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MODI A LEAP TOWARDS SAE L4 AUTOMATED DRIVING FEATURES

A leap towards SAE L4 automated driving features

D1.3 Report on border processes

30th September 2023

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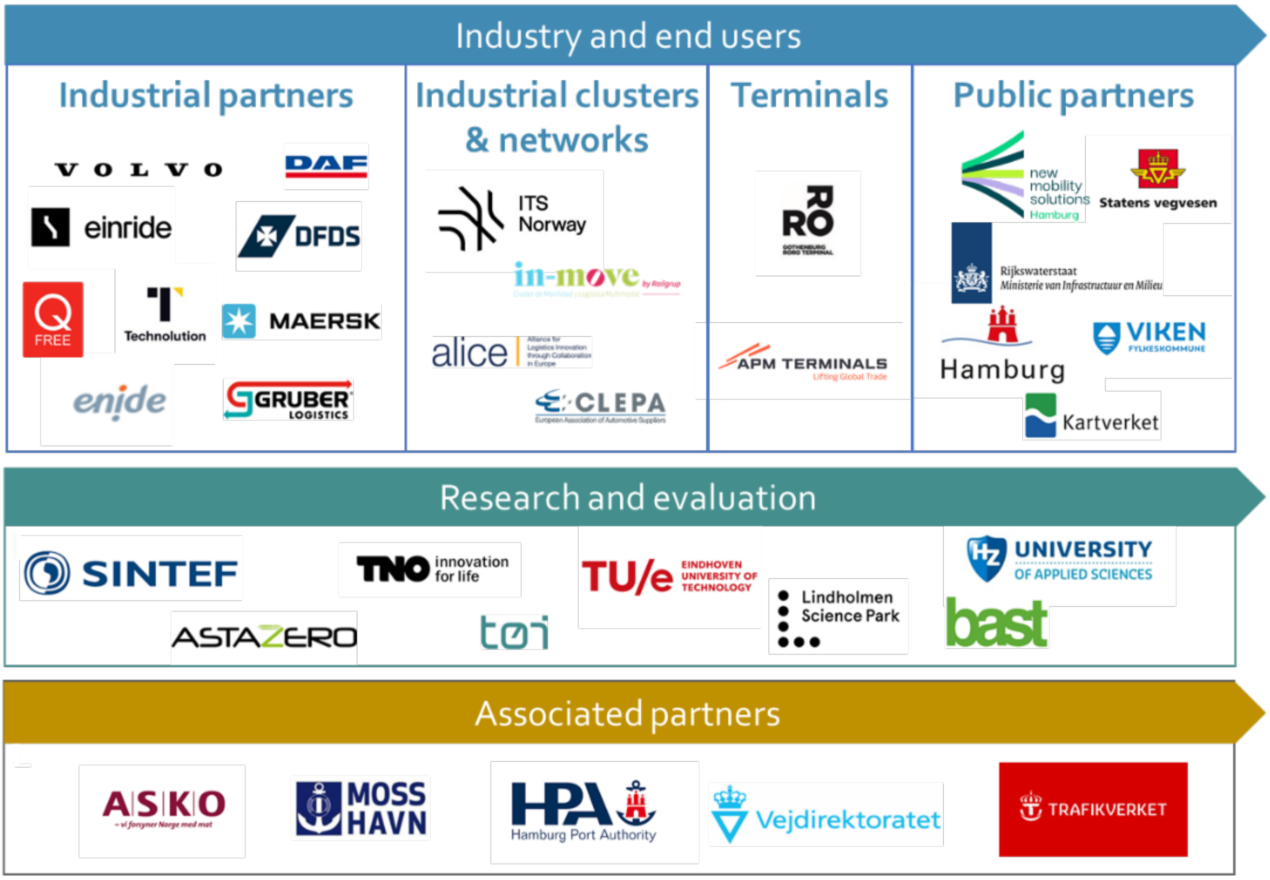

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Terms and abbreviations

Term / Abbreviation	Description
carrier	(a) in the context of entry, the person who brings the goods, or who assumes responsibility for the carriage of the goods, into the customs territory of the Union. However, (i) in the case of combined transportation, "carrier" means the person who operates the means of transport which, once brought into the customs territory of the Union, moves by itself as an active means of transport (ii) in the case of maritime or air traffic under a vessel- sharing or contracting arrangement, "carrier" means the person who concludes a contract and issues a bill of lading or air waybill for the actual carriage of the goods into the customs territory of the Union (b) in the context of exit, the person who takes the goods, or who assumes responsibility for the carriage of the goods, out of the customs territory of the Union. However: (i) in the case of combined transportation, where the active means of transport leaving the customs territory of the Union is only transporting another means of transport which, after the arrival of the active means of transport at its destination, will move by itself as an active means of transport, 'carrier' means the person who will operate the means of transport which will move by itself once the means of transport leaving the customs territory of the Union has arrived at its destination; (ii) in the case of maritime or air traffic under a vessel- sharing or contracting arrangement, "carrier" means the person who concludes a contract, and issues a bill of lading or air waybill, for the actual carriage of the goods out of the customs territory of the Union;
customs authorities	the customs administrations responsible for applying the customs legislation and any other authorities empowered under national law to apply certain customs legislation
customs controls	specific acts performed by the customs authorities in order to ensure compliance with the customs legislation and other legislation governing the entry, exit, transit, movement, storage and end-use of goods moved between the customs territory of the Union and countries or territories outside that territory, and the presence and movement within the customs territory of the Union of non-Union goods and goods placed under the end-use procedure
customs declaration	means the act whereby a person indicates, in the prescribed form and manner, a wish to place goods under a given customs procedure, with an indication, where appropriate, of any specific arrangements to be applied

customs formalities	all the operations which must be carried out by a person and by the customs authorities in order to comply with the customs legislation
customs representative	any person appointed by another person to carry out the acts and formalities required under the customs legislation in his or her dealings with customs authorities
customs status	the status of goods as Union or non-Union goods;
customs supervision	action taken in general by the customs authorities with a view to ensuring that customs legislation and, where appropriate, other provisions applicable to goods subject to such action are observed
declarant	the person lodging a customs declaration, a temporary storage declaration, an entry summary declaration, an exit summary declaration, a re- export declaration or a re-export notification in his or her own name or the person in whose name such a declaration or notification is lodged
economic operator	a person who, in the course of his or her business, is involved in activities covered by the customs legislation
entry summary declaration	the act whereby a person informs the customs authorities, in the prescribed form and manner and within a specific time-limit, that goods are to be brought into the customs territory of the Union
exit summary declaration	means the act whereby a person informs the customs authorities, in the prescribed form and manner and within a specific time-limit, that goods are to be taken out of the customs territory of the Union
holder of the goods	the person who is the owner of the goods or who has a similar right of disposal over them or who has physical control of them
holder of the procedure	(a) the person who lodges the customs declaration, or on whose behalf that declaration is lodged; or (b) the person to whom the rights and obligations in respect of a customs procedure have been transferred
permanent business establishment	a fixed place of business, where both the necessary human and technical resources are permanently present and through which a person's customs-related operations are wholly or partly carried out
person	a natural person, a legal person, and any association of persons which is not a legal person, but which is recognised under Union or national law as having the capacity to perform legal acts
person established in the customs territory of the Union	(a) in the case of a natural person, any person who has his or her habitual residence in the customs territory of the Union; (b) in the case of a legal person or an association of persons, any person having its registered office, central headquarters or a permanent business establishment in the customs territory of the Union
presentation of goods to customs	the notification to the customs authorities of the arrival of goods at the customs office or at any other place designated or approved by the customs authorities and the availability of those goods for customs controls;
release of goods	the act whereby the customs authorities make goods available for the purposes specified for the customs procedure under which they are placed

risk management	the systematic identification of risk, including through random checks, and the implementation of all measures necessary for limiting exposure to risk
temporary storage declaration	the act whereby a person indicates, in the prescribed form and manner, that goods are in temporary storage
forwarding agent	**Collins**: a person, agency, or enterprise engaged in the collection, shipment, and delivery of goods **Cambridge Dictionary**: a company that arranges for goods to be transported, especially to another country

Executive Summary

Border crossing refers to the process of a vehicle crossing a border between countries subject to different legislation or different customs, immigration or security standards. Border crossing between EU and Non-EU countries is more challenging than between EU countries in the Schengen Area, where the Schengen Agreement[1] allows for reduced custom controls. Border processes often involve pre-selection of vehicles for control, routing and stopping of vehicles for control, and cargo screening.

The aim of this deliverable is to identify requirements for higher communication and positioning network that will be needed for transfer of fully automated vehicles through a border crossing scenario.

The approach taken in this deliverable is to first explain important terminology and the basic technologies that are key to understanding the automation of border processes. These are namely C-ITS communication structures and a highly developed automated positioning of the vehicles within certain reference frames.

With that understanding the current processes are described. The human factor in these processes is not negligible and is commented below in the conclusions. The process was exemplarily described at Svinesund border between Sweden and Norway, because it is not only described as one of the MODI use cases, but is one of the most interesting borders in the EU. Within the EU regulations are less strict and diverse between countries, because of the established Schengen area.

The potential future processes are then established and its relevant objects and installments are described. These are accompanied by the descriptions regarding the standardization of interfaces and relevant international standards.

In the deliverable it was shown that very precise positioning and the correct reference frames are key to automated vehicles to pass a border of any kind. Especially a variation in systems between countries or between confined private and public areas can easily cause various issues

It has to be considered that this deliverable is an outlook into the future and everything written has to be evaluated by further MODI activities and by future research and on the roads.

1 Introduction

In the following chapter, a brief summary of the MODI project is followed by the introduction of deliverable D1.3 and an outline of its objectives. In section 1.3, the objectives of this deliverable are discussed regarding their relevance to the MODI project and how they are settled into the overall context of the project. Finally, an overview over the structure of this deliverable is given.

1.1 Project summary

MODI Ambitions: A leap towards SAE L4 automated driving features

The MODI project aims to accelerate the introduction of highly automated freight vehicles through demonstrations and by overcoming barriers to the rollout of automated transport systems and solutions in logistics. The logistics corridor from the Netherlands to Norway has been chosen for demonstration activities as the Netherlands, Germany, Denmark, Sweden, and Norway are expected to be among the first movers to implement fully automated vehicles in Europe.

MODI comprises five use cases, each describing a part of the logistics chain in confined areas and on public roads. It identifies what is already possible on an automated driving level without human interaction and what is yet to be developed. The MODI objectives are to:

- Implement new technology within the CCAM spectrum.
- Define recommendations for the design of physical and digital infrastructure.
- Demonstrate viable business models for connected and automated logistics.
- Perform technical and socio-economic impact assessments.

Major challenges include regulatory aspects and standardisation, border crossings, access control, charging, coordination with automated guided vehicles, loading/unloading and handover from the public to confined areas.

MODI test sites include a CCAM test corridor from Rotterdam to Oslo with specific use cases at Rotterdam (The Netherlands), Hamburg (Germany), Gothenburg (Sweden), and Moss (Norway).

The ambition of MODI is to take automated driving in Europe to the next level by demonstrating complex real-life CCAM use cases while:

- Showing the local, national, and international context of freight transport with CCAM vehicles, both in confined areas and on public roads.
- Cooperating and co-creating with logistics companies, road operators, vehicle OEMs, providers of physical and digital infrastructure and other stakeholders to bridge the gap between R&D and market readiness.
- Developing Lv 4 solutions for long-distance operational design domains.
- Creating innovative business models and improved business models across the logistics chain.
- Proving that the technology can soon deliver on promised benefits at relatively high speeds and medium traffic complexity, including a coordinated CCAM system to support smart traffic management.
- Paving the way to enable highly automatic transport on important corridors, connecting main ports across Europe.

- Accelerating CCAM in Europe by setting examples of business-wise CCAM integration in logistics.

1.2 Aim of the deliverable

Border crossing refers to the process of a vehicle crossing a border between countries subject to different legislation or different customs, immigration or security standards. Border crossing between EU and Non-EU countries is more challenging than between EU countries in the Schengen Area, where the Schengen Agreement[1] allows for reduced custom controls. Border processes often involve pre-selection of vehicles for control, routing and stopping of vehicles for control, and cargo screening.

Main border processes include:

- **Customs** - checking the goods crossing the border,
- **Security** - checking the vehicles used for transporting people and goods across the border. This also include mitigating possible threats caused by certain people or types of goods.
- **Immigration** - checking the people crossing the border.

In this Deliverable, we also consider border processes as relevant for goods vehicles crossing between a public road and a confined area, such as a port, terminal (e.g., train or airport) or consolidation center.

[1] https://www.schengenvisainfo.com/schengen-agreement/

A challenge MODI wishes to examine is how the design of border processes will need to change in order to accommodate high-level vehicle automation. This deliverable D1.3 aims to develop ideas for the design of future border processes that account for use of automated SAE Level 4 heavy goods vehicles in the future. A particular aim is to identify requirements for higher communication and positioning network that will be needed for transfer of fully automated vehicles through a border crossing scenario.

To achieve this aim, the approach is as follows:

- Explain important terminology and the basic technologies to understand modern border processes
- Describe the border crossing process today using the border between Sweden and Norway as an example
- Describe potential future processes and derive requirements and recommendations based on expert opinions
- Drawing inferences about how general goods vehicle transfer processes should be developed in EU/EEA countries to accommodate highly automated vehicles, by studying the following cases in-depth:
    - Heavy goods vehicles crossing the border between Sweden and Norway
    - Heavy goods vehicles crossing from public roads to a private, confined port area in Moss, Norway

In both cases we document and understand the current processes involved, and how they will need to change to accommodate highly automated trucks in line with relevant standards, which are also reviewed and ideas generated for development.

The requriements derived at the end of this deliverable can be understood as technical necessities to establish highly automated driving functions. Communication and positioning network is required continuously and stable to have a vehicle pass through a border crossing scenario fully automated.

