apotea. This allows long-haul trucks to pick up all cargo from a single location, at Apotea, thus increasing overall transport efficiency. The Einride vehicle operated daily from Monday to Friday, handling at least three transports per day depending on the customer’s needs.

During the MODI project, Einride upgraded their vehicle from Generation 2.0 to Generation 2.1, which featured significant technical improvements resulting in a safe increase in maximum speed, from 5 km/h to 15 km/h. This speed is considered sufficient for many industrial areas, but Einride is continuously working to increase the speed of the autonomous vehicle.

The demonstration followed these steps:

1. Einride vehicle picked up pallets at the Babyland warehouse (the pallets are loaded and load secured manually by Babyland’s staff).
2. Einride’s vehicle drove on a public road with mixed traffic.
    a. the vehicle drove up to 15 kmph on the straight stretches.

b. the vehicle slowed down before the sharp turns and received a rolling approval for the continuation from the Remote Operator.
c. when the vehicle received the approval from the Remote Operator, it completed the turn and continued driving the next stretch.
d. When the vehicle approached the loading dock, it received information on whether it should dock at loading dock A or B, as loading occurred at two different docks depending on the day.
e. When the vehicle received the information, it automatically reversed into the designated loading dock.

3. Apotea's staff manually unloaded the pallets from Einride's vehicle at the designated loading dock.

The Role of the Remote Operator
The vehicle is set to drive autonomously, following a predefined route. However, a Remote Operator supervises the operation.

- The Remote Operator does not drive the vehicle. The Remote Operator monitors the mission and provides high-level decision-making support. For example, when the vehicle couldn't safely see around the corner at Babyland, it stopped and asked the Remote Operator for instructions.
- The Remote Operator also visually inspected the Apotea site via cameras, helping the vehicle select an available loading dock and ensured the vehicle aligns perfectly with the loading dock.
- The Remote Operator is responsible for confirming the vehicle is safe to proceed at specific "approval points" along the route. The Remote Operator can adjust the chassis height (air suspension) remotely to align the Einride vehicle cargo floor with the dock ramp when needed.
- The vehicle interacts with traffic using a safety-first approach. If it meets another vehicle in a tight corner, it will stop and wait. If the situation is complex (e.g., the other driver waves it through), the Remote Operator must interpret the situation and authorize the vehicle to proceed.

Key learnings and findings

- Operational Efficiency: The autonomous shuttle successfully consolidated goods between the two warehouses, which optimized the efficiency of subsequent long-haul transport operations by centralizing cargo pickup.
- Speed and Safety: Increasing the vehicle's speed from 5 km/h to 15 km/h enhanced safety by reducing the frequency of overtaking manoeuvres attempted by other drivers on the public road.
- Speed and Loading time: Increasing the speed has also led to more time to load at the pick-up location, which is important for an industry that is working with fast deliveries - sometimes, delivering the same day of the order.
- Weather Sensitivity: The service operated through the Swedish winter. Despite the harsh conditions, the vehicle achieved high operational reliability. The primary limitation was that the current test permit prohibits driving during rain or snow.
- Remote Operator Role: A Remote Operator remains essential to bridge the gap between the autonomous vehicle and the non-digitalized warehouse environment by making high-level decisions.

- Connectivity Sufficiency: Standard public cellular networks and GNSS coverage were found to be sufficient to support the operation of a single autonomous vehicle in this specific environment.
- Societal Acceptance: Initial scepticism from warehouse staff turned into high social acceptance with site personnel noting they would truly miss the vehicle if it was removed. The warehouse staff reported reduced stress and high acceptance of the technology, valuing the consistent availability of the vehicle compared to the previous manual workflow.
- Corner Cases: Real-world testing proved vital for identifying "corner cases" and complex traffic interactions.

Partners involved in demonstration of the Sub-UCs

The table below lists the partners, associated partners and stakeholders actively participating in conducting the demonstration activities.

Table 24: Partners involved and their role in the sub-use case driving on public road.

Partner	Role in the sub-UC
Lindholmen Science Park (LSP)	UC leader
Einride (ERA)	Providing the CCAM vehicles for demonstration and the control tower
Babyland warehouse in Morgongåva	Providing the physical infrastructure (loading dock) and pallets with goods that was transported to Babyland warehouse in Morgongåva.
Apotea warehouse in Morgongåva	Providing the physical infrastructure (loading dock) where the pallets with goods from Babyland were delivered.

Vehicles

The following vehicles have been used during the demonstration activities.

Table 25: Vehicle used in the sub-use case driving on public road.

Vehicle	Owner
CCAM vehicle	Einride

Physical and Digital Infrastructure

The following physical and digital infrastructure have been used during the demonstration activities.

Table 26: Physical and digital infrastructure components in the sub-use case driving on public road.

Physical and digital infrastructure	Owner
Loading dock	Babyland warehouse in Morgongåva
Unloading dock	Apotea warehouse in Morgongåva
Remote operator	Einride

Constraints and limitations

The following constraints and limitations were considered during the demonstration activities.

This demonstration would not have been possible to conduct (or would have been conducted with limitations) under rainy or snowy weather given restrictions in the permission. The weather was optimal for the demonstration and could be conducted under normal operational conditions at site. No traffic incidents nor failing equipment were registered.

Demonstration activities

The following demonstration activities have been performed:

Table 27: Demonstration activities in the sub-use case driving on public road.

Demonstration activities	Dates
Driving on Public Road set up (preparations, mapping, calibration, pre-tests)	1 June – 1 September 2025
Filming	2 September 2025
Public demonstration	3 September 2025

Documentation

The following documentation in the form of presentations, pictures and videos etc have been collected.

Table 28: Descriptions of demonstration documentation for the sub-use case driving on public road.

Documentation description	Links
Film, recorded 2 September in Morgongåva)	https://vimeo.com/1168858845
Presentation at the MODI UC SE Final public event, 11 November 2025 at LSP.	Appendix 1: MODI UC SE Final Event, 2025-11-11 – extract from presentations

Volvo demonstration

This "Driving on Public Road" demonstration was a collaborative effort involving Volvo Group (providing the vehicles), Q-Free (providing C-ITS communication infrastructure), DFDS (logistics operator), and the Gothenburg RoRo Terminal (destination/origin).

The demonstration that was performed in the beginning of October 2025, utilized a Level 2 battery-electric Volvo truck equipped with V2X (Vehicle-to-Everything) technology to drive a "Hub-to-Hub" logistics route along the RV40 highway between the DFDS warehouse in Viared and the Gothenburg RoRo Terminal. The Gothenburg RoRo Terminal is located about 10 km west of Gothenburg. DFDS warehouse in Viared is an industrial area outside the city of Borås, about 60 km east of Gothenburg (total distance approx. 70 km)

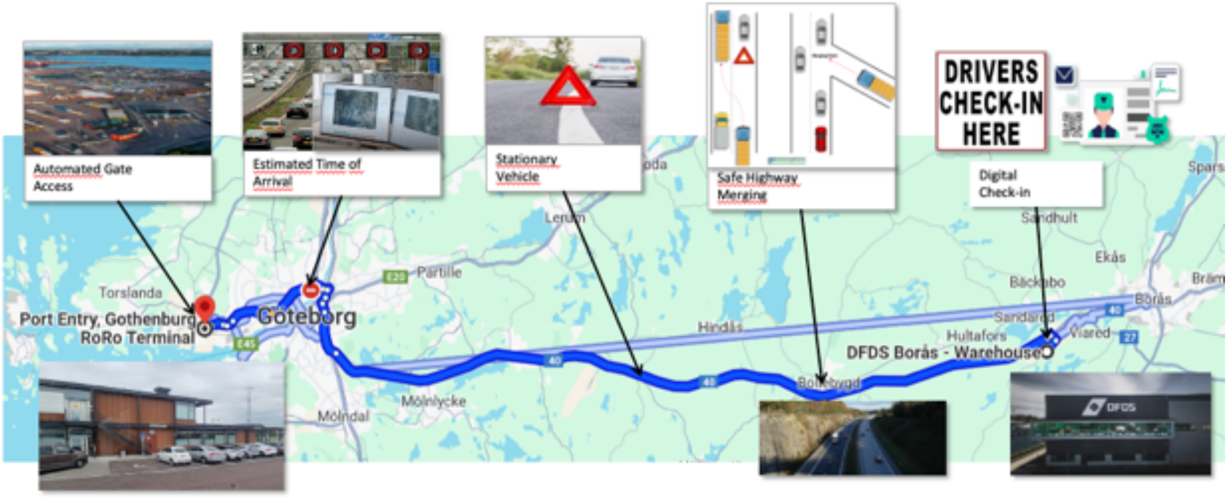


Figure 14: Volvos demonstration route, between Gothenburg RoRo Terminal and DFDS warehouse in Viared.

The demonstration focused on enhanced hub-to-hub driving through connected automation and digitalization. The aim was to support the transition towards higher levels of automated driving functions for logistics operations in environments where trucks and trailers operate in mixed traffic on public roads. This test focused on using connectivity to coordinate with other vehicles to improve safety and flow.

The demonstration included three specific C-ITS scenarios demonstrated along the route:

Scenario 1: Dynamic Estimated Time of Arrival (ETA) and Re-routing

This scenario demonstrated how connectivity helps heavy trucks avoid traffic jams caused by accidents, optimizing logistics flow.

- The Situation: Truck A departed from the DFDS warehouse in Viared heading toward the Gothenburg RoRo Terminal. A simulated car breakdown occurred near Kullamotet, causing a queue on the RV40.
- The Technology: The broken-down car broadcasted a DENM (Decentralized Environmental Notification Message) via both ITS-G5 (short-range) and the cellular network. Truck A received this message from a network node.
- The Action: Truck A reported the hazard to the DFDS back-office server. The server automatically calculated a new route to avoid the congestion and sent an updated Estimated Time of Arrival (ETA) and a new time slot for pickup at the Gothenburg RoRo Terminal.
- The Result: Following the new instructions, Truck A exited the RV40 at Grönkullenmotet, bypassed the queue, and re-entered the highway later, minimizing the delay.

Scenario 2: Cooperative Highway Merging

This scenario addressed the safety challenge of heavy trucks entering high-speed traffic from an on-ramp.

- The Situation: Truck A was driving on the RV40 approaching Grandalsmotet. Truck B attempted to enter the highway from the rest area Grandalen's on-ramp.
- The Action: The two trucks utilized Vehicle-to-Vehicle (V2V) communication to perform a "cooperative merge."
- The Result: The vehicles automatically negotiated speed and position, allowing Truck B to merge safely and smoothly into the traffic flow without forcing Truck A to brake abruptly or creating a dangerous situation.

