A leap towards SAE L4 automated driving features

D1.1 User and stakeholder requirements for automated transport in logistics

28th April 2023

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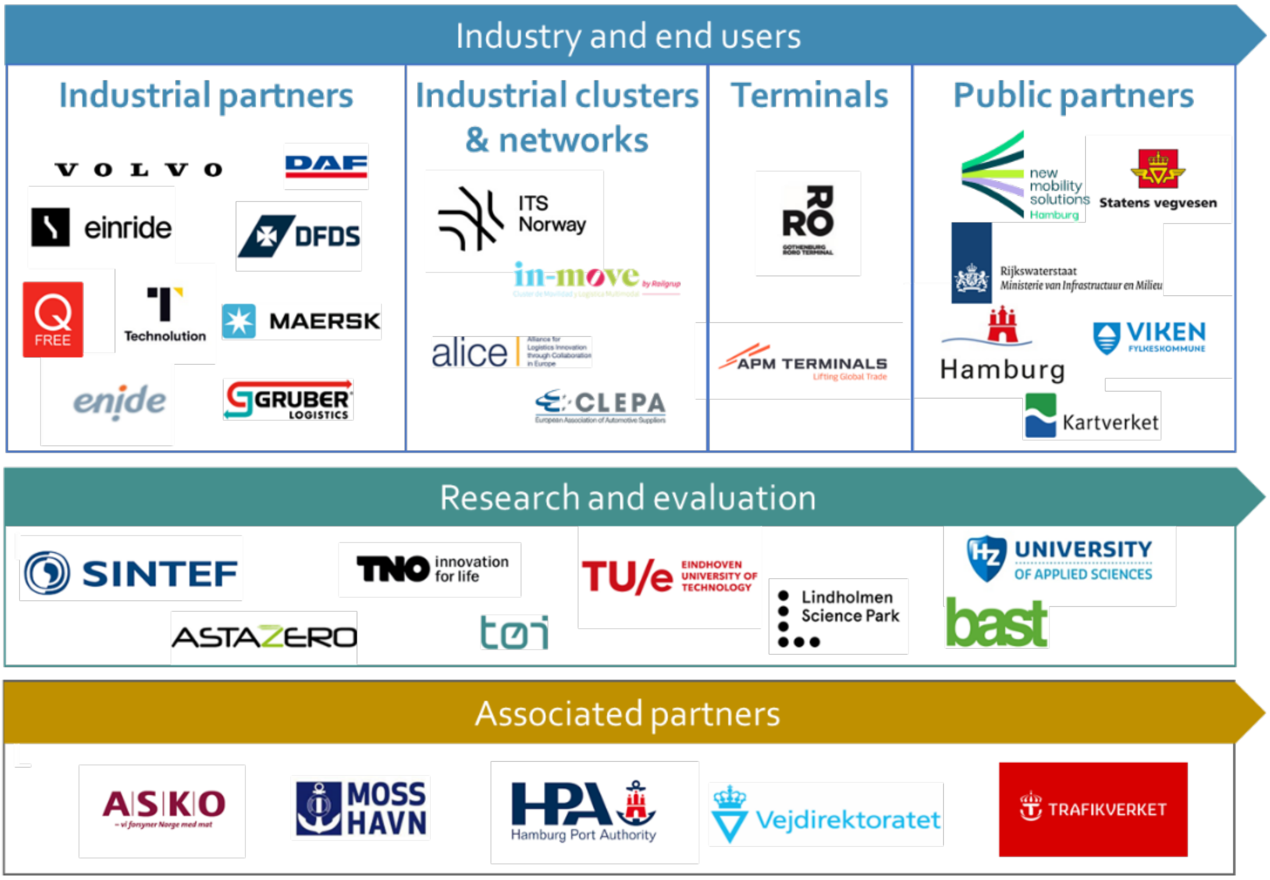