This deliverable focuses on the customs processes and security challenges that arise with implementing new standards for automated heavy goods vehicles.

1.3 Relation to MODI output

MODI WPs 1 to 4 build towards the demonstration of five use cases in WP5.

This Deliverable is part of WP1, which lays MODI's foundation by examining conditions for successful implementation and operation of automated trucks in logistics. WP1 will frame the specification and development of use cases by WP2, as well as the development of vehicle subsystems in WP3 and the physical and digital infrastructure in WP4.

WP1 frames MODI's subsequent activities in four ways:

1. Describes user and stakeholder requirements for automated transport in logistics.
2. Describes safety and security requirements for using automated transport in logistics.
3. Develops business models that create value for logistics operators of SAE L4 services.
4. Generates ideas and recommendations for adaptations to be made to infrastructure, regulations and standards, to enable broader deployment of CCAM.

The current Deliverable is generated by one of two tasks that address the fourth of these ways (The other task will generate a more complete Book of Recommendations towards the end of the MODI project.) All activities described for the DoA task in question (T1.4.1) have been used to generate this Deliverable. An exception are those activities on power relations between standardization authorities, which are of little relevance for the current Deliverable, and which will be reported later.

Based on the relevant MODI use cases described in Deliverable 2.1 this Deliverable gives a set of recommendations that are foreseen to have a major relevance and impact on the transfer processes Level 4 heavy goods vehicles must undergo and fulfill for a real-life implementation. In particular the Deliverable considers regulation, harmonization and standardization matters and cross-country and cross-domain differences that will be relevant for all use cases involving border processes as defined above.

The main technical aspects found in this Deliverable are relevant to MODI uses-cases *No 1: Border Crossing*, *No 2: Customs* and *No 4: Port*. These aspects include:

- Communication services
- Positioning services
- High-Definition (HD) maps

The related processes might differ depending on from which direction the vehicle is crossing a border.

In addition to the more technical aspects, there is an aspect of access to the border crossing areas concerning the use of the physical and digital infrastructure and the share of responsibilities between the owner/user of the automated vehicle and the border crossing area operator.

The recommendations made by this Deliverable will be considered particularly by relevant use cases co-designed in WP2 and developed and demonstrated in WP5. In developing use cases, technical requirements and recommendations arising from this Deliverable will need to be considered alongside and integrated with user and stakeholder requirements (D1.1), safety and security requirements (D1.2), connectivity requirements (D3.1) and automation requirements (D3.2), as well as recommendations related to physical and digital infrastructure arising from WP4.

1.4 Structure of the report

The deliverable at hand is structured as follows:

Chapter 1 is the introductory chapter of the deliverable. Besides the overall introduction, a relation the MODI project and the overall topic is outlined.

In Chapter 2 general standards that are important to understand the processes of border crossings, especially for the outlook on automated level 4 heavy goods vehicles, are explained. The importance of communication services, positioning and reference frames and High definition (HD) maps are outlined and roughly explained.

In Chapter 3, the processes at borders for a conventional driver operated heavy goods vehicle is described.

In Chapter 4 the border processes are designed for a potential highly automated vehicles scenario.

In Chapter 5 different types of interfaces are explained. The question of standardization processes for interfaces is raised and discussed.

In Chapter 6 requirements and recommendations are derived from all explanations given in the previous chapters.

In Chapter 7 relevant standards are discussed.

In Chapter 8 a summary and outlook can be found. The final conclusions were drawn and how they affect processes in the MODI project and future bordering processes with highly automated heavy goods vehicles.

2 Definitions and Terminology

In the following chapter, general standards that are important to understand the processes of border crossings, especially for the outlook on automated level 4 heavy goods vehicles, are explained. The importance of communication services, positioning and reference frames and High definition (HD) maps are outlined and roughly explained.

2.1 General standards

For the better understanding of modern border crossing processes or even potential more digitalized and automated processes in the future, a short introduction of Intelligent Transport Systems (ITS) standards and the specific terminology are introduced in the following section.

Generally, ITS architecture, C-ITS (Cooperative-ITS) application standards and terminology are developed by ISO TC204 ITS Working Group 1: Architecture (WG1). WG1 has already prepared two ISO standards covering terminology including ITS services specifically related to border crossings and automated vehicles crossing borders. The two standards are:

- ISO 14812 - Intelligent Transport Systems – Vocabulary [6]
    - All relevant ITS and C-ITS terms are introduced and should be used as far as possible when describing ITS- and C-ITS services and applications.
- ISO 14813-1 – Intelligent Transport Systems - Intelligent transport systems — Reference model architecture(s) for the ITS sector — Part 1: ITS service domains, service groups and services [7]
    - 10 ITS-service domains are defined, where the freight service domain has the following groups of ITS-services:
        - Commercial vehicle pre-clearance
        - Commercial vehicle administrative processes
        - Automated roadside safety inspection
        - Commercial vehicle on-board safety monitoring
        - Intercity freight transport fleet management
        - Intermodal information management
        - Management and control of intermodal centres
        - Management of dangerous freight
        - Management of heavy vehicles
        - Management of local delivery vehicles
        - Telematics applications for regulated vehicles (TARV)
        - Freight transport content identification management

Several of the service domains defined by ISO14813-1 include ITS and C-ITS services that are relevant for automated vehicle border crossings. Examples are Weigh-in-motion, Non-stop pre-clearance, Automated commercial vehicle administration, Automated border crossings, and Remote access to commercial vehicle safety data.

A service is described by its scope and high-level requirements and conditions. The example below shows the description of the ITS-service *Non-stop Pre-clearance* which will be demonstrated in the MODI project:

The scope of this service shall enable the safety, credentials, and size and weight data for transponder-equipped commercial vehicles to be electronically checked before they reach an inspection site.

The service shall operate under the following conditions:

> *(a) Safe and legal carriers and vehicles can travel without stopping for compliance checks at weigh stations, ports-of-entry, and other inspection sites.*
>
> *(b) Only illegal or potentially unsafe vehicles to be selected for the requirement to enter the site for an inspection.*

The ITS-service example above will in the MODI project be demonstrated without an On-Board-Equipment (OBE) carrying the safety, credentials, and size and weight data. However, the core functionality of the ITS service will remain by sending a pre-declaration from the virtual carrier central system to the Border Customs office system via internet minimum 2 hours in advance. The registration number of the automated vehicle will be read by the roadside equipment downstream the border customs area and Automatic Number Plate Recognition (ANPR) will be used for relating the vehicle approaching the customs area to the appropriate pre-declaration

The C-ITS architecture shown for the use cases in this deliverable is based on the ARC-IT methodology (Architecture Reference for Cooperative and Intelligent Transportation) [1]. It is recommended by ISO TC204 WG1 Architecture which also uses the methodology for describing ITS and C-ITS applications. More information on the methodology is available at https://www.arc-it.net/.

The ARC-IT architecture is divided in four levels: Enterprise, Functional, Physical and Communications view. For the purpose of this deliverable the Physical and Functional view are defined in combined diagrams. Physical Objects are defined to represent the major physical components of the ITS Architecture. The Functional objects are linked to the Physical objects defining the main functions of a Physical object.

The physical objects are organised into different Classes that define ITS at the highest level of abstraction. Five specific classes (Centre, Support, Field, Vehicle, and Personal) are used to group physical objects based on where they reside and how they behave and interact with other objects.

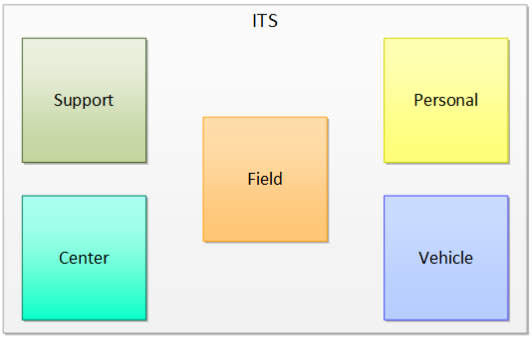

Figure 1 High level ITS classes for physical objects

The European Union Customs Code (UCC) [11] defines customs terms and definitions that have been used in this document. The most relevant UCC terms are given in Annex 1.

2.2 Communication services

A crucial aspect of level 4 vehicles in general is the establishment of a resilient system of communication between the vehicles and infrastructure.

The ITS station in the automated vehicle will communicate via air interfaces with other ITS stations in vehicles, roadside systems, central systems, and mobile equipment, e.g., smartphones and tablets with use case required apps, ref. Figure 2, where air interfaces are marked with red arrows. The communication will include short-range, e.g., DSRC and ITS-G5, and long-range (cellular) communication, e.g., 4 and 5G.

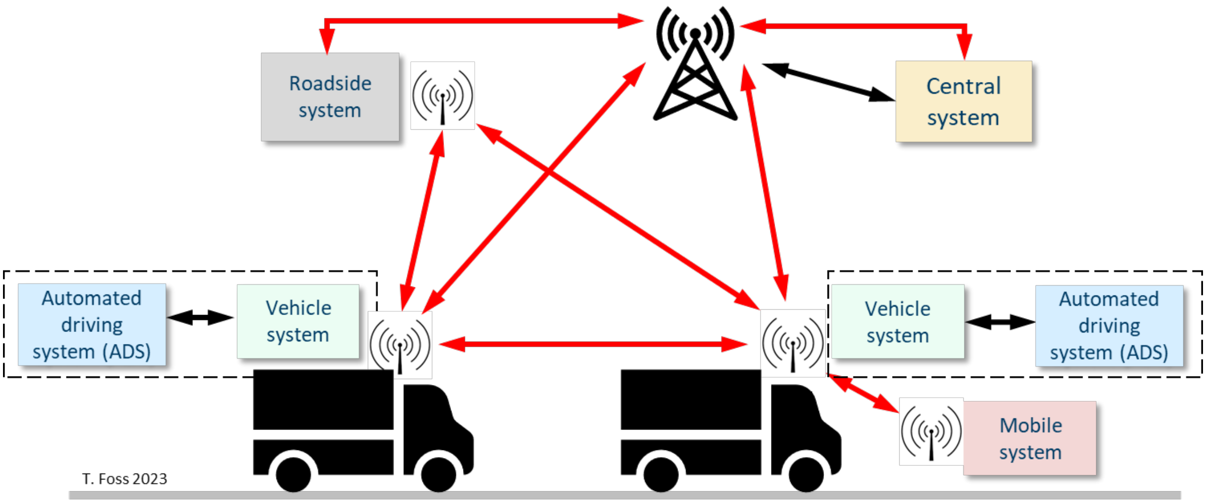

Figure 2: Multiple communication channels

The communication type and technology may change between countries and communication service providers. It may also change from one confined area to another in the same country. Hence, there is a strong need for an extensive communication application in the ITS station in the automated vehicle enabling multiple communication types and technologies and a seamless transfer from one communication type and technology to another.

2.3 Positioning and reference frames

2.3.1 Positioning services and technologies

Highly automated driving will likely require absolute positional accuracy well below one meter. For detailed navigation in complex areas such as customs and confined port areas, positional accuracy at the centimetre level may be required. The positional accuracy available from standalone Global Navigation Satellite Systems (GNSS) does not fulfil these requirements, but augmentation systems can improve it. The most accurate and reliable method among various augmentation techniques is Network Real-time Kinematic (NRTK) services. Two examples are CPOS in Norway and SWEPOS in Sweden, which improves the absolute positional accuracy to 1-2 cm within the coverage area of the services. Some other positioning services work across European borders but with lower positional accuracy or no coverage in some countries.

This implies that an automated vehicle crossing the Swedish-Norwegian border must use the SWEPOS GNSS positioning service on Swedish roads and the CPOS GNSS positioning service on Norwegian roads, ref. Figure 3.

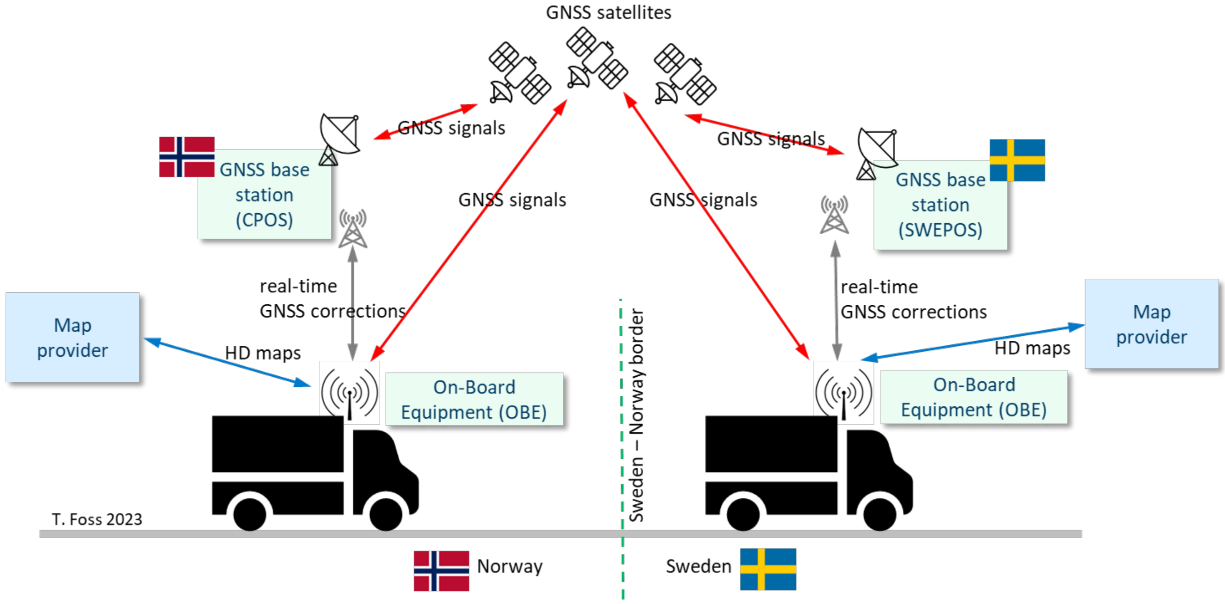

Figure 3: Provision of GNSS corrections and digital maps

NOTE: The term "local positioning services" is used in this deliverable. In the scope of the deliverable, the term refers to GNSS services with the required positional accuracy for the local area. The term must not be mixed with other services for small areas.