Figure 15: Successful demonstration of cooperative highway merging on the RV40 (left). The two Volvo trucks used for cooperative merging and passing, and the car from Q-Free used for "stationary vehicle" warning (right).

Scenario 3. Hazard Warning and Cooperative Passing

This scenario tested the ability of connected vehicles to "see around corners" and coordinate lane changes to avoid obstacles.

- The Situation: On the route between the Gothenburg RoRo Terminal and DFDS warehouse in Viared (between Kullamotet and Grönkullenmotet), Truck A (outer lane) and Truck B (inner lane) were driving side-by-side. A stationary vehicle (simulated breakdown) was blocking the outer lane ahead.
- The Technology: The broken-down car broadcasted a Road Hazard Warning (RHW) via ITS-G5 before the car was visible to the truck drivers.
- The Action: Both trucks received the warning immediately. They performed an automatic negotiation via V2V communication.
- The Result: Truck A successfully merged into the inner lane (ahead of or behind Truck B, depending on their negotiations) to pass the blocked vehicle safely, and continued to the DFDS warehouse.

Figure 16: Digital check-in at DFDS warehouse in Viared (left). Parked at designated loading dock at DFDS warehouse in Viared (right).

Key learnings and findings

- Validation: By validating the technologies demonstrated in the three scenarios, Volvo aimed to show that while full autonomy (Level 4/5) is a long-term goal, connected technologies (Level 2+) can provide immediate benefits in safety, productivity, and driver support.
- Logistics Efficiency: Integrating real-time traffic data with logistics systems enables dynamic re-routing and automatic terminal slot updates, significantly optimizing operational efficiency.
- Gate Access Security: Digital C-ITS "handshakes" proved more secure and reliable for terminal access than traditional camera-based license plate recognition, which can struggle with weather conditions.
- Cooperative Safety: Vehicle-to-Vehicle communication successfully enabled safer cooperative highway merging and provided advance warnings for stationary hazards like broken-down cars.
- Infrastructure Challenges: Physical limitations such as short highway entrance ramps and deteriorating road markings pose significant challenges for safe automated merging and lane keeping.
- Infrastructure Strategy: Automated systems must be designed to function without relying on perfect physical infrastructure, which should serve to enhance rather than enable core autonomous capabilities.
- Interoperability: The demonstrated C-ITS standards and vehicle functions proved fully interoperable.
- Digital Process Streamlining: Automated gate authentication eliminates manual check-in procedures, allowing drivers to receive loading instructions directly via an app.
- Mixed Traffic Readiness: Digitalizing vehicle identification and cargo data is a prerequisite for terminals to safely manage the coexistence of manual and autonomous vehicles.

Partners involved in demonstration of the Sub-UCs

The table below lists the partners, associated partners and stakeholders actively participating in conducting the demonstration activities.

Table 29: Partners involved and their role in the sub-use case driving on public road.

Partner	Role in the sub-UC
Lindholmen Science Park (LSP)	UC leader
Volvo (VOLV)	Providing the CCAM vehicles for demonstration
DFDS warehouse in Viared (DFDS)	Providing the physical infrastructure (gate)
Q-Free (QFREE)	Providing C-ITS information at site (along RV40)
Norwegian public road administration (NPRA)	Providing access to Nordic Way 3 server

Vehicles

The following vehicles have been used during the demonstration activities.

Table 30: Vehicle used in the sub use-driving on public road.

Vehicle	Owner
CCAM vehicles (Truck A and Truck B)	Volvo
Break-down vehicle	Q-Free

Physical and Digital Infrastructure

The following physical and digital infrastructure have been used during the demonstration activities.

Table 31: Physical and digital infrastructure components in the sub-use case driving on public road.

Physical and digital infrastructure	Owner
Gate at DFDS warehouse in Viared and digital protocols	DFDS warehouse in Viared
Road-side and vehicle unit with C-ITS communication with CAM and DENM messages, Digital protocols	Q-Free
Nordic Way 3 server and DENM messages	Norwegian publir road administration

Constraints and limitations

The demonstrations were done without any deviations due to traffic, weather nor failing equipment. Variable cloudiness, no rain, 12-15 degrees C.

Demonstration activities

The following demonstration activities have been performed:

Table 32: Demonstration activities in the sub-use case driving on public road.

Demonstration activities	Dates
Hub2Hub between GRT-DFDS set up (preparations, calibration, tests)	6 October – 7 October 2025
Filming	8 October 2025
Data collection	9 October – 10 October 2025

Documentation

The following documentation in the form of presentations, pictures and videos etc have been collected.

Table 33: Descriptions of demonstration documentation for the sub-use case driving on public road.

Documentation description	Links
Film, recorded 8 Oct 2025 at RV40 and at DFDS in Viared.	https://vimeo.com/1168867052
Presentation at the MODI UC SE Final public event, 11 November 2025 at LSP.	Appendix 1: MODI UC SE Final Event, 2025-11-11 – extract from presentations

Learnings

The “Key Learnings and Findings” are outlined in each respective sub-use case section.

In addition to these, additional insights were identified regarding the evaluation of the demonstration setup in the Swedish use case, as presented below:

The original vision – a continuous flow

The initial plan for the Swedish use case was to demonstrate a continuous "Hub-to-Hub" transport chain where Volvo would transport goods from the Gothenburg RoRo Terminal to the DFDS warehouse in Viared, and Einride were to take over the cargo for transport to another local warehouse, creating a seamless handover between the two manufacturers.

The operational reality – a geographical split

While Volvo's route between the Gothenburg RoRo Terminal and the DFDS warehouse in Viared proceeded as planned, the project faced challenges in executing Einride's part of the continuous flow since Einride couldn’t find a logistics customer near Viared available within the project's timeframe, that met the expectation about being able to demonstrate a real logistic flow.

The demonstrations were divided geographically, and into several sub-demonstrations carried out on different dates:

- Einride demonstrated Automated Loading and Unloading at the DFDS warehouse in Viared.
- Einride demonstrated Gate Access and Automated Charging at AstaZero proving ground.
- Einride demonstrated Driving on Public Road in Morgongåva, at a road between the Babyland and Apotea warehouses.
- Volvo demonstrated Gate Access at Gothenburg RoRo Terminal and Driving on Public Road along the route between Gothenburg and Viared.

Partner and permit challenges

The fact that not all partners for the demonstrations were in the project from the beginning led to uncertainties regarding both place and timing of the demonstrations as well as the ability to apply for the permit:

- Einride did not have suppliers for the automated systems at the start of the project. They had to independently find and contract STILL (for the automated forklift) and Rocsys (for the automated charging) during the project's lifecycle.
- The permit from the Swedish Transport Agency for the public road drive in Morgongåva was not granted until August 2025, this was only weeks before the demonstration deadline, causing some stress for the project leadership.

However, as concluded in the next section, there are also advantages with late selection of technology suppliers and partner sites for demonstrations. It´s more about being able to handle the uncertainties through continuous risk management and mitigation plans.

Conceptual success

At the end, the demonstrations were all a success. The demonstrations conceptually proved the full automated logistics chain:

1. First Mile: Einride consolidated goods automatically (demonstrated at Morgongåva).
2. Transfer: Goods were loaded automatically (demonstrated via Automated Loading and Unloading at Viared) and the vehicle was charged automatically (demonstrated at AstaZero).
3. Middle Mile: A Volvo truck picked up the consolidated goods and transported them via a highway to the port (demonstrated on the route between Gothenburg and Viared).
4. Gate Access: Both vehicles utilized digital handshakes when entering terminals (demonstrated at AstaZero and at Gothenburg RoRo Terminal).

The Swedish use case team concluded that being patient regarding the selection of partners and sites was necessary to ensure the right suppliers and real customers were involved, rather than forcing a less effective solution earlier in the process.

Contribution to MODI objectives

In addition to the Key findings and lessons learned in each sub-UC section, and the insights into the setup of the demonstrations above, this section considers the UC Sweden demonstrations' contributions with regards to the overall MODI objectives.

MODI objective 1: Implement the latest technology and overcome major CCAM deployment barriers for logistics by demonstrating business oriented and well integrated CCAM systems across a corridor.

• The Swedish use case successfully demonstrated end-to-end automation across a "hub-to-hub" logistics chain, uniting vehicle OEMs, terminal operators, and technology providers.

• It overcame key deployment barriers by taking Cooperative, Connected and Automated Mobility (CCAM) technologies out of isolated testing facilities and integrating them into real-world commercial operations.

• The use case validated that combining intelligent vehicles with digitalized transport systems significantly enhances operational safety, efficiency, and sustainability within the logistics sector.

Sub-objective 1.1: Develop and implement innovative technologies on a variety of CCAM vehicles for transport of goods.

• Volvo Group implemented Level 2 battery-electric trucks equipped with advanced C-ITS technology to execute complex cooperative maneuvers, such as highway merging and hazard warnings.

• Einride deployed its next-generation Level 4 autonomous, cab-less electric trucks to operate daily commercial freight routes between warehouses.

• The use case integrated cutting-edge complementary hardware onto these vehicles, including STILL's self-driving forklifts for automated loading and Rocsys's robotic arms for hands-free autonomous charging.

Sub-objective 1.2: Develop a standardised interface for coordinating automated vehicles as part of the digital infrastructure, which is validated in logistics operational use cases that have a high business prospect for deployment and are fulfilling the needs of logistics stakeholders.

• A secure C-ITS "digital handshake" was validated as a standardized interface for automated gate access, allowing vehicles to digitally authenticate themselves and automatically receive internal routing instructions without manual checks.

• The use case successfully integrated real-time Estimated Time of Arrival (ETA) updates directly into logistics back-office systems, enabling dynamic terminal slot re-allocation and active rerouting around highway hazards.

• Demonstrations highlighted that standardized protocols like OCPP 2.0.1 and ISO 15118 are essential for seamlessly integrating autonomous fleets with energy-based charge planning and transport management systems.

Sub-objective 1.3: Demonstrate physical and digital infrastructure solutions towards a successful and quick CCAM deployment in private areas and the public domain.

• In the public domain, digital infrastructure solutions were demonstrated using Roadside Units (RSUs) to broadcast MAP/SPaT and hazard messages, enabling safer navigation and dynamic routing on highways like the RV40.