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Terms and abbreviations

Term / Abbreviation	Description
AR	Aggregated requirement. A user or stakeholder requirement derived from and summarising a larger number of original requirements.
AI	Artificial intelligence.
ALICE	Alliance for logistics innovation through collaboration in Europe.
ANPR	Automatic number plate recognition.
AT	Automated truck. In this report we often use the term to mean a highly automated truck capable of self-driving to a large extent. We largely avoid the term “autonomous” as this implies no need for human operators. The level of automation we are talking about is usually made clear by the context.
AV	Automated vehicle. Can carry passengers or goods.
CCAM	Cooperative, connected and automated mobility.
C-ITS	Connected intelligent transport systems.
DI	Digital infrastructure.
DUI	Driving under the influence (of alcohol or narcotics).
EC	European Commission.
EU	European Union.
ERP	Enterprise resource planning.
ETA	Expected time of arrival (of delivery or truck).
FMS	Fleet management system.
GDPR	General data protection regulation.
HGV	Heavy goods vehicle.
HZ	Stichting HZ Unversity of Applied Sciences.
HMI	Human-machine interaction.
HVO	Hydrotreated vegetable oil. A fuel that gives reduction in fossil gas emissions.
KPI	Key Performance Indicator.
IoT	Internet of Things.
L2	Level 2 automation technology - gives steering and brake/acceleration support to a human driver on board.
L4	Vehicle capable of driving fully automated in proper settings without the assistance or intervention of a human driver.
LGV	Laser-guided vehicle.
LIDAR	Laser imaging, detection, and ranging.
LMS	Logistics management system.
LSP	Lindholmen Science Park.
MS	Management system.
ODD	Operational design domain.
PDI	Physical and digital infrastructure.
PI	Physical infrastructure.
R	Road actors.
R&D	Research and development.
RAR	Road actor aggregated requirement.
RFID	Radio-frequency identification.
ROA	Road authority, owner or operator.
ROI	Return on investment.

Term / Abbreviation	Description
RSE	Roadside equipment.
SAE	Society of Automation Engineers.
SIN	SINTEF, applied research institute based in Norway.
SME	Small and medium-sized enterprises.
TAR	Technology developer aggregated requirement.
T	Technology developers or Technology and development.
TCO	Total cost of ownership.
TMS	Transport management systems.
TNO	Applied research institute based in Netherlands.
TOI	Norwegian Center for Transport Research (TØI).
U	Users of automated trucks and solutions in logistics.
UAR	User aggregated requirement.
VRU	Vulnerable road users.
V2C	Vehicle-to-cloud.
V2I	Vehicle-to-infrastructure.
V2V	Vehicle-to-vehicle.
WMS	Warehouse management system.
WP	Work package.

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Executive Summary

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.

This current Deliverable (D1.1) identifies preliminary user and stakeholder requirements for highly automated freight vehicles in logistics. Later work packages within the MODI project will assess, develop and refine these user requirements and use them to guide the development of solutions. This will ensure that MODI's demonstration activities address the concerns end-users and stakeholders, who will then be motivated to implement automated transport and other automated solutions in logistics.

In this Deliverable we:

- review relevant existing approaches to eliciting requirements for the use of automated transport solutions in logistics;
- identify user and stakeholder groups that are most relevant for MODI use cases;
- identify barriers, drivers and perceived requirements for using level 4 (L4) automated trucks in the type of logistics operations that MODI's demonstration activities appeal to; and
- derive and aggregate preliminary user and stakeholder requirements from the barriers, drivers and perceived requirements identified.

The **review of existing approaches** to requirements elicitation showed that cooperative, connected and automated mobility (CCAM) for logistics has received less attention in EU projects than CCAM for passenger transport. Where highly automated freight transport has been considered, types of users, user contexts and requirement groupings vary widely. Little has been done to explore requirements created by interactions between different groups of users and stakeholders.

As a result of the review, we identified ways in which identification of user and stakeholder requirements in MODI should build on existing work, first by generating requirements for use of automated trucks in long-distance international haulage, and second by focusing on what is needed for automated trucks to take logistics and society forward. To achieve the latter, we saw it would be important to develop user requirements for automated truck use in operational design domains (ODDs) that are relevant to the existing operations of logistics actors.

Following the review, users were identified representing a range of logistics actors with the potential to purchase or lease automated trucks for transport and distribution. These included freight forwarders, shippers, transporters, third-party logistics companies, wholesalers, logistics platforms and terminal operators. Two main stakeholder groups were identified: i) technology developers, including original equipment manufacturers (OEMs), CCAM providers and terrestrial connectivity providers; and ii) road authorities, owners and operators. Subject matter experts and worker representatives were also identified as important sources of requirements.