2.3.2 Reference frames

A pair of coordinates alone does not result in a useful position accuracy. The coordinates need to be defined within a reference frame, which in geodesy is a specific set of parameters for associating a coordinate pair to a point on the surface of the Earth. As the Earth's surface is composed of a set of tectonic plates that are continuously moving, reference frames also need to consider tectonic movement.

Different reference frames are valid on a global or regional scale. A specific point or physical object, independent of whether it is moving or not, will have different values for coordinates depending on which reference frame is used. For example, the global reference frame ITRF2014 considers the whole globe with tectonic movement. On the other hand, the regional European ETRF89 is fixed to the Eurasian plate, with constant positions according to the position of that plate in 1989. Due to continental drift, the difference between ITRF2014 and ETRF89 increases over time. In 2021, the difference was approximately 70 cm (see Figure 4), but with deformations within the plate.

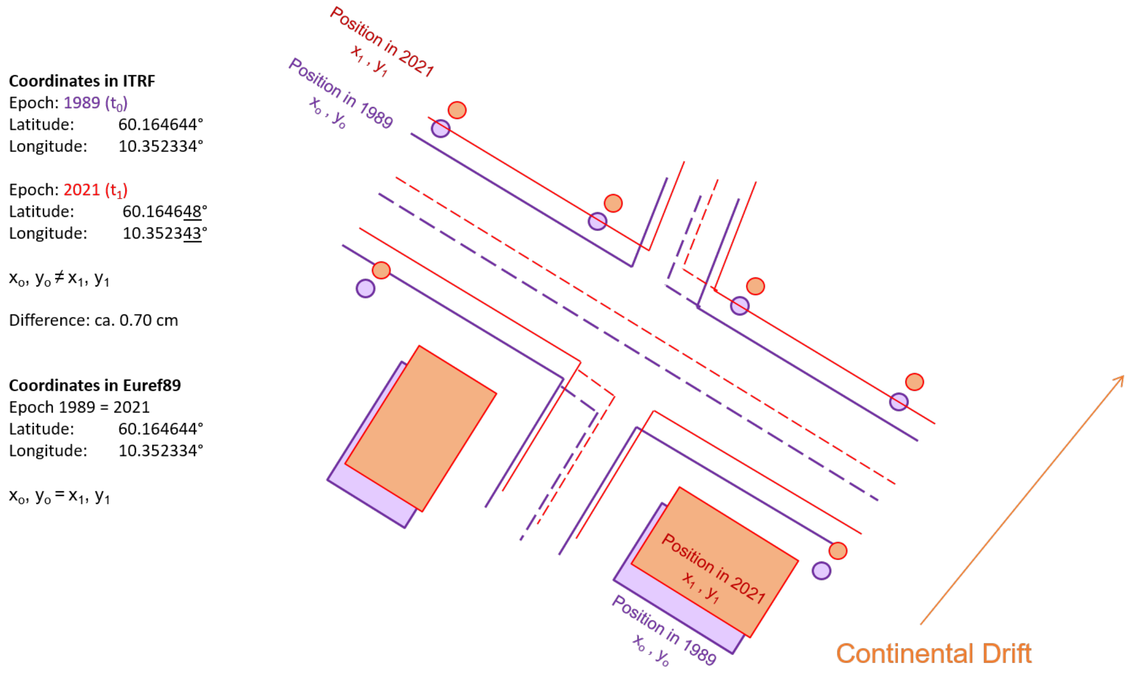

Figure 4: Map sketch with different timestamp and reference frames

Distinct European countries have calculated and implemented national and more precise variants of ETRS89 than the general European model for the best possible accuracy within the individual country. Coordinates in ETRS89 and the national versions can differ from 1-2 cm and sometimes more. The Nordic countries have calculated a common precise variant of ETRS89 that is further refined and implemented in Sweden as SWEREF99 for use in their SWEPOS system and Norway as EUREF89 for use in the CPOS systems. Other countries, like Germany and The Netherlands, also have their national implementations of ETRS89.

Positioning systems and digital maps use various reference frames. Therefore, it is essential to know which reference frame a set of coordinates refers to, either from a positioning service, an information service like DATEX II, or a digital map. The end user (the Automated Driving System in the vehicle) must ensure that the same reference frame is used when combining positions from different sources. This is done by transformations between reference frames and projections through a mathematical framework developed in the geodetic professional field.

2.4 High-Definition (HD) maps

Highly automated vehicles require a detailed digital representation of the road infrastructure and its environment to enable navigation in compliance with traffic signs, signals, and road markings under all conditions. The detailed representation is often called a High-Definition (HD) map and consists of building blocks (layers) with static and dynamic information.

The static building blocks (base maps, terrain models, lane maps, navigation restrictions, etc.) are primarily prepared for the vehicle in advance, although updates will be required on the road. Dynamic information, such as accidents and road works, must be provided continuously to the vehicles.

As mentioned in section2.3.2, vehicles need to use the same reference frame for positioning services and digital maps. Besides, an automated vehicle crossing a border must ensure that it is connected to local services providing updates to HD maps.

3 Border processes – state of the art

In the following chapter the processes at borders for a conventional driver operated heavy goods vehicle is described.

Initially, two examples on border crossings are described to give an idea of where the border processes are taking place and what the framework looks like in terms of fluctuation and workload. In the following section of this chapter, state-of-the-art border processes as seen today are described.

3.1 Examples on border crossings

3.1.1 Border between Sweden and Norway

The border between Sweden and Norway is 1630 km long and the second longest border between two European countries (after the border between Russia and Ukraine). There are 64 public border crossing areas between Norway and Sweden, but the border crossing at Svinesund (E6) in the south is the major one. The Annual Average Daily Traffic (AADT) was 13.274 vehicles per day in 2022, and 17% of the AADT was Heavy Goods Vehicles (HGV).

In Figure 5 the location of the border crossing at Svinesund and exemplarily the daily variation in vehicles (all vehicles) on Wednesday, 10.05.2023 is shown.

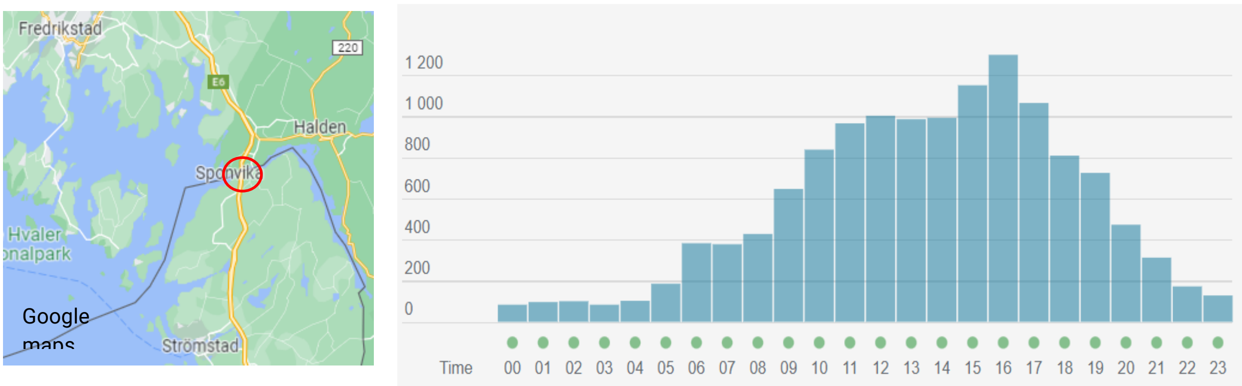

Figure 5: Location of Svinesund crossing and examplary variation on a weekday at Svinesund (10.05.23)

The border crossing area at E6 Svinesund in Norway, which is the scenario for the MODI sub-use cases Border crossing (No1) and Customs (No2), is located about 1,5 km north of the Sweden-Norway border. The area covers both the area for the Norwegian customs and the Norwegian Public Roads Administration (NPRA) vehicle control station (see Figure 6).

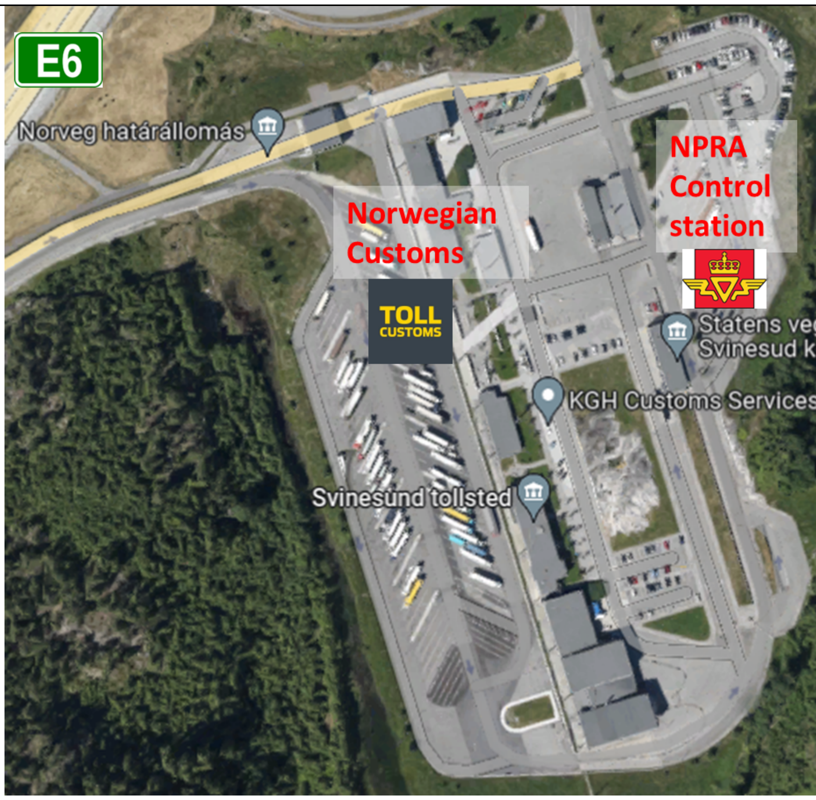

Figure 6: Svinesund (E6) Customs and vehicle control station (Source: Google Maps)

3.1.2 Entering Moss Port

As for Moss Port, the border crossing scenario for this deliverable will be entering Moss Port's confined area. The Moss port will be an exemplary for the scenario for MODI use case "Port" (No 4). It is most likely that all aspects foreseen to be relevant in this deliverable will also apply for this type of crossing between a public and a private area as well.

Moss port is a confined area with access control at the main gate, dividing the port from the publicly available transport road network outside the port. Figure 7 shows the access control at the main gate. The access control at the gate could be compared with the border control at the Svinesund border area (see section above). The driving of automated vehicles inside the port 'border' will take place in another jurisdiction than the jurisdiction governed by road authorities for the roads leading to and from the port. That implies that the owner/user of the automated vehicle will need permission to use the road vehicle transport areas inside the port area.

Figure 7: Location and access to Moss port (Source: Google Maps/Streetview)

It is assumed that this type of confined area has local high-definition (HD) maps for their transport corridors and areas that may change from time to time depending on the use of available areas. It could also be assumed that this type of confined area may have its own secure communication channels and profiles for traffic management and other exchange of information.

3.2 General Custom procedures at Svinesund

In MODI, solutions for automated freight transport will be developed. As part of this, the current process for customs processing, i.e., contact between the driver/vehicle and the customs inspectors, was mapped, as well as an outline of land use in customs processing. The information is important to understand what automation processes must decide on where contact between people is necessary today, e.g., on-site dialogue about errors/irregularities with the load and/or vehicle, and will also be used in the design of the demonstration in MODI. This was inspired by a similar and more elaborating study done in Canada (Canada Port of Entry/highway border crossing) examining likely issues associated with passage of highly automated trucks, including trucks with no person on board (Anderson, Anderson and Tannou, 2018).

The following chapter will give an outline of the custom procedures at Svinesund at the border between Sweden and Norway.

Process for customs at Svinesund customs station

The customs agency informed that their task is mainly to ensure that the goods are correctly declared, against customs, duties and other regulatory authorities. They also check correct documentation and the correct amount of goods, weight and types of goods, sender and recipient. There are special rules for, e.g., agricultural goods (plants and animals) to which the Norwegian Food Safety Authority is connected, and the Norwegian Customs Authority enforces 15 different regulations at the border related to different types of goods.

As of today, there are two methods for the customs process; digital customs clearance (digitoll) and conventional customs clearance.

Digitoll

Digital customs clearance is an ongoing pilot until 2025 and only applies to a small selection of companies (14 companies) with large volumes and which mostly have "everything in order". The system implies that all goods are mostly declared in advance and the vehicles can pass past customs and the forwarding area without stopping (zone 1 on a separate map). All necessary forms are registered in a so-called *Manifest* which contains information about sender and recipient, name of driver and time estimate for arrival at the customs station. In addition, there are invoices, plant certificates etc. Most often, it is a freight forwarder who has taken care of the documents in the manifest in advance. The manifest must basically be submitted in advance and no later than two hours before arrival. The papers are valid within a time interval of six hours, that means two hours before arrival to four hours after expected arrival. Customs handles import, export, forwarding and transit (goods are cleared in stock within three days at the latest and before the goods is sold).