• In private areas, physical infrastructure solutions for Autonomous Loading and Unloading (ALUL) were tested, revealing the critical need to standardize loading dock dimensions and replace manual wheel chocks with automated locks.

• The Swedish Transport Administration concluded that CCAM vehicles must possess enough onboard intelligence to operate safely despite physical infrastructure limitations (e.g., short ramps, poor lane markings), asserting that infrastructure should "enhance, not enable" automation.

MODI objective 2: Define recommendations for supporting infrastructure, vehicle regulation and standards to enable broader CCAM deployment and future large-scale pilots.

• The use case generated comprehensive "Books of Recommendations" advising on the need for unified EU-wide communication protocols and standardized physical logistics interfaces to avoid costly custom software integrations for every terminal.

• Regulatory guidance was provided to resolve legal "grey areas" concerning international liability for load securing when no human driver is present.

• Recommendations emphasized the necessity of defining security levels and mandatory data-sharing rules (e.g., VIN numbers) to resolve GDPR uncertainties at terminal borders.

MODI objective 3: Demonstrate business models and partnerships for CCAM logistics.

• The demonstrations proved that scaling CCAM requires robust, cross-sector partnerships spanning vehicle manufacturers, logistics providers, and infrastructure managers.

• The use case validated new operational business models, such as "freight capacity as a service," which integrates transport operations with dynamic energy tariffs and charge planning to maximize asset utilization.

• A strong business case was established for deploying 24/7 automated operations to directly mitigate the transport sector's severe projected shortage of over 700,000 drivers.

MODI objective 4: Perform technical and socio-economic impact assessments and communicate them in real world CCAM conditions.

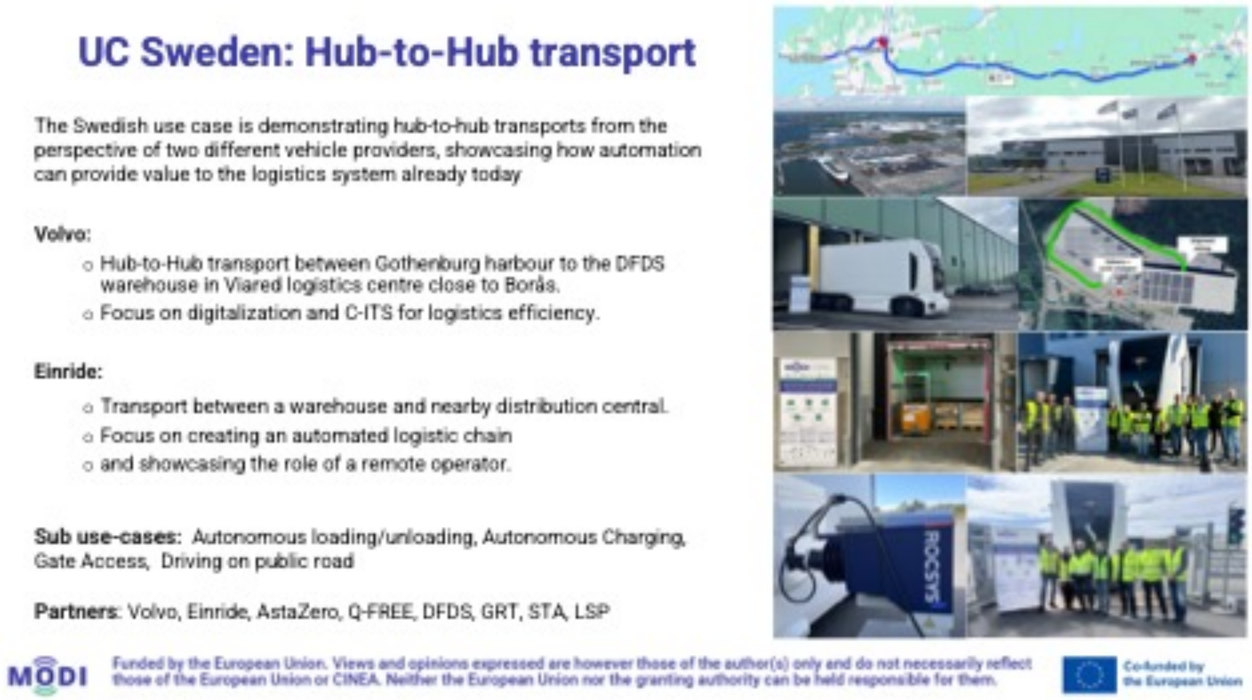
• Real-world testing provided critical technical assessments, identifying operational edge cases—such as heavy snowfall, complex mixed traffic, and varying road geometries—that theoretical simulations often miss.

• Socio-economic assessments highlighted highly positive societal acceptance and reduced stress among warehouse personnel when working alongside automated vehicles.

• The use case actively communicated its findings through public events and defined the critical transitional role of the "Remote Operator" to bridge the gap between autonomous vehicles and legacy warehouse operations.

Appendix 1: MODI UC SE Final Event, 2025-11-11 – extract from presentations


MODI CCAM:
Rotterdam to Oslo
Moss/Oslo, Norway
MODI CCAM test corridor
Gothenburg, Sweden
Hamburg, Germany
Rotterdam, the Netherlands
The Netherlands: Port operations
Germany: Motorway to confined area
Sweden: Hub-to-hub
Norway: Border to port
Source: Jarl Morten Andersen/Dagsavisen


UC Sweden: Hub-to-Hub transport
The Swedish use case is demonstrating hub-to-hub transports from the perspective of two different vehicle providers, showcasing how automation can provide value to the logistics system already today
Volvo:
Hub-to-Hub transport between Gothenburg harbour to the DFDS warehouse in Viared logistics centre close to Borås.
Focus on digitalization and C-ITS for logistics efficiency.
Einride:
Transport between a warehouse and nearby distribution central.
Focus on creating an automated logistic chain
and showcasing the role of a remote operator.
Sub use-cases: Autonomous loading/unloading, Autonomous Charging, Gate Access, Driving on public road
Partners: Volvo, Einride, AstaZero, Q-FREE, DFDS, GRT, STA, LSP
ROCSYS
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UC Sweden – The Movie
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Swedish Transport Administration – Peter Smeds, Senior analyst
11.42 Key Results & Book of Recommendation
11.45 Q/A
12.00 Mingle lunch
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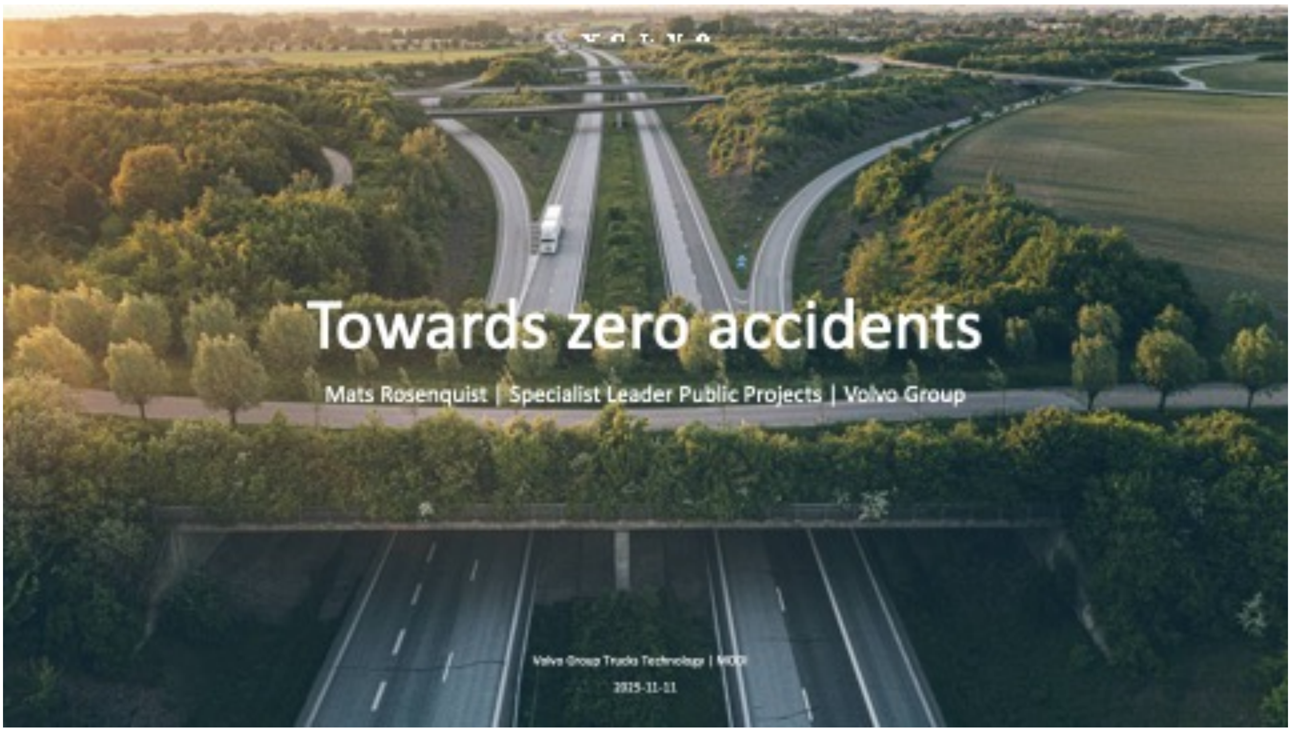
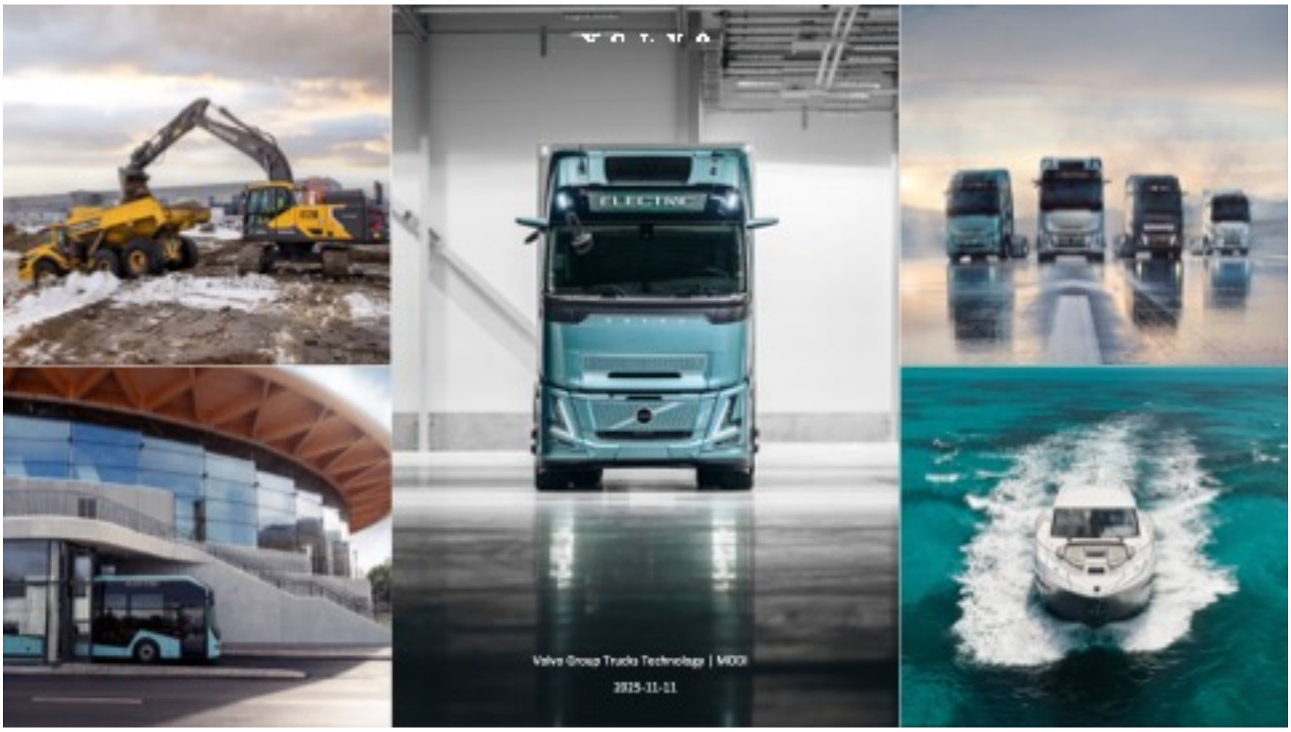
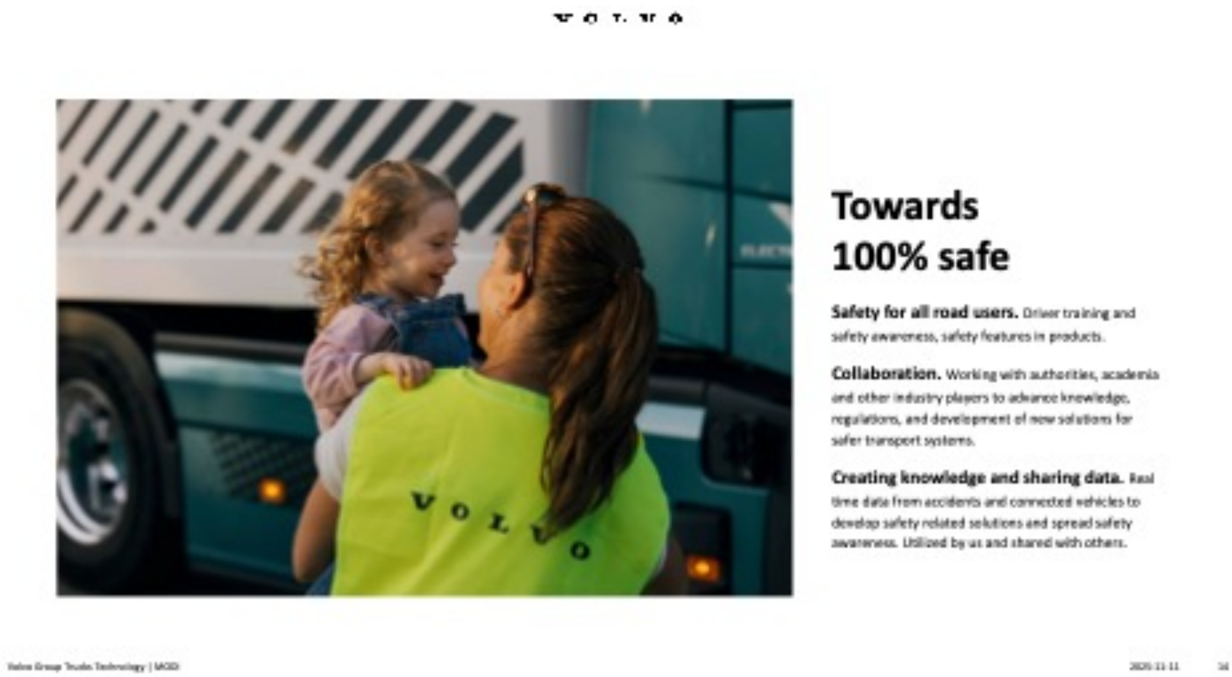