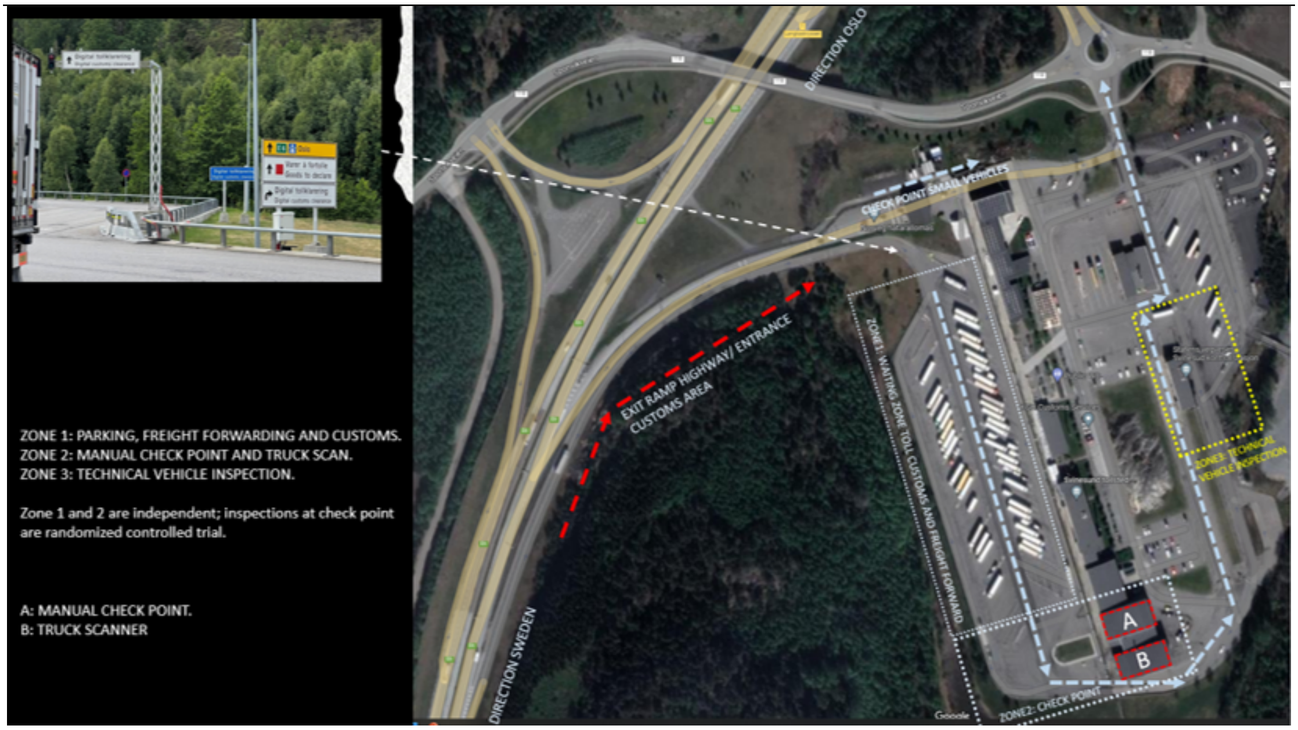

Figure 8 Svinesund border

Sometimes, however, goods vehicles passing via digital toll can be stopped at a red light. This happens if the customs officers discover irregularities/errors when they review the manifest. Most often, the manifest is assessed on the same day as the vehicle is due to arrive. This procedure can also be based on intuition from experienced officers and previous events related to the company, driver and/or the vehicle that make them want to stop the vehicle. Such a stop with a digital toll in that case gives the vehicle a red light just before entering zone 1. In that case, the driver must drive to zone 1 for handling (parking, forwarding, customs).

If the vehicle was given the green light (do not stop), the lorry continues through zone 2 (control zone). There, the vehicle and driver can also be taken out for manual and/or scanning of the vehicle/goods. Finally, they can also be stopped for technical vehicle control operated by the Norwegian Road Administration (zone 3).

If the vehicle had a red light (stop), it must, as mentioned, be handled in zone 1, before it continues to zone 2 or technical vehicle inspection (zone 3), cf. the section above.

In practice, there are only few reported incidents of needing toll inspection with the 14 large and well-established companies that are part of the trial scheme for digital tolls at Svinesund border.

Conventional customs clearance

Any vehicle / driver who does not use Digitoll must stop in zone 1 for registration of entry into Norway. For carriers who have all their papers in order, this is in practice a short stop (given that there is not much of a queue at the customs station itself) where they go to an express gate and have their papers stamped. Some have a printer in the vehicle and print the document from there. Others deliver a sequence number to the freight forwarder (KGH) and get papers there before going to the customs expedition. The customs inspector reads the document right there. Sometimes it leads to checks for various reasons (intuition, strange behavior, content/irregularities in the document and/or if the driver does not know what kind of goods they are carrying. If everything is ok, the customs procedure is cleared, and the driver continues on to zone 2 and zone 3 following the same procedure as for digital tolls.

3.3 Physical view on custom procedures

In Figure 9: Customs System of Systems (SoS) today an overview of an abstract state-of-the-art customs system of systems is shown as it is established at European borders to Non-EU countries today. In the following sections the physical objects including their functional objects are described in detail. The overview is compliant with the terms, roles and responsibilities defined in the EU Customs Code [11].

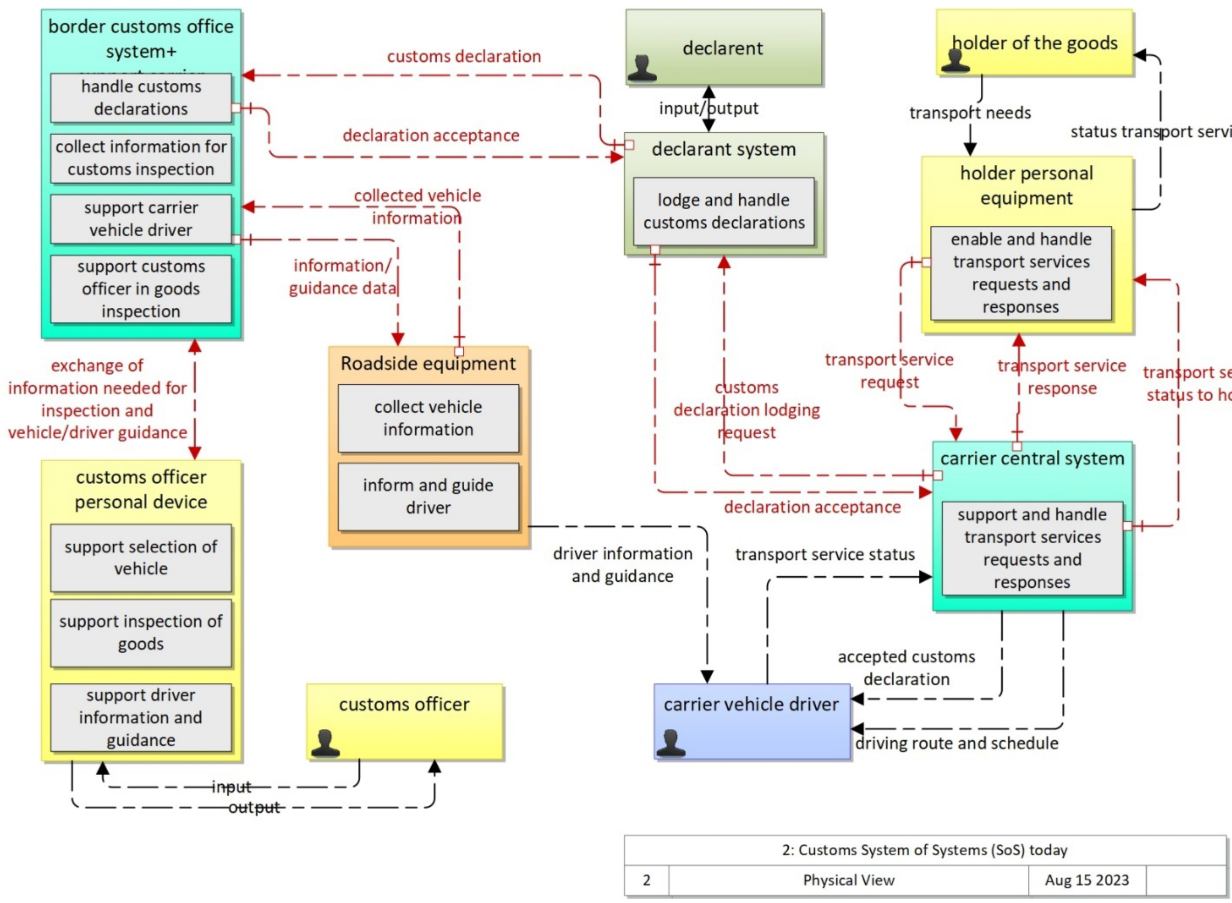

Figure 9: Customs System of Systems (SoS) today

3.3.1 Holder personal equipment

The *holder* of the goods is defined in UCC [11] as ‘the person who is the owner of the goods or who has a similar right of disposal over them or who has physical control of them’. The holder has a transport need and uses his/her personal equipment, e.g., a pc, a tablet, or a smartphone, to communicate his/her request for transport services provided by a carrier. A *carrier* is defined in UCC [11] as: ‘in the context of entry, the person who brings the goods, or who assumes responsibility for the carriage of the goods, into the customs territory of the Union'. There is a similar definition for the context of exit. The holder personal equipment can also receive responses to holder requests and receive status information on the transport service provided by the carrier.

The holder personal equipment has an application that enables and handles transport services requests and responses. This could be web-related applications on a pc or mac or it could be an app on a smartphone or tablet. The application handles requests and responses as well as status reports on the transport and customs services provided.

3.3.2 Carrier central system

The Carrier central system handles the interfaces to the holder personal equipment, the carrier vehicle driver, and the declarant system. The interface to the holder of the goods is described in 3.3.1.

One of the tasks for the carrier transporting goods that will cross one or more national borders, will be to prepare a customs declaration and send it to the appropriate customs office. The UCC describes different alternatives on how this could be done, e.g., directly to the customs office at the border(s) or through a local customs office. The person operating the declarant system is named *declarant* in UCC and defined as: 'the person lodging a customs declaration, a temporary storage declaration, an entry summary declaration, an exit summary declaration, a re- export declaration, or a re-export notification in his or her own name or the person in whose name such a declaration or notification is lodged'. The declarant is an abstract role and could in real-life be the same legal entity as the carrier or it could be a company providing customs support services. The format of a customs declaration is defined in EU Customs Data Model [4].

The interface to the carrier vehicle driver(s) provides the driver with the necessary documents, e.g., the accepted customs declaration and the driving route and schedule and any other documents required enabling the driver to carry through his task. The driver provides the carrier central system with information on the transport service status. This could also include information sent directly from the vehicle to the carrier driver central system, e.g., the vehicle automatically sending its position to a fleet management application installed in the carrier central system.

3.3.3 The Border customs office system

The border customs office system has interfaces to the declarant system, the roadside equipment, and the customs officer personal device. The interface to the declarant system is quite simple and shown in Figure 9: Customs System of Systems (SoS) today. The functional object in the border customs office system is *handle customs declarations*. In Figure 9 it is assumed that the declarant request on handling of the customs declaration, is coming directly to the border customs office, but it may also come via a local customs office near the declarant.

The interface to the roadside equipment is related to the functional objects *collect information for customs inspection* and *support carrier vehicle driver*. The information collected could for instance be vehicle registration number, number of axles, axle loads and total weight. This could e.g., be used for pre-selection of vehicles. The information to the driver sent via the roadside equipment could be given by means of variable message signs and different types of signals, e.g., ordinary traffic signals and lane control signals.

The interface to the customs officer personal device covers the exchange of information enabling the customs officer to select vehicles subject to inspection of the goods carried by the vehicle. The interface also covers the information exchange required by the customs officer to carry through an effective and correct inspection of the goods, e.g., the customs declaration and information collected by the roadside equipment. The information collected by the roadside equipment, e.g., the registration number may also give access to databases holding information that could be relevant for the inspection. The interface could also include information that enables the customs officer to guide the vehicle, ref. the interface between the border customs office system and roadside equipment described above.

3.3.4 Customs officer personal device

The customs officer personal device covers both fixed equipment, e.g., a PC, and mobile equipment, e.g., tablets. Hence, the personal device supports the customs officer to perform his tasks, both when working in his office and working out in the field and control halls.

The interface to the border customs office system is described in 3.3.3. The personal device may also have an interface to the roadside equipment (not shown in the figure) with the same interface as between the border customs office system and the roadside equipment depending on the distribution of functional objects for each implementation. The personal device could also be a digital twin of the customs office system.

3.3.5 Roadside equipment

The roadside equipment covers both equipment used for collecting information about the vehicles approaching the border customs office and the equipment used for informing and guiding the drivers. The interface to the border customs office system is described in 3.3.3.

Figure 10 shows an example on roadside equipment (RSE). The RSE has both sensors (cameras) mounted in the street light pole, a variable message sign on the gantry leg (no message shown in the picture) and lane control signals above the lanes (green arrows in the picture).

It is assumed that the roadside equipment continuously collects information from approaching vehicles and forward automatically all information collected to border customs office system where the functional object collect information for customs inspection uses the information, e.g., for pre-selection of vehicles.

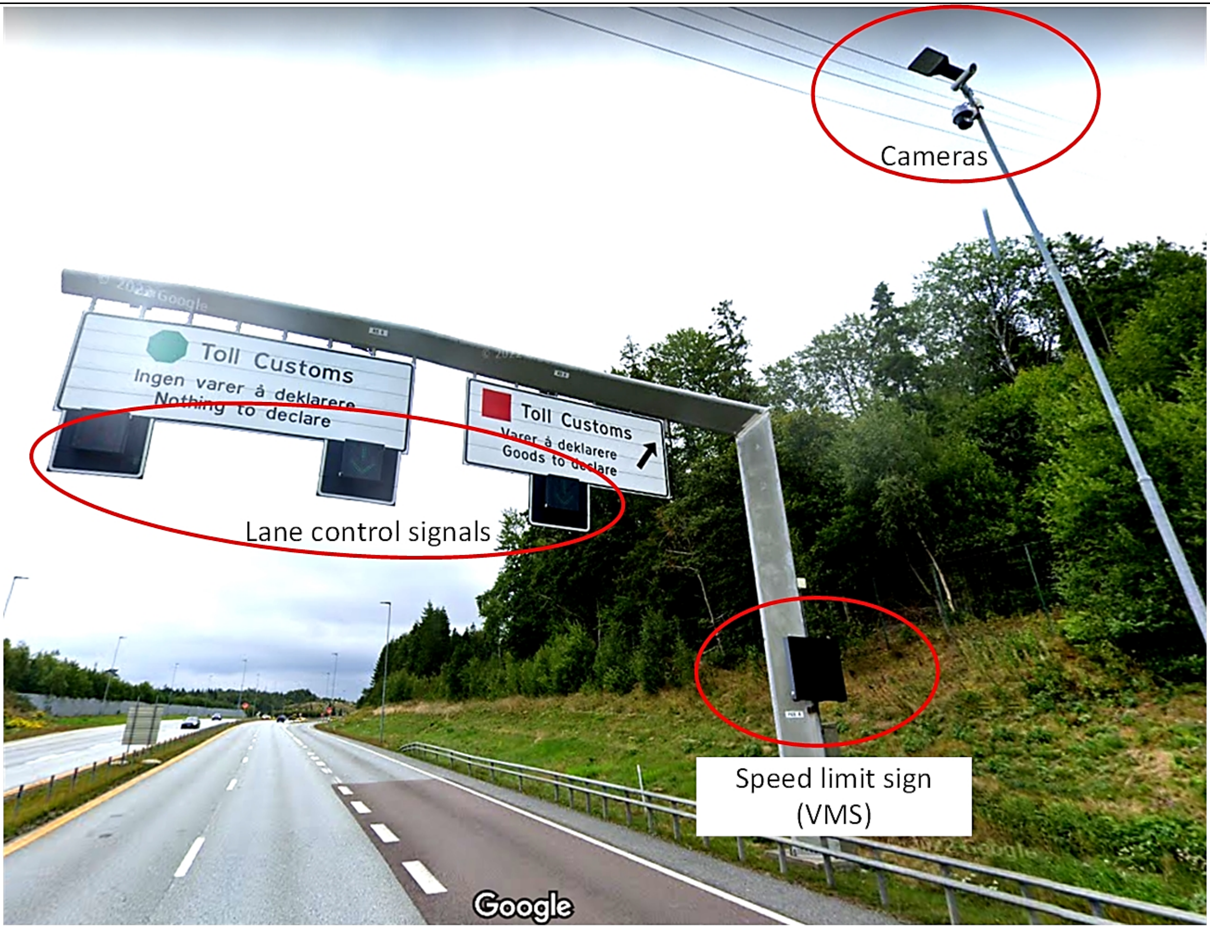

Figure 10: Example on Roadside equipment at Svinesund Customs, Norway (picture source: Google aps/Streetview)

4 Border processes – MODI scenario

Figure 11 shows the Physical view (ref. section 2.1) of the Border crossing System of Systems (SoS) in a MODI scenario with automated vehicles. The physical objects with their functional objects related the provision of the border crossing processes are described in the following text.

The SoS includes a system for remote driving as it is assumed that there will be a need for remote driving at the border in some scenarios, e.g., when a border officer wants to perform a manual control for some specific reasons or perform a random control of the data declared by the automated vehicle before entering the border area.

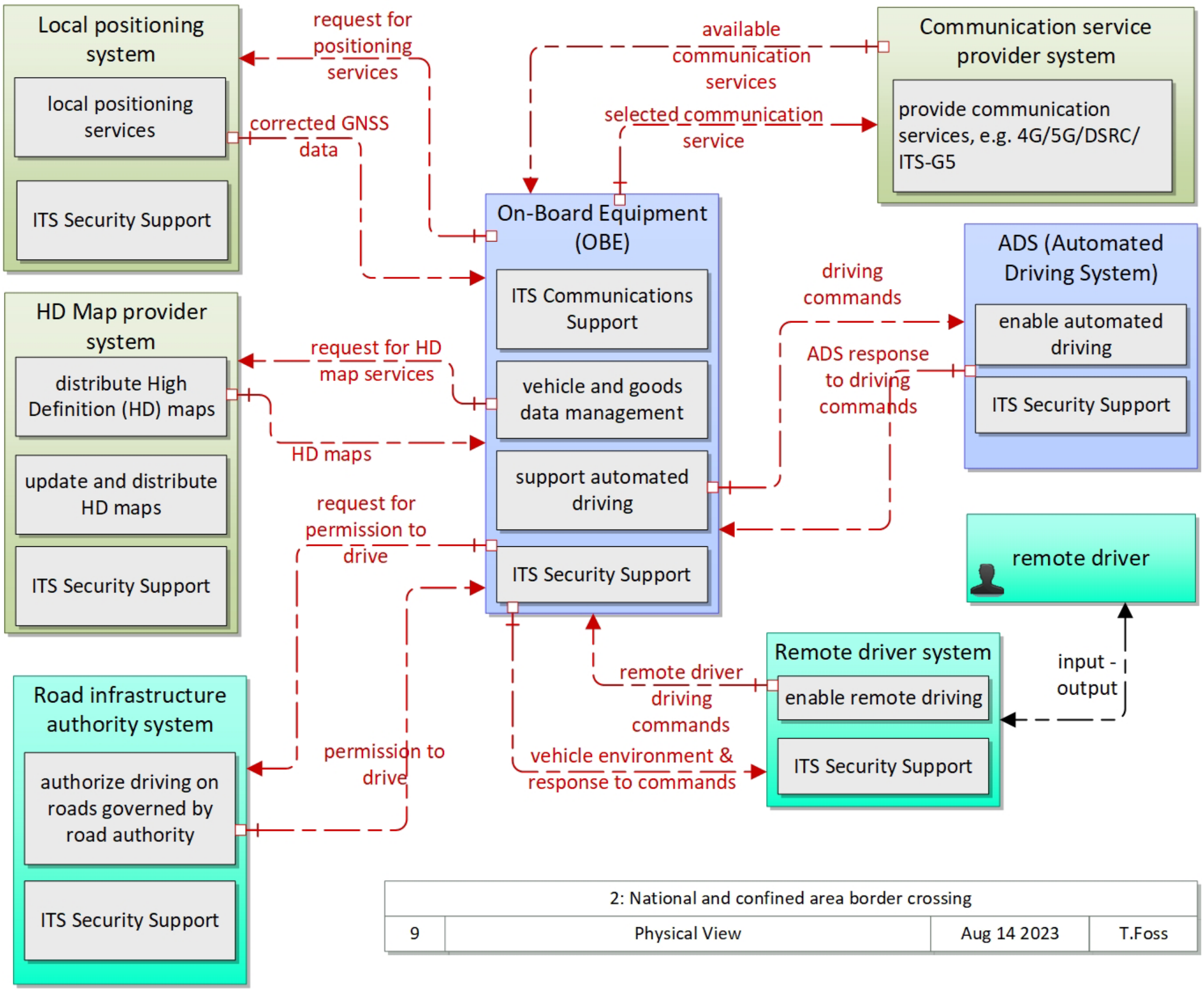

Figure 11: Border crossing System of Systems (SoS) in MODI scenario

NOTE: The figure above shows physical objects that will be part of the C-ITS environment whenever an automated vehicle moves. However, when the automated vehicle crosses a border, e.g., between countries or public and confined areas, the physical objects may change concerning hardware/software, constraints and prerequisites, functional and security requirements and operator. These changes should be unambiguously defined and published ensuring a safe, secure, and seamless border crossing.

4.1 Specific physical objects of relevance

The **On-Board Equipment (OBE)** is a physical object integrated in the automated vehicle information and communication technologies (ICT) -network and connected to the *Communication service provider system, Local positioning system, HD map provider system, Road infrastructure authority system, Remote driver system and Automated driving system (ADS)*. Due to its functionality and multiple interfaces to other objects, the OBE is a crucial object in the physical and functional view of the border crossing use case.

The OBE has four functional objects:

- *ITS communication Support* that supports the standardised ITS communication types and profiles, e.g., ITS-G5, DSRC, and 5G.
- *Vehicle and goods data management* which covers all functions needed for data management of all vehicle and goods data stored in the OBE
- *support automated driving* supporting the Automated Driving System with the required information and interface to the environment external to the vehicle, e.g., the interface to the remote driver system
- *ITS Security Support* ensuring the required level of security.

The main functional object in this use case is the *support automated driving*. The functional object exchange data and services with the all the other physical objects shown in Figure 11.

However, the ITS Security Support is also a particularly important functional object as the security services shall protect the crucial and vulnerable data and communications ensuring confidentiality, integrity, and availability as a minimum of security measures.

The functional object ITS Security Support is defined in ARC-IT [1] as: 'ITS Security Support provides communications and system security functions to the ITS Object, including privacy protection functions. It may include firewall, intrusion management, authentication, authorization, profile management, identity management, cryptographic key management. It may include a hardware security module and security management information base.'

The ITS security is of course an issue for all the physical objects in Figure 11. The air interfaces to the local positioning service system and the HD map provider systems are also vulnerable interfaces that should be protected against attacks, e.g., protection against jamming of GNSS corrected data.

The interface to the *remote driver system* covers two important information flows: 1) *remote driver driving commands* that consists of the driving commands given by the remote driver, and 2) *vehicle environment & response to commands* that consists of information on the vehicle environment, e.g., information from cameras installed in the front, the rear end, and the sides of the vehicle. Another option is 360 degrees cameras on the top of the vehicle. The information flow also includes the confirmation of the execution of the remote driver commands.

The interface to the *ADS* covers messages from functional object *support automated driving*. The driving commands are transmitted from the remote driver system via the OBE and the ADS response to the commands. In the physical and functional view, the OBE and ADS is shown as two separate physical objects. In real life implementations the functional objects of the OBE and ADS can be integrated in the same physical object, e.g., the vehicle ICT system and network. It may be a more secure solution that the functional objects are logically separated even if they are integrated in the same physical object, due to security mechanisms safeguarding the access to the ADS. An option to what is shown in Figure 11 is that driving commands and responses to those goes directly to the remote driver system and not via the OBE. However, ideally the interface between the remote driver system and the vehicle should be a standardised and open interface that provides flexibility to allocate the tasks of the remote driver to others than the vehicle manufacturer, e.g., to a border crossing officer.

The main functional object of the **communication service provider system** is to support the automated vehicle with different types of communication services enabling the automated vehicle to communicate with its environment and exchange the required data information and services for the automated driving. It is assumed that the communication service provider broadcasts its services, and that the OBE responds to the broadcasted set of services with a message including the preferred/selected communication service.

The MODI deliverable D3.1 Report on connectivity requirements [12] has an extensive description of communication types and technology and requirements for the use cases and is not further described in this part of D1.3

The interfaces for the different communication types and technology are defined by international, European, and national standards and/or regulations, ref. [12]. The functionality of the **local positioning system** and its relationships to other physical objects are described in chapter 2.3 on page 17.

The functionality of the **HD map provider system** and its relationships to other physical objects are described in chapter 2.4 on page 19.

The **Automated Driving System (ADS)** is defined in ISO 22736 [10], also known as SAE J3016, as:

The hardware and software that are collectively capable of performing the entire DDT (Dynamic Driving Tasks) on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a Level 3, 4, or 5 driving automation system.

NOTE: In contrast to ADS, the generic term “driving automation system” refers to any Level 1 to 5 system or feature that performs part or all of the DDT on a sustained basis. Given the similarity between the generic term, “driving automation system,” and the Level 3 to 5 specific term, “automated driving system,” the latter term should be capitalized when spelled out and reduced to its abbreviation, ADS, as much as possible, while the former term should not be.

Figure 12 shows how the execution of the application Dynamic Driving Tasks (DDT) is supported by ADS and other vehicle systems. Vehicle active safety systems, e.g., emergency breaking, is not part of the ADS according to [10]. Other vehicle systems include vehicle sensor systems, e.g., cameras, radars, and sensors on moving parts.

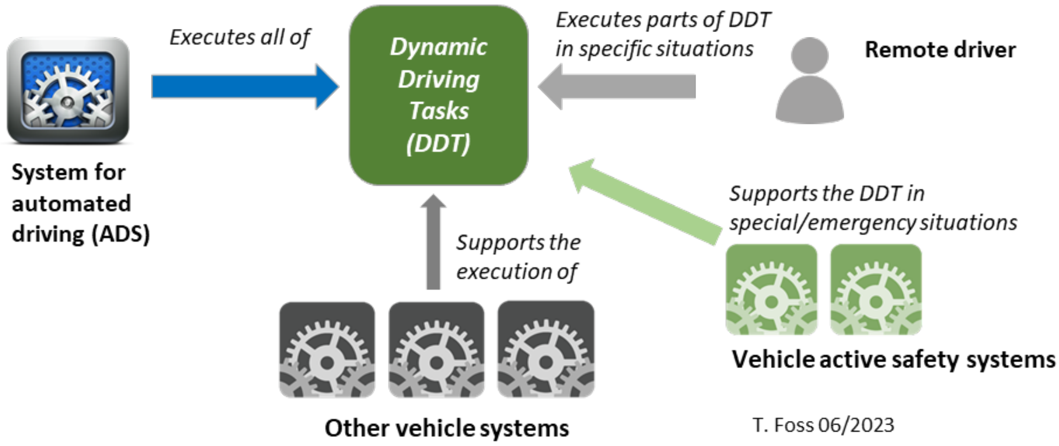

Figure 12: Execution of Dynamic Driving Tasks (DDT)

Remote driving is defined in [10] as follows:

> *Real-time performance of part or all of the DDT and/or DDT fallback (including, real-time braking, steering, acceleration, and transmission shifting), by a remote driver.*
>
> *NOTE 1: A receptive remote fallback-ready user becomes a remote driver when she/he performs the fallback.*
>
> *NOTE 2: The remote driver performs or completes the OEDR (Object and Event Detection and Response) and has the authority to overrule the ADS for purposes of lateral and longitudinal vehicle motion control.*
>
> *NOTE 3: Remote driving is not driving automation.*
>
> *NOTE 4: Remote driving of a vehicle by a human is sometimes referred to as "teleoperation." However, "teleoperation" is not defined consistently in the literature, and thus, to avoid confusion, is not used herein.*

The **remote driver system** allows and supports the remote driver, whoever that may be, to remotely drive the automated vehicle. As one of the vulnerable physical objects, the access control to the system must have strong security mechanisms as well as strong security mechanisms in the interface to the vehicle (OBE).