Towards zero accidents
Mats Rosenquist | Specialist Leader Public Projects | Volvo Group
Volvo Group Trucks Technology | MODI


Volvo Group Trucks Technology | MODI


Our vision for the future of transportation and infrastructure
100%
SAFE
100%
FOSSIL-FREE
100%
MORE PRODUCTIVE


Towards
100% safe
Safety for all road users. Driver training and safety awareness, safety features in products.
Collaboration. Working with authorities, academia and other industry players to advance knowledge, regulations, and development of new solutions for safer transport systems.
Creating knowledge and sharing data. Real time data from accidents and connected vehicles to develop safety related solutions and spread safety awareness. Utilized by us and shared with others.

Building on EU projects

AEROFLEX – Aerodynamic and Flexible Trucks for Generation of Long-Distance Road Transport

ENSEMBLE – Enabling safe multi-brand platooning for Europe

HI-DRIVE – Addressing challenges toward the deployment of higher automation

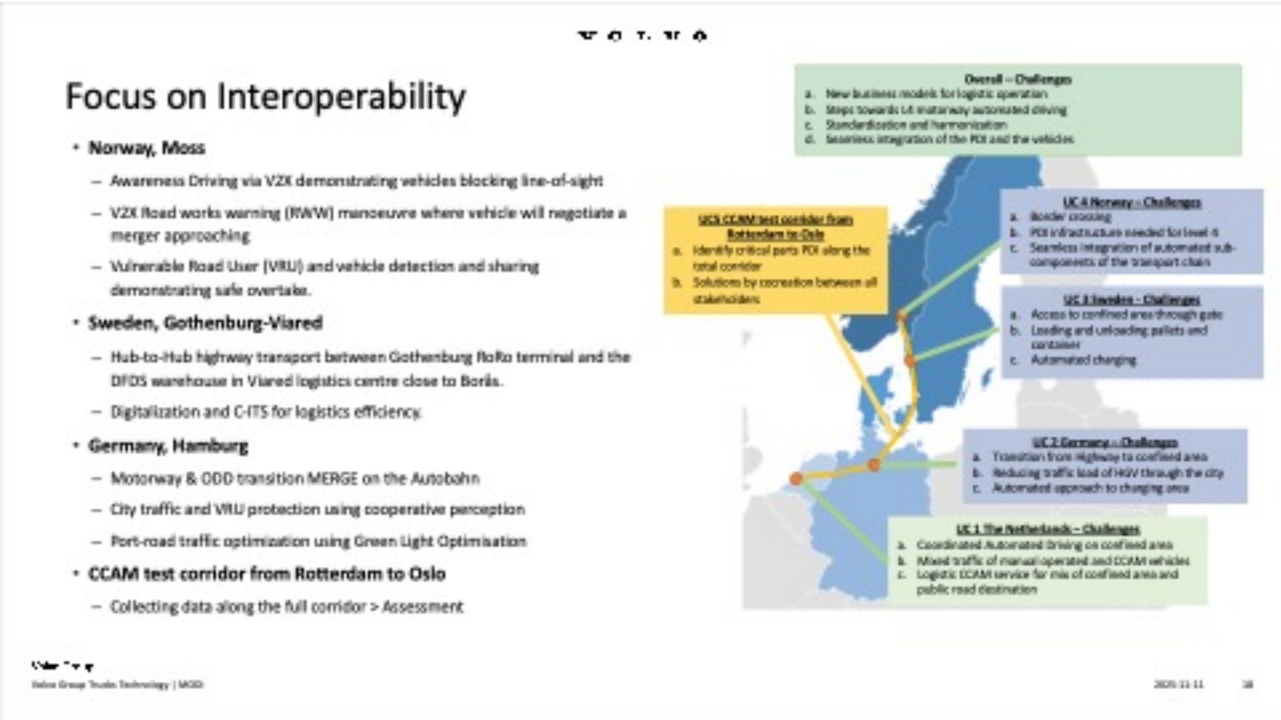
ZEFES – Taking Zero-Emission Long-Haul Freight Transport in Europe to the next level

MODI – Pave the way for highly automated solutions to improve European logistic chains

Volvo Group's role in MODI

- Volvo Group provides **C-ITS equipped L2 BEV vehicles** focusing on **V2X connectivity and services** interoperability and the benefits of the logistics users needs.
- Volvo Group participates in UC Germany (**Hamburg**), Sweden (**Gothenburg**), Norway (Svinesund – **Moss**) and in the overall **Rotterdam to Oslo corridor**.
- Volvo Group is work package leader for coordinating all use-cases.