The main information flows in the interface are shown in Figure 13.

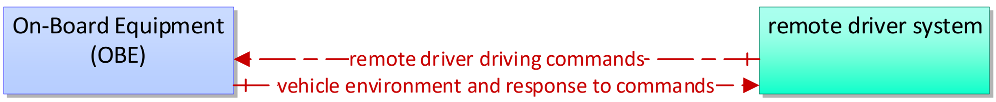

Figure 13: Information flows between OBE and remote driver system

The driving commands from the remote driver is sent to the OBE. From the OBE to the remote driver system there is an information flow with two important sets of data. The first set is the environment data from the vehicle sent to the remote driver system enabling the remote driver to see the surroundings of the vehicle meaning the area available for driving and the objects that have an impact on the decisions of the remote driver. This could be, e.g., other vehicles, pedestrians and cyclists, traffic sign and signals, signs/guidance from customs officers or other authorised persons, and any kind of fixed or moving object that may conflict with the planned and/or foreseen trajectory of the automated vehicle. The other set of data is the data informing the remote driver that the execution of his/her commands has been fulfilled.

There is also execution of security services before and during the transmission of data, but they are not shown in the figure above. This interface is vulnerable, has a substantial risk and must be protected by strong security mechanisms to ensure, as a minimum, confidentiality, integrity, and availability of the remote driver driving commands.

A vehicle without a driver requires a specific permission to use the roads owned and operated by the road infrastructure authority, e.g., national road authorities like the Norwegian Public Road Administration and the Swedish Transport Administration when crossing the border. For confined areas, the road infrastructure authority could e.g., be a port authority.

The OBE (or the person in charge of the OBE) requests the permission to drive the automated vehicle on the roads governed by road authority. The permission is granted and stored in the OBE to be checked by authorised control personnel, e.g., border control officers responsible for the control of vehicle safety and security.

4.2 Customs in a scenario with automated vehicles

Figure 14 shows the Customs System of Systems in a scenario, e.g., MODI, with automated vehicles. The physical objects with their functional objects are described in the following text.

The SoS for Customs includes two physical objects that are already described, in chapter 4.1. Hence, they are not further described in this clause.

NOTE: Some of external objects shown in Figure 11: Border crossing System of Systems (SoS) in MODI scenario are not shown in Figure 14: Customs System of Systems (SoS) in MODI scenario avoiding an overload of the figure.

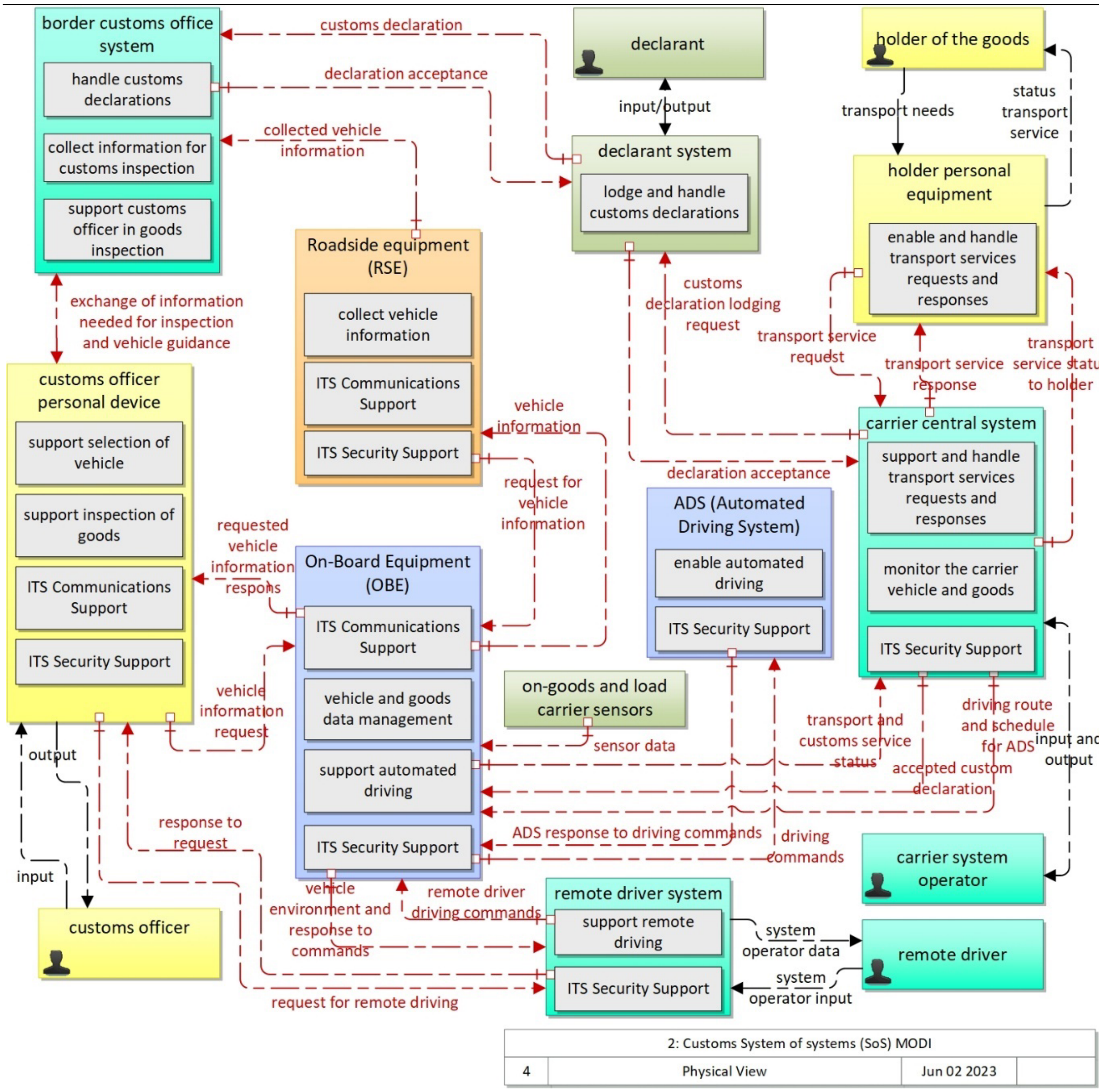

Figure 14: Customs System of Systems (SoS) in MODI scenario

4.2.1 Holder personal equipment

The holder personal equipment is the same as described in section 3.3.1 as for functionality and interfaces.

4.2.2 Carrier central system

The Carrier central system handles the interfaces to the holder personal equipment, the carrier vehicle On-Board Equipment (OBE), and the declarant system. The interface to the holder personal equipment is described in section 3.3.1.3.3.2 The interface to the declarant as well as the basic functional objects are described in section 3.3.2.

The analogue interface to the driver in manually driven vehicles transporting goods is replaced with a digital interface to the On-Board Equipment in the automated vehicle transporting the goods. The digital information transferred to the OBE covers the accepted custom declaration and the driving route and schedule to be used by the ADS (Automated Driving System). The two information flows are comparable with the documents given to the driver in the 'today' scenario.

The information flow *transport and customs service status* from the OBE to the Carrier central system enables the operator of the carrier central system to continuously monitor the transport of the goods. Sensors on the goods (if available) connected via short-link communication to the OBE, enables the carrier also to continuously monitor the status of the goods, e.g., temperature, vibrations, and shock.

4.2.3 Border customs office system

The border customs office system has interfaces to the declarant system, the roadside equipment, and the customs officer personal device. The basic functional objects of the Border customs office system are described in section 3.3.3. The interface to the declarant system is described in section 3.3.4.

The interface to the roadside equipment is related to the functional object *collect information for customs inspection*. The information continuously collected from vehicles approaching the border customs area could for instance be vehicle registration number, VIN, number of axles, axle loads and total weight. This could e.g., be used for pre-selection of vehicles. The collection of information could take place by both roadside equipment sensors and ITS communication, e.g., ITS-5G or DSRC, with the OBE in the vehicle. The last option enables collection of specific vehicle data that could be important concerning the pre-selection of vehicles.

The interface to the customs officer personal device is described in section3.3.3.

4.2.4 Customs officer personal device

The customs officer personal device covers both fixed equipment, e.g., a PC, and mobile equipment, e.g., tablets. Hence, the personal device supports the customs officer to perform his tasks, both when working in his office and working out in the field and control halls. The personal device could also be a digital twin of the customs office system.

The interface to the border customs office system is described in section 3.3.3. The personal device could also have an interface to the On-Board Equipment (OBE) enabling the customs officer to communicate with the vehicle and request information that could be relevant for the goods inspection without being connected to the border customs office system. The interface could possibly also enable the customs officer to send an emergency break message to the automated vehicle in case an emergency should occur.

In case of an automated vehicle subject to customs inspections, there is a need for remote driving in the customs area. It will not be possible to include the movement of the vehicle in the customs area in the information flow *driving route and schedule for the ADS* as this will be decided on the spot by the customs officers. Type of vehicle, type of goods, type of inspection, e.g., scanning, and availability in inspection lines will be examples on parameters that will decide how the vehicle is moved around in the customs area. The customs officer personal device enables the custom officer to request remote driving from the remote driver system. The custom officer could also be an option concerning the role *remote driver,* possibly with the remote driving system integrated in the customs officer personal device.

4.2.5 Roadside equipment

The roadside equipment covers equipment used for collecting information about the vehicles approaching the border customs office. The interface to the border customs office system is described in section 3.3.3. It is assumed that the roadside equipment continuously collects information from approaching vehicles and forward automatically all information collected to border customs office system where the functional object *collect information for customs inspection* uses the information, e.g., for pre-selection of vehicles. The information collected comes both from the roadside equipment sensors and the ITS communication with the OBE.

4.2.6 On-Board Equipment (OBE)

The basic physical objects and interfaces are described in 4.1on page 30 covering the OBE basic functional objects and interfaces to:

- **Local positioning Systems** with their functional objects *local positioning services* and *ITS Security Support*
- **Communication service provider systems** with their functional objects *provide communication services*
- **ADS (Automated Driving System)** with its functional objects *enable automated driving* and *ITS Security Support*
- **Remote driver systems** with their functional objects *enable remote driving* and *ITS Security Support*
- **Road infrastructure authority systems** with their functional objects *authorize driving on roads governed by road auth*ority and *ITS Security Support*

In addition to these physical objects with their functional objects, the OBE will have relationships to the following physical objects and interfaces in the Customs use case (N02):

- Customs officer personal device described in 4.2.4
- Carrier central system described in 4.2.2
- Roadside Equipment (RSE) described in 4.2.5
- On-goods and load carrier sensors

The main functional object in relation to the use case NO2 Customs is the *vehicle and goods data management*. However, the ITS Security Support is also a very important functional object as the security services are designed to protect the crucial and vulnerable data and communications ensuring confidentiality, integrity and availability as a minimum of security measures.

The interface between the OBE and the RSE enables the customs officers to collect information about vehicles approaching the customs area. The information can be collected by sensors being part of the RSE, e.g., cameras and inductive loops and piezoelectric cables in the road surface. The information can also be collected by short-link communication between the RSE and the OBE enabling the transfer of data on both the vehicle itself, types of goods and their status, the driving route and schedule and other information relevant for the customs inspection.

The interface to the remote driver system covers to important information flows:

- *Remote driver driving commands* that consists of the driving commands given by the remote driver. The remote driver could be a person at the customs area, or it could be a person in a remote vehicle control centre. In the first case one could even foresee that the customs officer personal device and the remote driver system was integrated in the same physical object allowing for that the customs officer could control the movement of the vehicle when inside the customs area.
- *Vehicle environment and response to commands* that consists of information on the vehicle environment, e.g., information from cameras installed in the front, the rear end, and the sides of the vehicle. Another option is 360 degrees cameras on the top of the vehicle. Also, information from vehicle sensors, e.g., sensors on moving parts of the vehicle, will be important information to send to the remote driving system. The information flow also consists of responses to the driving commands from the remote driver. Combined with the dynamic information on the vehicle environment it supports the remote driver in monitoring and controlling the movement of the vehicle.

The interface to the ADS is described in 4.1..

The interface between the OBE and the carrier central system is used for transferring the digital versions of the documents that today is carried by the driver or stored in goods data hubs accessible by authorised persons or organisations. However, the interface also allows for a quite extensive flow of information of the status of the transport service, customs and goods status compared to the situation today. The OBE can continuously or e.g., every hour, send information to the carrier on the progress and status.

4.2.7 ADS (Automated Driving System)

The ADS is described in section 4.1.

4.2.8 The remote driver system

The remote driver system is described in section 4.1.