Gothenburg: Enhanced Hub-to-Hub Driving
- Through Connected Automation and Digitalization
Automated Gate Access
Estimated Time of Arrival
Stationary Vehicle
Safe Highway Merging
DRIVERS CHECK-IN HERE
Digital Check-in
Port Entry, Gothenburg RoRo Terminal
Göteborg
DFDS Borås - Warehouse


Focus on Interoperability
Norway, Moss
Awareness Driving via V2X demonstrating vehicles blocking line-of-sight
V2X Road works warning (RWW) manoeuvre where vehicle will negotiate a merger approaching
Vulnerable Road User (VRU) and vehicle detection and sharing demonstrating safe overtake.
Sweden, Gothenburg-Viared
Hub-to-Hub highway transport between Gothenburg RoRo terminal and the DFDS warehouse in Viared logistics centre close to Borås.
Digitalization and C-ITS for logistics efficiency.
Germany, Hamburg
Motorway & ODD transition MERGE on the Autobahn
City traffic and VRU protection using cooperative perception
Port-road traffic optimization using Green Light Optimisation
CCAM test corridor from Rotterdam to Oslo
Collecting data along the full corridor > Assessment
Overall – Challenges
a. New business models for logistic operation
b. Steps towards L4 motorway automated driving
c. Standardization and harmonization
d. Seamless integration of the PDI and the vehicles
UC4 Norway – Challenges
a. Border crossing
b. PDI infrastructure needed for level 4
c. Seamless integration of automated sub-components of the transport chain
UC3 Sweden – Challenges
a. Access to confined area through gate
b. Loading and unloading pallets and container
c. Automated charging
UC2 Germany – Challenges
a. Transition from Highway to confined area
b. Reducing traffic load of HGV through the city
c. Automated approach to charging area
UC1 The Netherlands – Challenges
a. Coordinated Automated Driving on confined area
b. Mixed traffic of manual operated and CCAM vehicles
c. Logistic CCAM service for mix of confined area and public road destination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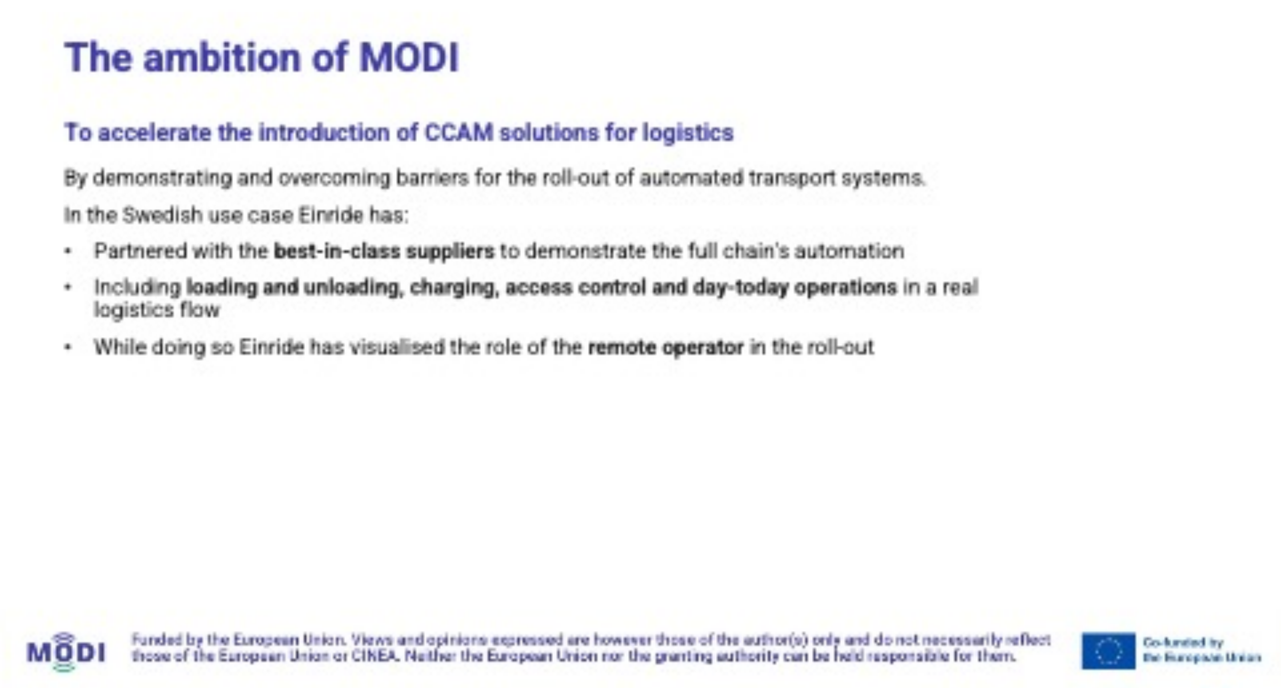
The ambition of MODI
To accelerate the introduction of CCAM solutions for logistics
By demonstrating and overcoming barriers for the roll-out of automated transport systems.
In the Swedish use case Einride has:
• Partnered with the best-in-class suppliers to demonstrate the full chain's automation
• Including loading and unloading, charging, access control and day-today operations in a real logistics flow
• While doing so Einride has visualised the role of the remote operator in the roll-out
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Automated Logistics

Why is this relevant?

- Electric and automated freight solution tackles major industry challenges: transport inefficiencies, greenhouse gas emissions, and a global shortage of professional truck drivers
- Future proofing our business
- Understanding of operational challenges
- Validate HW and SW
- Increase societal acceptance

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Automated Logistics

The Test and Demonstration

- Third party safety assessment performed by RISE
- Permit for daily operation with new generation vehicle approved by Transportstyrelsen
- A new generation vehicle deployed at Apotea
- Daily operations conducted from December - September
- Goods are being transported every day, minimum 3 shipments a day
- Remote operator in Gothenburg
- Demo event in early September

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Automated Logistics

Learnings

- It is important to deploy early and get the chance to validate the HW and SW
- Operate and learn in a logistics flow
- Handle rain and snow are important features for increased operational uptime
- Snowbanks can create a problem - clear maintenance instructions
- Increasing speed from 5 - 15 km/h resulted in less overtakings by other trucks
- Increased social acceptance
- Public network is enough for deployment of at least one autonomous vehicle on the site
- Poor GNSS coverage by the loading dock
- The RO is important to bridge the technology gap to enable autonomous operations already today

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Autonomous Loading and Unloading

Why is this relevant?

- The current Einride use case for autonomous transports is repetitive flows and short distance. Loading and unloading is an important part of that flow
- Manually loading pallets with a fork lift has proven to create wear and tear to the inside of the cargo hold
- Customers have expressed a wish to automate this use case
- Higher automation at the site, increase the need to solve the challenge
  - Removing the driver from the loading dock offers challenges regarding responsibility:
  - Who/what will do the actual loading/unloading of the goods to/from the cargo hold?
- Which business partner is responsible for the task of loading/unloading when removing the driver?
- Working at the loading bay is an unsafe working environment since accident can happen in this interface

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Autonomous Loading and Unloading

The Test and Demonstration

- Loading and unloading EU-pallets with STILL
- March - April 2025 at DFDS warehouse in Viared
- Test
  - Measuring speed of loading/unloading
  - Tolerance SDV, dock and autonomous vehicle

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Autonomous Loading and Unloading

Learnings

- The system should be set up to increase system efficiency
- Autonomous loading/unloading will lower the risk of wear and tear to the inside of the cargo hold, and thus reduce risk of unwanted downtime. It also decreases maintenance cost for the SDV.
- Removing manual interaction leads to increased overall safety
- Interesting to follow product and market development in the US and in Europe
- Offering solutions for end to end automated transports, including loading and unloading, builds customer trust
- Go to market can be supported by partners

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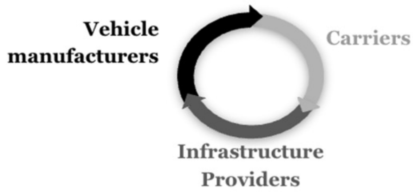
Autonomous Charging

Why is this relevant?

- Mature solution **incompatible** with autonomous flows, but compatible solutions are immature
- Long **production lead times** and vehicle lifespans require advance planning
- **Dependency** across system create a chicken-and-egg dilemma



- The industry is expected to evolve through cumulative **adjustments**
- This favour **technologies aligned** with existing system and practices

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Autonomous Charging

The Test and Demonstration

- A **Rocsys** robotic arm was installed at the charging station at the AstaZero test track
- The Einride autonomous vehicle used the charger and robotic arm for charging for a **period of 4 weeks**
- Testing primarily reliability and robustness

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Autonomous Charging

Learnings

- If the use case requires automated charging, a robotic arm could be a **viable option**
- The solution is robust, has an acceptable level of tolerance and is **reliable**
- Electrification + Digitalisation + Automation
- It needs to be all or nothing, **SW + HW**

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Gate Access

Why is this relevant?

- Different solutions
  - Key pad with PIN code
  - Access card
  - Phone number
  - License plate reading by cameras
  - Electric tags (DSRC or RFID)
- Access to a site, and also within a site
- Different levels of security and cybersecurity

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Gate Access

The Test and Demonstration

- Using C-ITS as a standardised gate access technology
- The test and demonstration was conducted at AstaZero
- In May 2025
- The remote operator received C-ITS messages conveyed from the gate, then ordered the vehicle to act accordingly

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Gate Access

Learnings

- The value of demonstrating a new type of access control that are using standard technology and messaging has the potential to:
  - Increase the value of C-ITS as a technology
  - Increase the level of standardisation for gate access control
- The solution is robust and works for the intended use case
- Needs to be integrated with a yard operating system

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The role of the remote operator
• Autonomous loading and unloading
• Gate allocation
• Make sure the vehicle is correctly docked and in the correct state
• Oversee loading/unloading
• Responsibility for cargo securing as legal driver
• Communicating with warehouse
• Autonomous charging
• Initiate charging
• Gate access
• Send mission to autonomous vehicle
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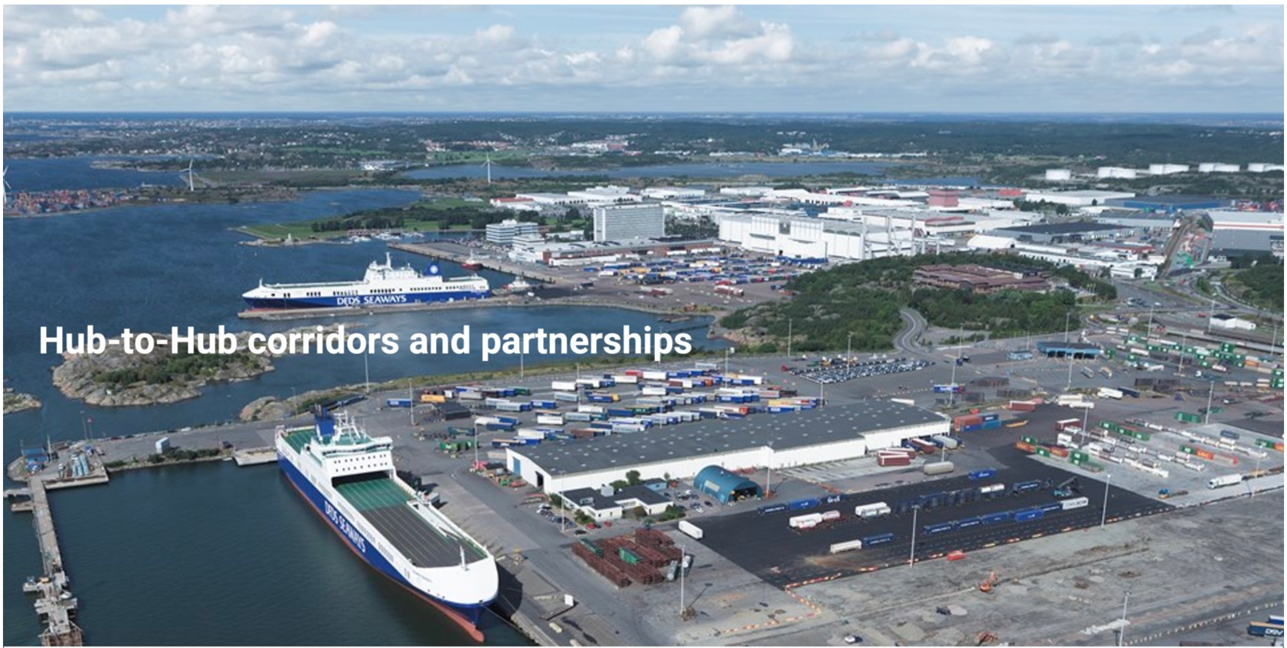

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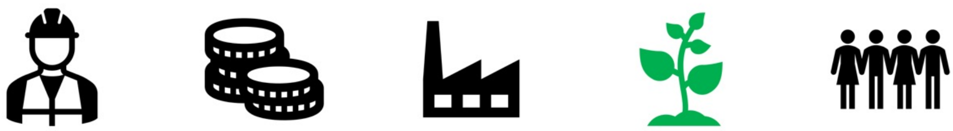
Why is autonomous relevant for DFDS?



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Our hardware to automate
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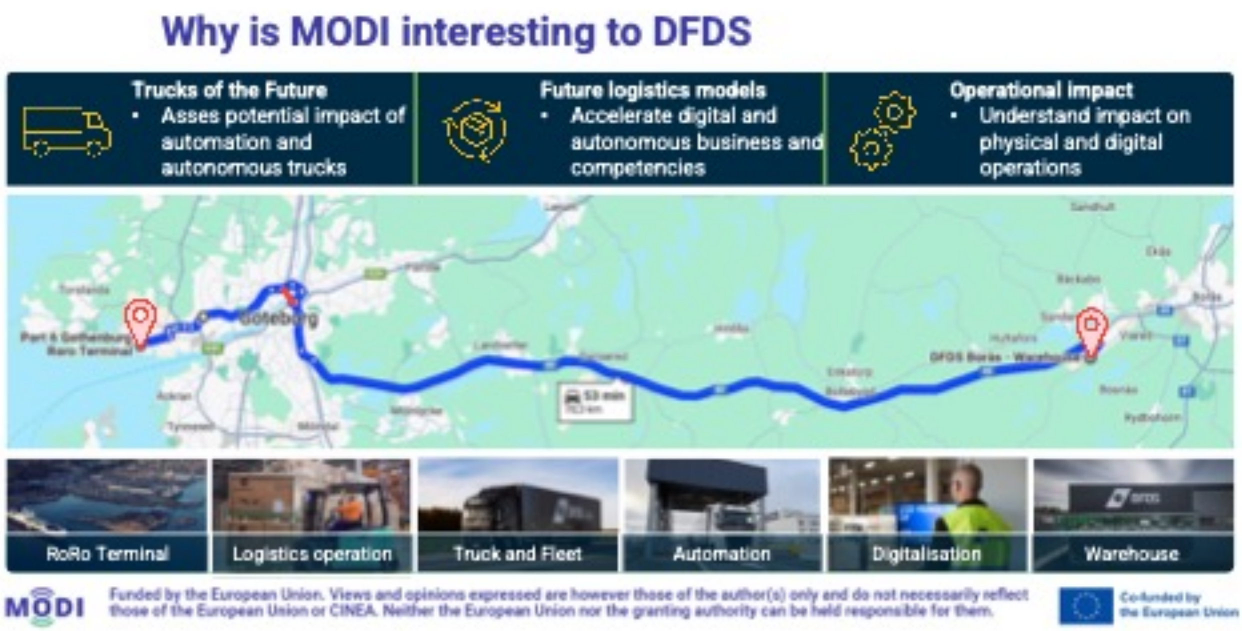
Why is MODI interesting to DFDS
Trucks of the Future
Asses potential impact of automation and autonomous trucks
Future logistics models
Accelerate digital and autonomous business and competencies
Operational impact
Understand impact on physical and digital operations
Göteborg
RoRo Terminal
Logistics operation
Truck and Fleet
Automation
Digitalisation
Warehouse
MODI


DFDS Role in Use Case
Logistics Operator
Transport and fleet planner
Digitalisation and automation of processes
Site operator
Warehouses, terminals and other logistics sites
Digital and physical infrastructure
Business model impact
Future partnership models
Future business models
DFDS
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Swedish Hub-to-Hub use case
Fleet (AS-IS)
• Mixed (BEV & ICE)
• 3 drivers / truck
Flows (AS-IS)
• Contract logistics
• 2-5 trips / day
Operation (AS-IS)
• Manual booking & follow-up
Göteborg
53 min
RoRo Terminal
Transport Planning
Truck and ETA
Gate access
Document handling
Warehouse
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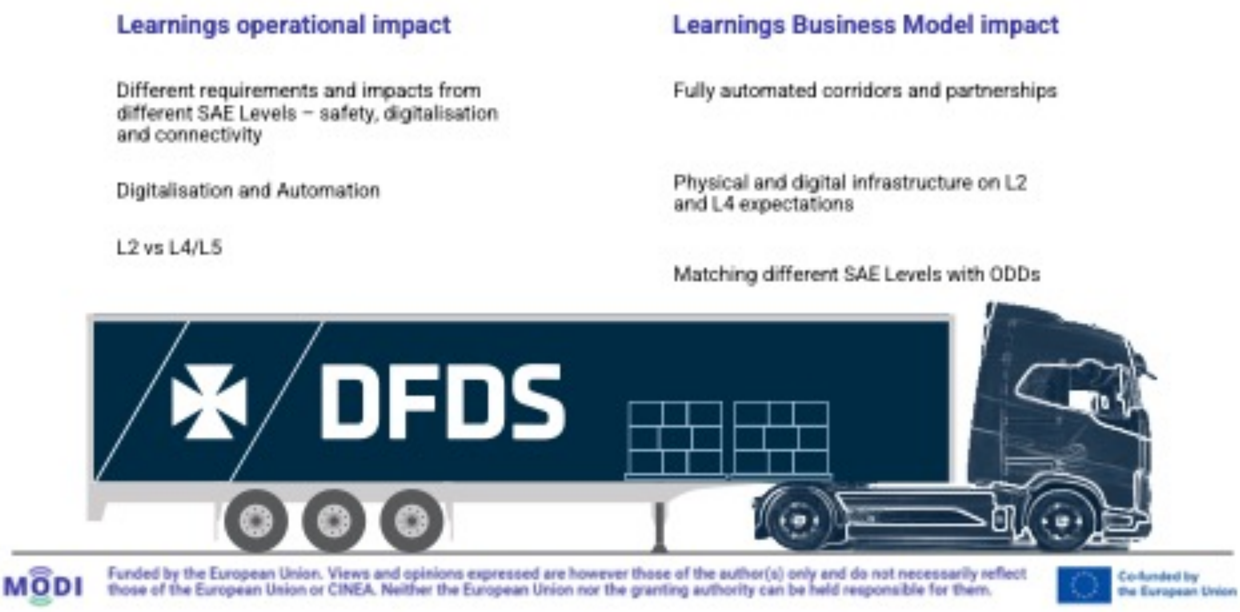
Learnings operational impact
Different requirements and impacts from different SAE Levels – safety, digitalisation and connectivity
Digitalisation and Automation
L2 vs L4/L5
Learnings Business Model impact
Fully automated corridors and partnerships
Physical and digital infrastructure on L2 and L4 expectations
Matching different SAE Levels with ODDs
DFDS
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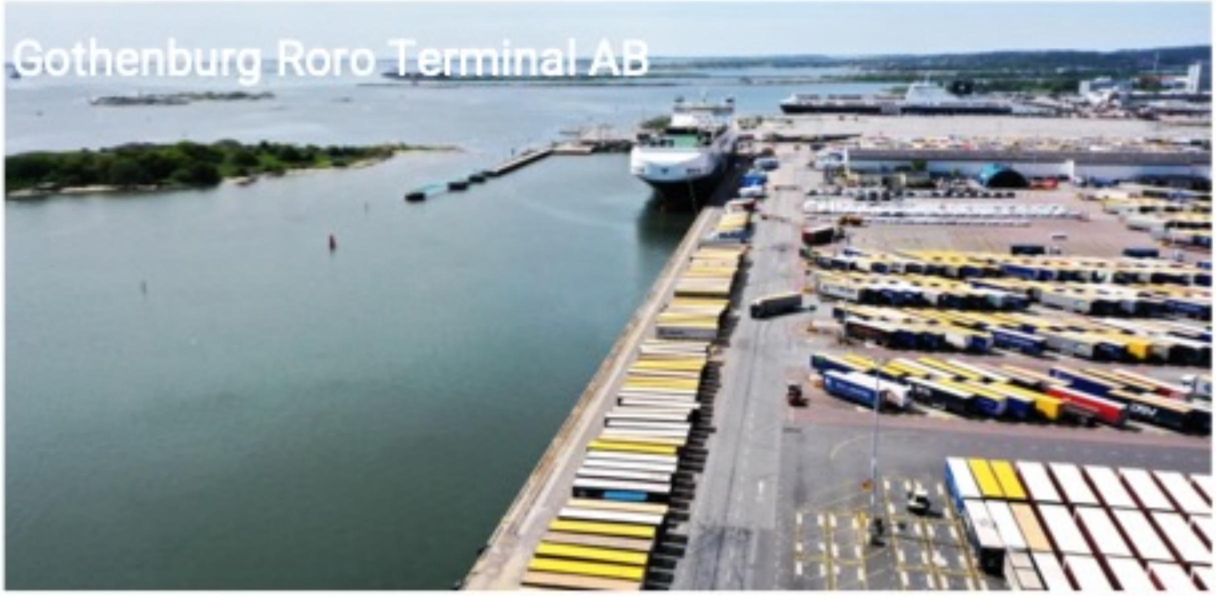

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Why is autonomous relevant for GRT?