5 Standardisation of interfaces

5.1 OBE - On-board Equipment

The OBE is a crucial physical object with its functional objects and multiple interfaces. The OBE, aka ITS on-board equipment, is defined in ISO TS 14812 [6] as a *vehicle system that provides all ITS functionality on-board the vehicle*. Two notes related to the definition are:

> Note 1 to entry: ITS on-board equipment relates to any functionality. When there is a need to distinguish between core functionality and that by a special vehicle, the term can be further refined by indicating the type of vehicle to which the on-board equipment relates. For example, emergency vehicle on-board equipment can provide specialised functionality.
>
> Note 2 to entry: The on-board equipment may also perform other functions.

Of the six different interfaces to the OBE there is only one with fixed line communication. The rest of the interfaces are air interfaces which makes the OBE vulnerable for security attacks and requires an extensive awareness and a range of security mechanisms to keep the risk to an acceptable level. ISO 21177:2023 [10] is a relevant standard that contains specifications for a set of ITS station security services required to ensure the authenticity of the source and integrity of information exchanged between trusted entities. The five physical objects having an air interface to the OBE have all the functional object ITS Security Support as described in 4.1. The sixth interface, i.e., the OBE – ADS interface is considered to be an internal vehicle interface under the control of the vehicle manufacturer.

The OBE has four functional objects:

- *ITS communication Support* that supports the standardised ITS communication types and profiles, e.g., ITS-G5, DSRC, and 5G.
- *Vehicle and goods data management* which covers all functions needed for data management of all vehicle and goods data stored in the OBE
- *support automated driving* supporting the Automated Driving System with the required information and interface to the environment external to the vehicle, e.g., the interface to the remote driver system
- *ITS Security Support* as described in 4.1.

5.2 OBE interfaces

5.2.1 OBE – remote driver system

The interface and the recommendations in relation to the interface is described in chapter 4.1.

5.2.2 OBE – ADS

The OBE – ADS interface is shown in Figure 15. The interface is considered as an internal vehicle interface in charge of the vehicle manufacturer, and it is not further elaborated in this document.

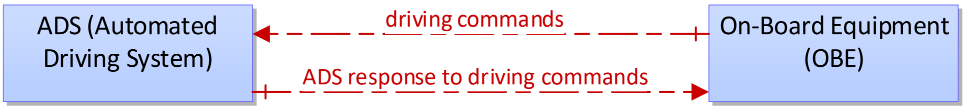

Figure 15: Information flows between OBE and ADS

5.2.3 OBE – Carrier central system

The OBE – carrier central system is shown in Figure 16.

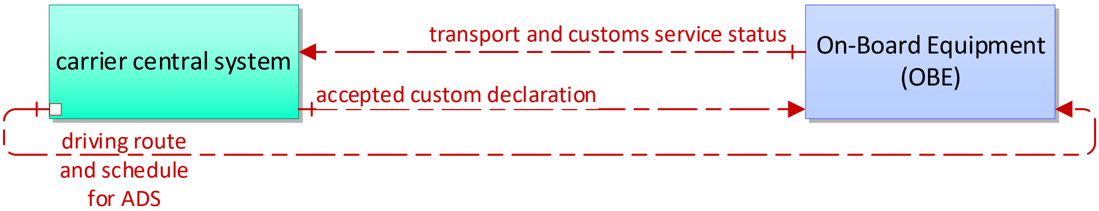

Figure 16: Information flows between OBE and carrier central system

The carrier system operator downloads the driving route with references to high-definition (HD) digital maps and the driving schedule for the ADS. The driving route should preferably be a set of alternative routes enabling the ADS to select the best choice based on driving conditions and unexpected incidents that may occur during driving. The accepted customs declaration and other information relevant for the customs inspection is also downloaded to the OBE enabling the customs officer and RSE to read the information whenever needed. The OBE reports to the carrier central system on 1) the status of the transport of the goods, 2) the customs processes and 3) possibly the status of the goods transported in case there are on-goods and/or load carrier sensors connected to the OBE.

There is also execution of security services before and during the transmission of data, but they are not shown in the figure above. This interface is vulnerable, has a high risk and must be protected by strong security mechanisms to ensure, as a minimum, confidentiality, integrity and availability of the driving route. The data stored in the OBE must be stored in a secure way and access to the data store requires authorisation of the entity accessing the data store. Unauthorized access to the driving route may change the driving route to another destination, a risk that could be mitigated or avoided by continuously monitoring of the vehicle position and comparing it with the original driving route.

5.2.4 OBE – RSE interface

The OBE – RSE interface is shown in Figure 17.

Figure 17: Information flows between OBE and RSE

The RSE requests information from the vehicle OBE when the vehicle arrives at the customs area. There could be several RSEs, e.g., 1-2 km downstream the customs area for collecting information enabling the customs officer (or an application in the border customs office system) to pre-select vehicles for customs inspection. The OBE responds with the vehicle information which possibly also includes information about the goods carried.

Although the interface in most cases is a read-only interface it should be protected by security mechanisms, e.g., two-way authentication ensuring that the OBE and RSE are real entities authorised to exchange correct information. An example on a possible threat is that the OBE sends fake information to avoid pre-selection for inspection or there are two OBEs in the vehicle where the real one is 'muted' in one or another way and the fake is responding to the RSE.

5.2.5 OBE – customs officer personal device interface

The OBE – customs officer personal device interface is shown in Figure 18.

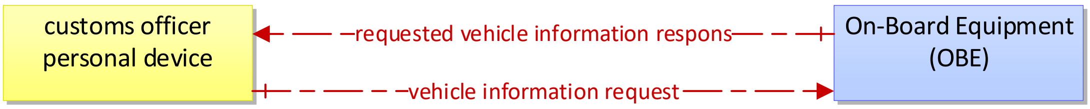

Figure 18: Information flows between OBE and Customs officer device

The interface could be compared with the OBE – RSE interface described in 5.2.4. The interface will probably be based on requests from the customs officers when inspecting a vehicle and the goods carried, collecting additional information to the information collected by the RSE and transferred to the customs officer personal device via the border customs office system. Although the interface in most cases is a read-only interface it should be protected by security mechanisms, e.g., two-way authentication ensuring that the OBE and customs officer personal device are real entities authorised to exchange correct information. A possible threat is that fake customs officer personal devices can collect crucial information about the goods carried.

As the OBE has a connection to the ADS it should be considered whether the Customs offices personal device should have some kind of emergency application enabling the customs officer to stop the automated vehicle, e.g., when the vehicle sensors do not observe or sense obstacles in the planned trajectory of the vehicle or when the remote driver apparently has not full control of the vehicle and/or its environment.

5.2.6 OBE – on-goods and load carrier sensors

Figure 19 shows the interface between the OBE and sensors integrated or fixed to the goods and/or load carriers. The sensors can register different parameters like temperature, shock, and vibrations above acceptable levels.

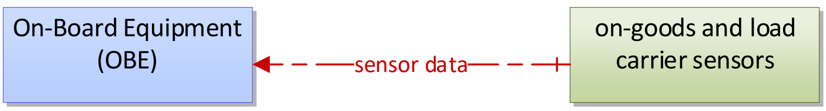

Figure 19: Information flows between OBE and on-goods and load carrier sensoers

The goods and load carrier can also store and transmit other relevant information about the goods. The interface between the OBE and goods should consider that there will be more advanced On-Goods Equipment (OGE) that implies a possibility for a more advanced monitoring of the goods enabling the customs officer to benefit from the data stored in the OGE and the functional objects of the OGE as described in [5] and [2].

Figure 20 shows a figure from [5] where the access points for communication with the OGE is Supply Chain Control Systems and Traffic Management Systems. The Customs Office Personal Device and Border Customs office central system could have been added as a two other access points. The middle box of the OGE box shows the data stored and the lower box shows the functional objects. The functional objects include applications like two-way authentication, read, write and delete data, and monitor transport, route, status and environment.

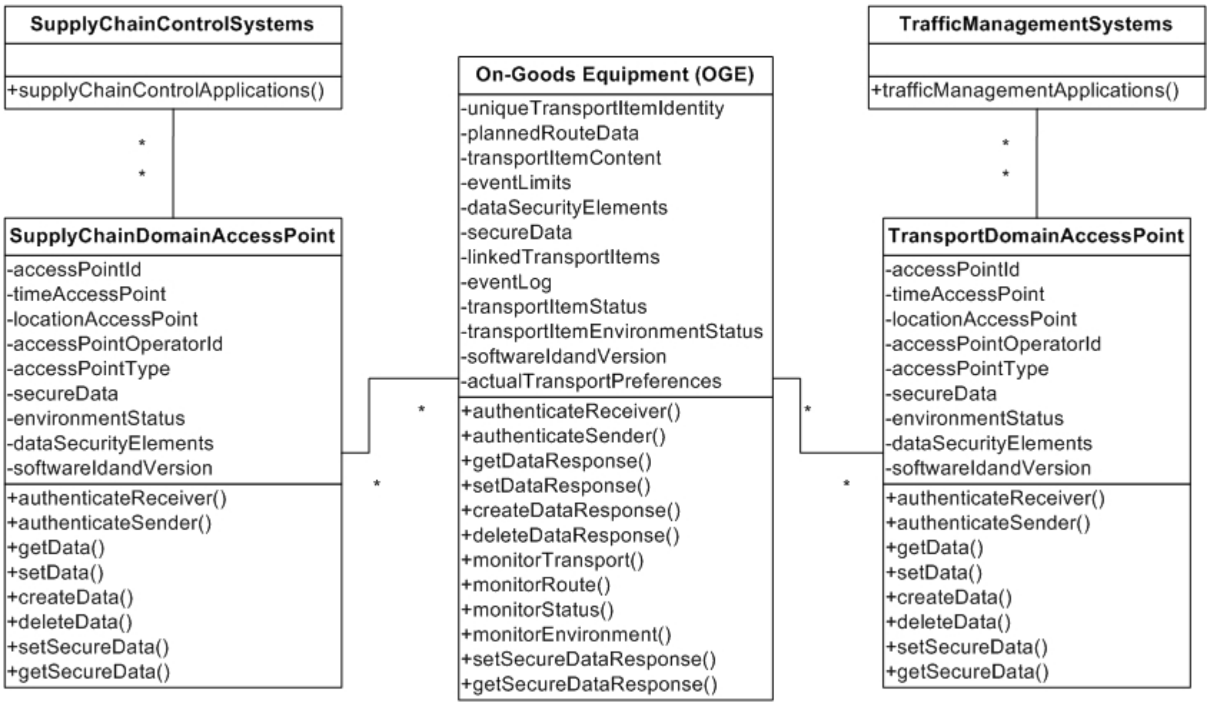

Figure 20: Data stored and functional objects in On-Goods Equipment (Source:[5])

Entity 1	Entity 2	Comment
Border customs office system	Declarant system	Interface should be based on the Union Customs Code (UCC) [11] and [4].
Border Customs office system	Customs officer personal device	Internal interface compliant with security, functional and data requirements for Customs officer tasks and UCC [11] and [4].
Border customs office system	Roadside equipment	Build on OBE – RSE interface
Customs officer personal device	Remote driver system	There should be an EU standard for the interface avoiding vehicle manufacturer dependent interfaces that could imply separate interfaces for each type of vehicle make and model. The interface requires a high security level.

Entity 1	Entity 2	Comment
Declarant system	Carrier central system	Web-applications based on UCC, [11] and [4].
Holder personal equipment	Carrier central system	Can be carrier dependant web-applications, but preferably there should be European guidelines harmonising the user interface to European carriers for transport and customs services.

Table 1 Other interfaces

6 Requirements and recommendations

Based on the previous clauses, there are several requirements and recommendations derived in this deliverable. These are stated and explained below.

6.1 Requirements

The following requirements can be understood as technical necessities to establish highly automated driving communication and positioning network that is required to have a vehicle pass through a border crossing scenario fully automated.

MODI_BC_Req_01: Automated vehicles crossing a border between two countries or between a publicly available road network and a confined area shall comply with the connectivity requirements defined in MODI deliverable D3.1 Report on connectivity requirements [12] and the vehicle automation requirements in MODI deliverable D3.2 Report on automation requirements.

MODI_BC_Req_02: The On-Board Equipment in the automated vehicle shall have a communication module fulfilling the connectivity requirement defined in MODI deliverable D3.1 Report on connectivity requirements [12].

NOTE: Relevant requirements in D3.1 are e.g., MODI_CR_TBN_01, MODI_CR_TBN_02, and MODI_CR_TBN_03.

MODI_BC_Req_03: When crossing a border, the automated vehicle shall be able to connect to national, regional and local communication and C-ITS services, e.g., real-time traffic information (most often National DATEX II service), weather information, C-ITS services, confined area services, etc.

NOTE: Relevant requirements in D3.1 are e.g., MODI_CR_PR_01, MODI_CR_PR_02 and MODI_CR_PR_03

MODI_BC_Req_04: When crossing a border, e.g., between two countries or between a publicly accessible area and a confined area with access control, the automated vehicle shall connect to a positioning service with the required accuracy for the area the vehicle enters.

NOTE: More detailed requirements for positioning services are defined in MODI D3.2 Report on automation requirements, clause 3.4.1, Relevant requirements are MODI_AR_PT_01 to MODI_AR_PT _10.

MODI_BC_Req_05: When crossing a border, the automated vehicle shall ensure that the same reference frame is used when combining positions from positioning services, information services, digital maps and C-ITS services.

NOTE*:* This is one of the most crucial requirements related to border crossings.

MODI_BC_Req_06: When crossing a border, the automated vehicle shall connect to the national, regional and local services for the provision of static data updates as well as the services for dynamic information.

NOTE: Relevant requirements in D3.1 are e.g., MODI_CR_PR_01, MODI_CR_PR_02 and MODI_CR_PR_03

MODI_BC_Req_07: The OBE and its interfaces to other ITS and C-ITS objects shall be protected by security mechanisms and measures ensuring a minimum level of confidentiality, integrity, and availability.