Objective: To study the requirement from automation and autonomous technology on terminal operations

Key points:

- ETA and gate access for autonoumus vehicles
- Digital and physical infrastructure – interaction areas between man and machine
- Understanding our customers needs and how to adapt to those
- What will the impact for the terminal be and how we can use the new technology to our advantage

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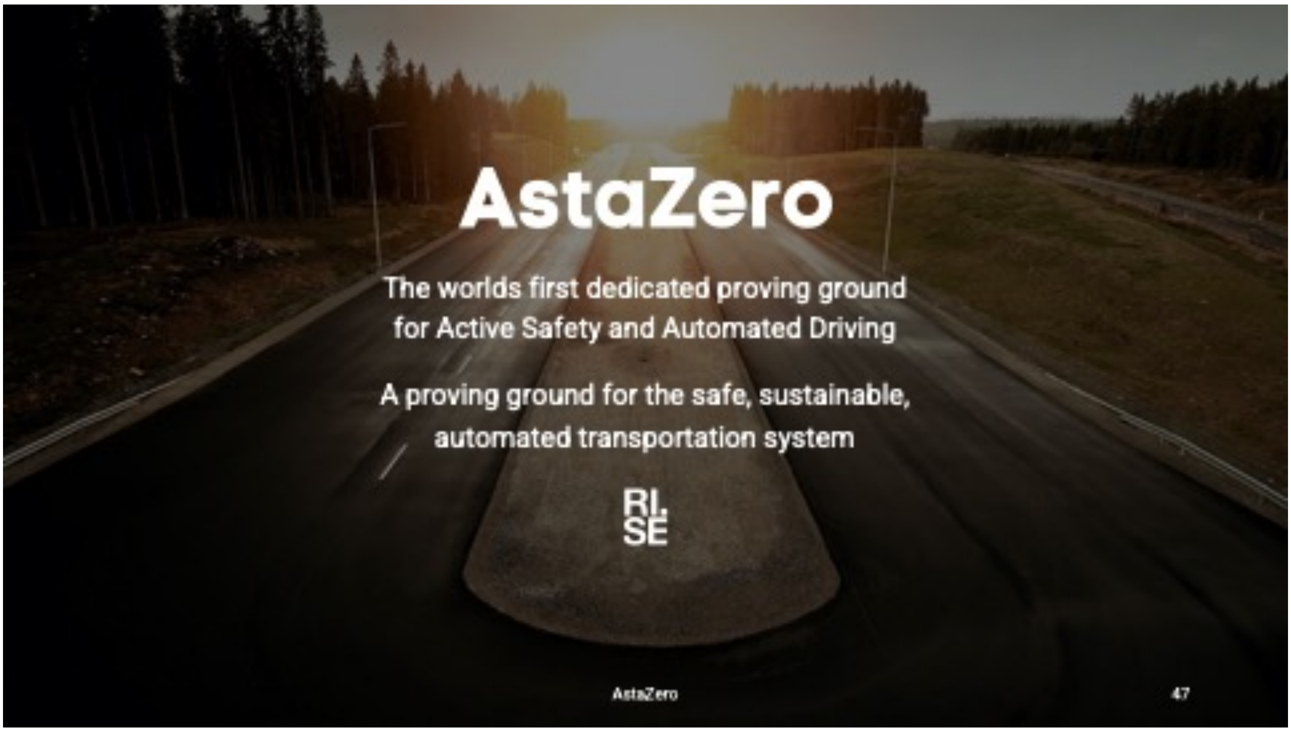
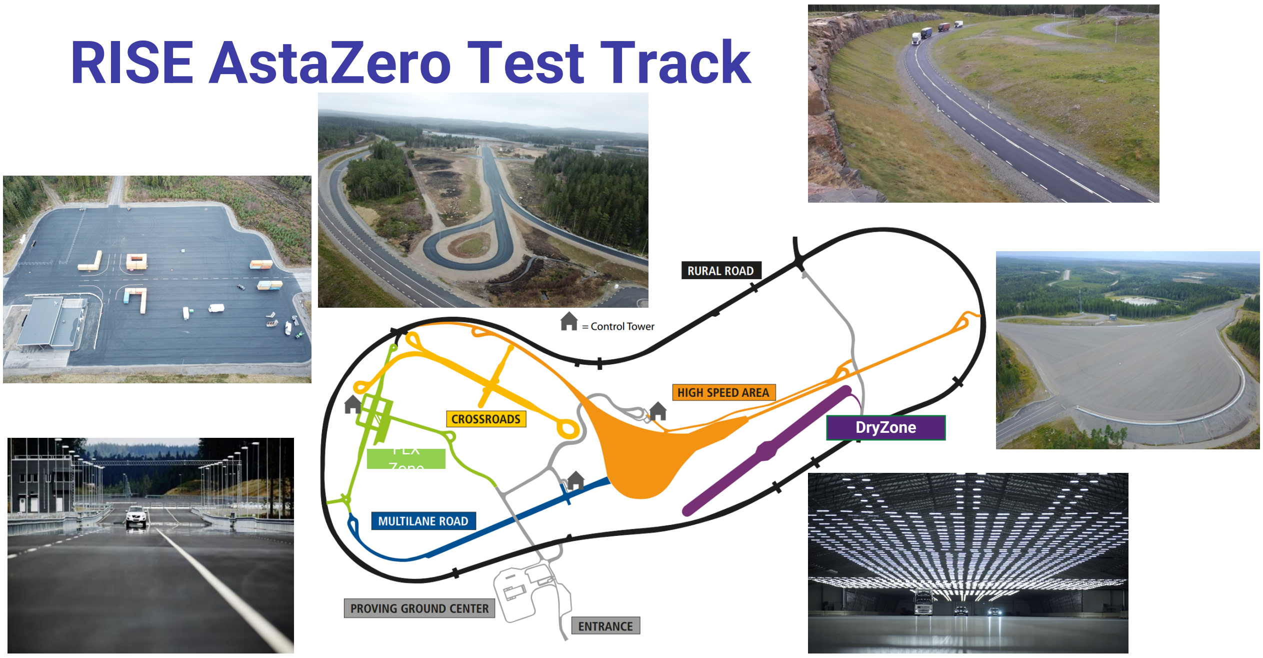
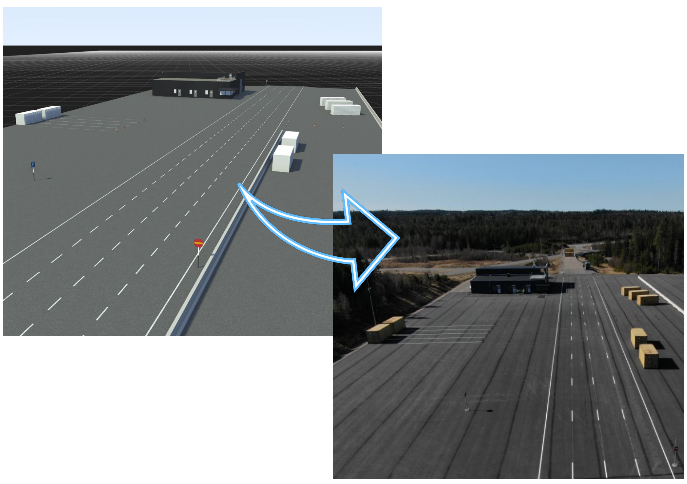


AstaZero
The worlds first dedicated proving ground for Active Safety and Automated Driving
A proving ground for the safe, sustainable, automated transportation system
RI. SE
AstaZero
47

RISE AstaZero Test Track



Physical replication of Target Operational Domains in Controlled Environments



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Vehicles ready for demonstrations

Risk assessment

Requirements from:
- Vehicle regulations
- Trial permits
- Road owner
- Site owner

Safety of the intended functionality

Operational disturbance?

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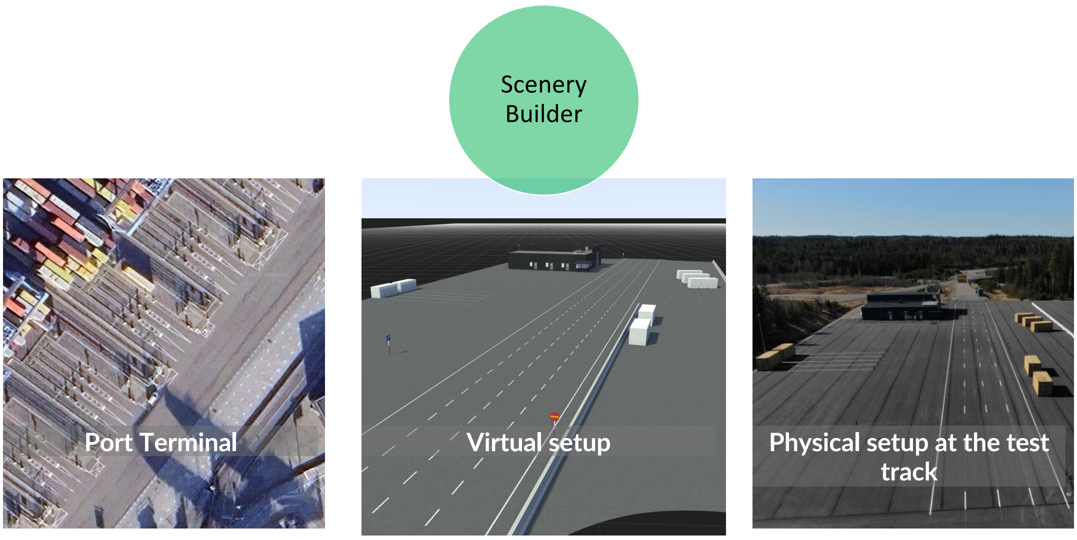
AstaZero test planning factory



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Apotea
Gökholmen
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Possible usage of the test planning factory: UC SE
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Possible usage of the test planning factory

- Stakeholder understanding of behaviour
  - Authorities
  - Site owners
  - Managers in development
- Testing "at site" without disturbance
- Test risk scenarios

What more?