MODI_BC_Req_08 The system of Systems (SoS) for border crossing and SoS for Customs shall be based on a security and certificate architecture defined in [13] and [9].

6.2 Recommendations

The following recommendations are given based on the previous clauses and with a motivation, why these are sensible to consider within the MODI scope.

Recommendation D1.3-1:

There is an urgent need for regulations and agreements that define the responsibilities of the involved actors in an ambiguous way independent of who the *remote driver* is e.g., the vehicle manufacturer, a border crossing officer, or a company providing monitoring and remote driving services.

Motivation: Lack of unambiguous regulations and agreements concerning roles and responsibilities will be a major obstacle for a safe, secure and seamless remote driving in cases where a remote driving incident may cause fatalities, injuries and/or damage of other objects.

Recommendation D1.3-2:

The two information flows between OBE and remote driver system should be recorded for later review and learning, e.g., AI supporting the remote driving, and/or investigation in case an unexpected incident occurs, e.g., an accident.

Recommendation D1.3-3:

There should be a CEN Application Programming Interface (API) for the OBE – Remote driver system interface based on CEN and ISO C-ITS standards.

Motivation: A CEN API will enable an interoperable, secure, flexible, and effective remote control of automated vehicles moving around in European border areas, customs areas, harbours, terminals, and similar traffic areas where the driving route for the automated vehicle is not available in advance. Lack of such an API is expected to cause the development of proprietary solutions that will be a major challenge for operators of automated vehicles and operators of border, customs and other confined areas.

Recommendation D1.3-4:

The CEN API for the OBE – remote driver system interface should amongst others be based on the ISO 7856 Intelligent transport systems — Remote support for LSAD[1] systems - (RS-LSADS) — Performance requirements, system requirements.

[1] LSADS - low speed automated driving system

Motivation: The scope of ISO 7856 is the following [2]:

- *This document describes remote support, which is the provision of information or intervention in DDT (Dynamic Driving Tasks) to LSAD (Low Speed Automated Driving Systems) operated at Level 4 automation on predefined routes by a remotely located human in order to facilitate trip continuation.*
- *This document is applicable to RS-LSADS in vehicles that provide passenger transport or logistics services on predefined routes.*
- *This document defines the terms and definitions related to RS-LSADS and the system architecture of RS-LSADS.*
- *This document specifies types of RS-LSADS, remote monitoring, remote assistance and remote driving under very limited conditions, and conditions when they can be activated.*
- *This document specifies the performance requirements, system requirements and performance test procedures of RS-LSADS.*
- *This document specifies the data to be communicated between vehicles and RS-LSADS but does not specify protocols and other aspects of communication itself.*
  This document is applicable to remote support of operational and tactical functions, but does not apply to strategic functions.
  Besides, communication and shift of telecom provider and swapping from, e.g., CPOS to SWEPOS might result in a period with no GNSS correction data. The vehicle must be able to navigate in such discontinuity of positioning services, for example, by finding their relative position to landmarks with known and accurate positions.

Recommendation D1.3-5:

There should be a CEN Application Programming Interface (API) for the OBE – Road infrastructure authority centre system interface based on CEN and ISO C-ITS standards.

Motivation: A CEN Application Programming Interface (API) will enable an interoperable, secure, flexible, and effective control of the automated vehicle permission to use the road infrastructure governed by the road infrastructure authority. The same interface could be applied for interfaces between roadside equipment (RSE) and personal equipment, e.g., tablets used by road authority control personnel.

Examples on standards that could be used as basis for a CEN profile standard are:

- ISO 14906:2022 Electronic fee collection — Application interface definition for dedicated short-range communication
- EN 15509:2023 Electronic fee collection - Interoperability application profile for DSRC

[2] https://www.iso.org/standard/82951.html

Recommendation D1.3-6:

There should be a CEN Application Programming Interface (API) for the OBE – carrier central system interface based on CEN and ISO C-ITS standards.

Motivation: A CEN API will enable customs officers and other authorised persons, e.g., police and road authorities, to access the information about the vehicle route based on the same interface specification. This is very relevant in cases where the vehicle is transporting dangerous goods.

Recommendation D1.3-7:

There should be a CEN Application Programming Interface (API) for the OBE – RSE interface based on CEN and ISO C-ITS standards.

Motivation: A CEN API will enable customs officers and other authorised persons, e.g., police and road authorities, to access the information about the vehicle and possibly the goods being transported. This is very relevant in cases where the vehicle is transporting dangerous goods. The ISO and CEN interface standards for electronic fee collection, [8] and [3] and standards published by ISO TC204 WG7 Commercial Fleet Management could be relevant standards to build on.

Recommendation D1.3-8:

There should be a CEN Application Programming Interface (API) for the OBE – customs officer personal device based on CEN and ISO C-ITS standards.

Motivation: A CEN API will enable customs officers and other authorised persons, e.g., police and road authorities, to access the information about the vehicle and possibly the goods being transported. This is very relevant in cases where the vehicle is transporting dangerous goods. The ISO and CEN interface standards for electronic fee collection, [8] and [3] and standards published by ISO TC204 WG7 Commercial Fleet Management could be relevant standards to build on. The interface could possibly include services and data that enables the customs officer to stop the automated vehicle in emergency situations.

Recommendation D1.3-9:

There should be a CEN Application Programming Interface (API) for the OBE - On-goods and load carrier sensors based on CEN and ISO freight standards.

Motivation: A CEN API will enable customs officers and other authorised persons, e.g., police and road authorities, to access the information about the goods being transported and monitor the status of the goods. The API will enable different types of sensors for different types of goods and load carriers to communicate with the OBE. The standard should preferably consider on-goods equipment (OGE) and the data exchanged, security mechanisms and functionality of such devices. The ISO standards for freight published by ISO TC204 WG7 General fleet management and commercial/freight could be relevant standards to build on. Other relevant standards are described in [2].

7 Relevant international standards

7.1 ITS security support

The OBE is a crucial physical object with its functional objects and multiple interfaces. The OBE, aka ITS on-board equipment, is defined in ISO TS 14812 [6] as a *vehicle system that provides all ITS functionality on-board the vehicle*.

Of the six different interfaces to the OBE there is only one with fixed line communication. The rest of the interfaces are air interfaces which makes the OBE vulnerable for security attacks and requires an extensive awareness and a range of security mechanisms to keep the risk to an acceptable level. ISO 21177:2023 [10] is a relevant standard that contains specifications for a set of ITS station security services required to ensure the authenticity of the source and integrity of information exchanged between trusted entities.

The scope of ISO 21177 is:

> *This document contains specifications for a set of ITS station security services required to ensure the authenticity of the source and integrity of information exchanged between trusted entities, i.e.:*
>
> *— between devices operated as bounded secured managed entities, i.e., "ITS Station Communication Units" (ITS-SCU) and "ITS station units" (ITS-SU) as specified in ISO 21217; and*
>
> *— between ITS-SUs (composed of one or several ITS-SCUs) and external trusted entities such as sensor and control networks.*
>
> *These services include the authentication and secure session establishment which are required to exchange information in a trusted and secure manner.*
>
> *These services are essential for many intelligent transport system (ITS) applications and services including time-critical safety applications, automated driving, remote management of ITS stations (ISO 24102-2), and roadside/infrastructure-related services.*

The ISO 21177 standard also refers to other standards that are relevant for C-ITS security:

> *ETSI TS 102 941, Intelligent Transport Systems (ITS); Security; Trust and privacy management*
>
> *ETSI TS 103 097, Intelligent Transport Systems (ITS); Security; Security header and certificate formats*
>
> *IEEE 1609.2 including Amendment 1, IEEE Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages*
>
> *IEEE 1003.1:2017, IEEE Standard for Information Technology--Portable Operating System Interface (POSIX(R)) Base Specifications, Issue 7*

7.2 Automated vehicles driving at low speeds

Automated vehicles crossing borders and driving in confined areas are expected to keep a low speed while doing so. Two relevant ISO standards are shortly described below. Low-speed automated driving systems (LSAD) is defined as automated driving system that has a maximum speed of 8,89 m/s which equals 32 km/h. The two standards described have also several normative reference that could be relevant for the MODI use cases.

ISO 22737:2021 Intelligent transport systems — Low-speed automated driving (LSAD) systems for predefined routes — Performance requirements, system requirements and performance test procedures.

The requirements in the standard are both relevant for slow driving through border crossings and predefined routes in confined areas, e.g., a route from the gate to a ramp for loading/unloading. The introduction to the standard is as follows:

The move towards automated driving systems is leading to a shift in the way people, goods and services are transported. One such new mode of transport is low-speed automated driving (LSAD) systems, which operate on predefined routes. LSAD systems will be used for applications like last-mile transportation, transport in commercial areas, business or university campus areas and other low-speed environments.

A vehicle that is driven by the LSAD system (which can include interaction with infrastructure) can potentially have many benefits, like providing safe, convenient, and affordable mobility and reducing urban congestion. It can also provide increased mobility for people who are not able to drive. However, with different applications of LSAD systems in the industry worldwide, there is a need to provide guidance for manufacturers, operators, end users and regulators to ensure their safe deployment.

The LSAD system requirements and procedures specified herein are intended to assist manufacturers of the LSAD systems in incorporating minimum safety requirements into their designs and to allow end users, operators, and regulators to reference a minimum set of performance requirements in their procurements.

ISO CD 7856 (under development) Intelligent transport systems — Remote support for LSAD systems (RS-LSADS) — Performance requirements, system requirements and performance test procedures

The requirements in the standard are both relevant for remote driving through border crossings and predefined routes in confined areas.

The introduction to the standard is as follows:

For the sustainable operation of mobility services using ADS, it is currently necessary to support the functioning of the system by humans, and remote support enables mobility services to continue beyond the constraints of ODD. The low speed of LSAD systems equipped vehicles makes remote support less challenging.

The combination of LSADS and remote support will enable ADS equipped vehicles to be implemented in society at an early stage. This standardisation proposal indicates the technical requirements of remote support for LSADS so that vehicle manufacturers and transport providers can introduce this technology.

Remote support is beneficial to the transport industry in improving the efficiency of transport operations, increasing safety, reducing operating costs.

Currently individual development and demonstration projects for remote support of LSADS are implemented in several regions and countries, including EU, UK, the USA, Canada, Australia, Korea, and Japan etc. In some regions, social implementation has been achieved and legal requirements are beginning to be put in place.

This standardisation is intended to provide a common basis for LSADS development, to support fast and smooth market implementation and to ensure rapid deployment of the technology.

ISO/SAE PAS 22736 (SAE J3016), which is being developed by TC204/WG14, defines remote assistance and remote driving. In addition, in ISO 22737 (LSAD system) external entity support is described.

8 Conclusions

The aim of this deliverable was to describe current border processes and then take a look into the future and develop an idea how these processes will look like with SAE level 4 heavy goods vehicles in use.

Eventually, requirements and recommendation regarding the digital processes are derived. These are specifically relevant for the Norwegian use case regarding the border crossing between Norway and Sweden. The Swedish use cases, where a heavy goods vehicle is driving from a terminal onto public roads and then into a confined port area. The third relevant use case from the Netherlands is dealing with terminal operations including entering or exiting through gates towards or from public roads.

In the deliverable it was shown that very precise positioning and the correct reference frames are key to automated vehicles to pass a border of any kind. Especially a variation in systems between countries or between confined private and public areas can easily cause various issues. It has to be guaranteed that the personnel is kept safe under all circumstances, while very heavy vehicles are autonomously navigating around them. A variation of a few centimeters could be life threatening in the worst case.

Moreover, the intuition of experienced staff is not to be underestimated regarding irregularities and errors in the process regarding regulation and customs. The personal contact will completely disappear in an automated scenario and might make decisions on whether to double check a vehicle more challenging. A remote driving option could be considered in such a case or the staff needs to be enabled to make early decisions on further inspections prior to the vehicle arriving to the border, so that the vehicle could be guided to a special and secluded area.

It has to be considered that this deliverable is an outlook into the future and everything written has to be evaluated by further MODI activities and by future research and on the roads. The requirements and recommendations written down in this deliverable should be considered recommendations to the oncoming MODI activities and will be adapted in the final book of recommendations, if necessary.

9 References

[1] Architecture Reference for Cooperative and Intelligent Transportation, United States Department of Transportation, https://www.arc-it.net/

[2] Dreyer, H. and Foss, T., Intelligent goods in transport systems, 2012 (book)

[3] EN 15509:2023 Electronic fee collection - Interoperability application profile for DSRC

[4] EU Customs Data Model - EUCDM GUIDANCE DOCUMENT, EUROPEAN COMMISSION, as downloaded May 25, 2023, https://taxation-customs.ec.europa.eu/system/files/2021-01/eucdm_guidance_document_en.pdf

[5] Foss, T., The integration of control systems for the supply chain and transportation domains, 12th World Conference Transport Research, July 11-15, 2010 – Lisbon, Portugal, Selected proceedings

[6] ISO 14812 – Intelligent Transport Systems – Vocabulary, https://www.iso.org/standard/79779.html

[7] ISO 14813-1 – Intelligent Transport Systems - Intelligent transport systems — Reference model architecture(s) for the ITS sector — Part 1: ITS service domains, service groups and services, https://www.iso.org/standard/57393.html

[8] ISO 14906:2022 Electronic fee collection — Application interface definition for dedicated short-range communication

[9] ISO 21177:2023 Intelligent transport systems — ITS station security services for secure session establishment and authentication between trusted devices

[10] ISO/SAE PAS 22736:2021 Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles, also known as SAE J3016.

[11] Regulation (EU) No 952/2013 of the European Parliament and of the Council of 9 October 2013 laying down the Union Customs Code (recast), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R0952

[12] Zhu, J. et al., 2023, MODI D3.1 Report on connectivity requirements

[13] European Commission, Certificate Policy for Deployment and Operation of European Cooperative Intelligent Transport System (C-ITS), Release 3, May 2023.