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Agenda

- 10.00 Welcome
- 10.03 Introduction to MODI and UC SE
- 10.10 Premiere UC SE film
- **10.35 Results and learnings**
  - Volvo Group - Mats Rosenquist, Public Partnerships
  - Einride - Pia Wijk, Project Manager, Research & Innovation
  - DFDS – Mads Skovsgaard Rasmussen, Project Manager, Innovation & Partnerships
  - Gothenburg RoRo Terminal - John Wikström, Digital Development Manager
  - Asta Zero - Johanna Persson, R&D Engineer
  - **Swedish Transport Administration – Peter Smeds, Senior analyst**
- **11.42 Key Results & Book of Recommendation**
- **11.45 Q/A**
- **12.00 Mingle lunch**

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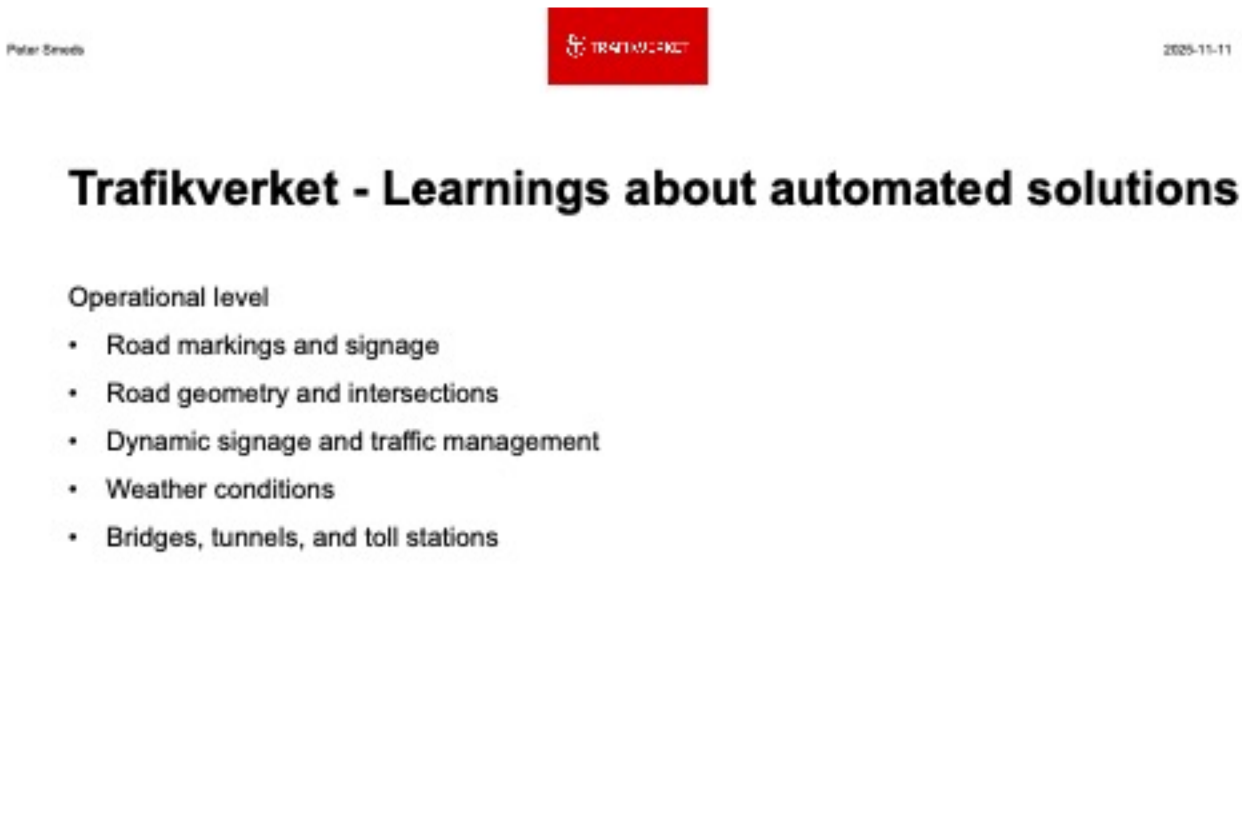
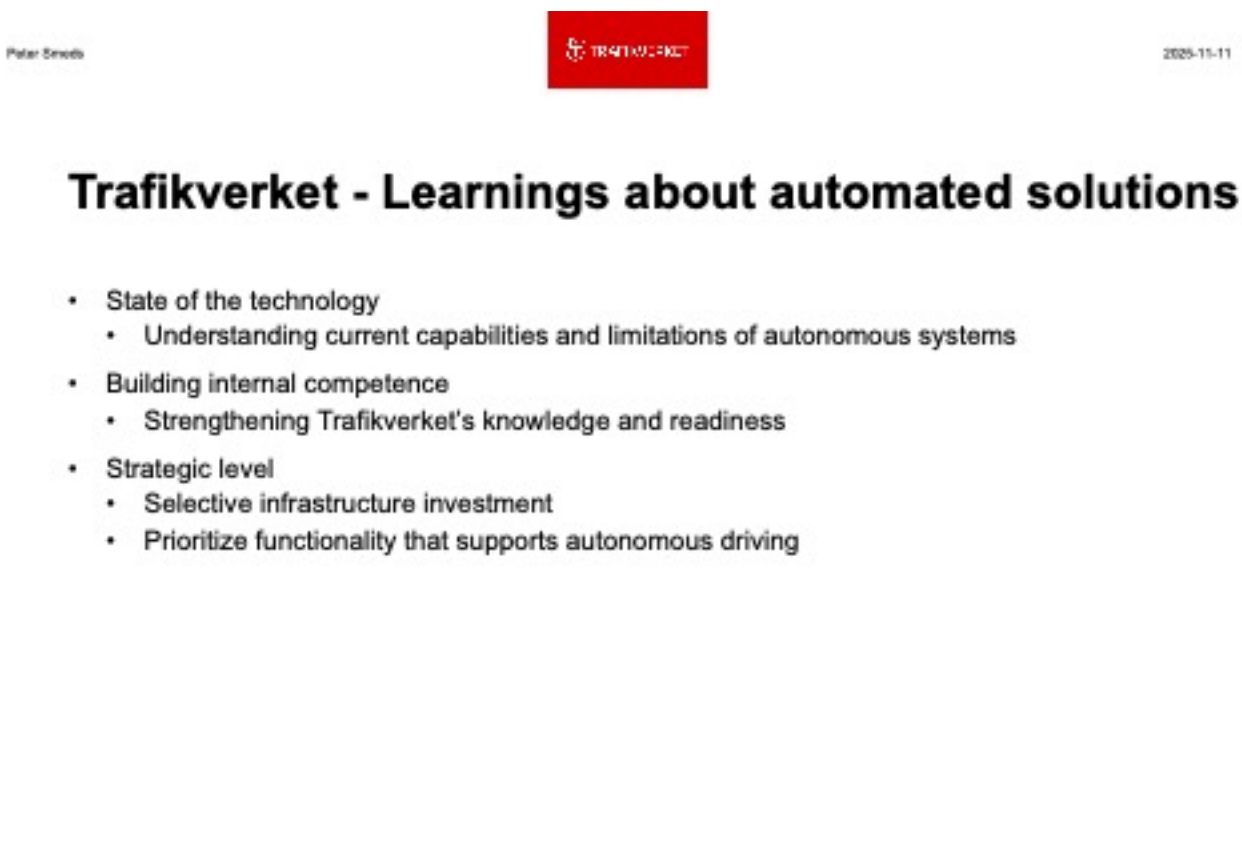

Trafikverket - Learnings about automated solutions
Operational level
• Road markings and signage
• Road geometry and intersections
• Dynamic signage and traffic management
• Weather conditions
• Bridges, tunnels, and toll stations


Trafikverket - Learnings about automated solutions
• State of the technology
• Understanding current capabilities and limitations of autonomous systems
• Building internal competence
• Strengthening Trafikverket's knowledge and readiness
• Strategic level
• Selective infrastructure investment
• Prioritize functionality that supports autonomous driving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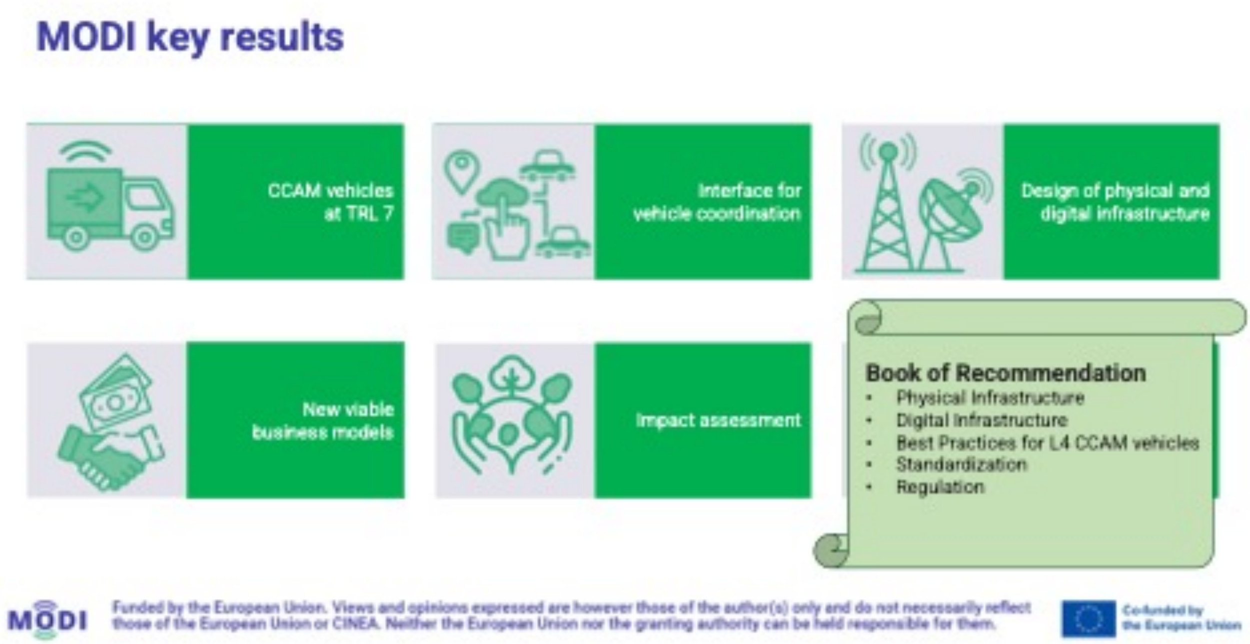
MODI key results
CCAM vehicles at TRL 7
Interface for vehicle coordination
Design of physical and digital infrastructure
New viable business models
Impact assessment
Book of Recommendation
• Physical Infrastructure
• Digital Infrastructure
• Best Practices for L4 CCAM vehicles
• Standardization
• Regulation
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THANK YOU FOR YOUR TIME!
MODI
A LEAP TOWARDS SAE L4 AUTOMATED DRIVING FEATURES
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