User and stakeholder requirement elicitation began by identifying barriers, drivers and perceived requirements through 60 in-depth, semi-structured interviews with 104 participants from over 50 organizations representing the users and stakeholders identified. Organizations represented were based in 11 European and four other countries. Analysis of interviews resulted in 48 final aggregated requirements, comprising 21 user requirements, 11 technology developer requirements and 16 road actor requirements. These specify needs the different actors have, to address challenges, maintain or improve existing functions or realize new value. Final requirements were aggregated from 384 original requirements, and the original requirements were generated by considering underlying needs evident among 1,934 interview statements describing drivers, barriers and directly perceived requirements for using highly automated trucks in logistics.

The 21 aggregated **user requirements** include 8 value requirements stating how automated trucks need to generate net cost savings, help address capacity limitations (due to driver shortage) and improve working conditions in logistics. Net savings should be achieved by reducing driver costs, reducing costs arising from traffic incidents, and increasing cost efficiencies through integration of the automated transport function into i) digital management systems, ii) physical terminal operations and iii) other automated processes.

Users specified an additional 13 requirements that set out conditions on value achievement by highly automated trucks in logistics. These include a need to account for the needs of smaller logistics actors through new business models; a gradual evolution of existing terminal infrastructure and systems; and safe, secure and low-emission operations. Users require also that the development of automated truck systems considers and accounts for all tasks drivers do in existing systems. Users require access to the competence needed to: maintain new technology; set up remote monitoring and assist operations; re-gear logistics and fleet management systems; and set up processes that support the potential of increased capacity from 24/7 operations offered by automated truck systems. Usability and evaluation of the effects of highly automated trucks on business outcomes are also specified as user requirements.

Stakeholder requirements describe how technology developers need to develop and exploit new business opportunities from L4 automation technology and develop technology further to realize business opportunities. Developments are needed to the L4 technology (vehicle, infrastructure, connectivity), information flows and interfaces (with an implicit requirement for diverse actors to share data), and vehicle structure. Developers have several requirements of other actors who they must work with to develop remote monitoring and assist functions, to standardize the upgrading of roads and regulations, and to develop standard, reliable connectivity and high-quality maps.

Road actor requirements can be grouped according to whether they address the effects of automated trucks or the development of procedures, rules and regulations. Road authorities require automated trucks to fulfil their potential to improve safety, and reduce congestion, emissions, and energy and land use for society – without reducing levels of technology acceptance. Several functions that road operators carry out should benefit from automated trucks, including traffic monitoring and management, accident investigations, infrastructure improvements and maintenance and inspections. Optimal models need to be developed for traffic control operations and distribution of tasks and information between the remote functions of road and automated truck operators. Development of diverse standards, rules and regulations is required to account for connected vehicles and roads, and new roles for operators.

Worker requirements include a need for gradual introduction of automated trucks, giving employees and society the time they need to adapt, re-educate, gain trust, and ensure safe, secure and fair systems. Drivers should be engaged in the development of automated trucks as they have unique insight and experience that should be accounted for.

Thus, preliminary requirements for the use of highly automated trucks in logistics have been specified to inform subsequent MODI activities. Because they have been kept broadly applicable, several steps will be needed between the requirements we have identified and the specification of solutions for MODI. An important first step will be for co-creation groups assess the validity, plausibility and relevance of each user and stakeholder requirement in the context of each envisaged use case. This will include checking whether each aggregated requirement gets to the heart of a unique underlying issue that is important to address in that specific use case. Several of MODI's partners are also "users" who will be involved to assess, refine and iteratively develop the preliminary requirements that we have identified, as demonstration activities and ODDs begin to emerge.

Various analyses of the requirements included in this Deliverable will also inform MODI as individual use cases and demonstration activities progress. One analysis will guide the selection of appropriate requirements for each envisaged demonstration. A second analysis, which compares user requirements identified by the EU project AWARD with those we identified, will also be useful to consider as MODI activities are developed. A third analysis suggests some differences in the focus of requirements among the different actor types, which may be important to attend to. Logistics actors accept that the technology is or will be developed to allow automated transport of goods in traffic, and their requirements mostly concern integration of automated trucks at terminals. In contrast, the requirements of road/port authorities and road operators are more concerned with integration of automated trucks with existing road traffic. Technology developers are and should be concerned with both areas. They should recognize that both terminal and road owners require that automated trucks be implemented with only minimal, simple or gradual modifications to the existing physical infrastructure. Developers need to help logistics actors and road authorities understand the value of automated trucks, for instance by giving them information they need for return-on-investment (ROI) or socio-economic cost-benefit calculations, or by helping them with the digital integration of automated trucks with existing management systems. The challenge for commercial developers is how they come together to tackle such challenges, and how they can present to road authorities their common needs for regulations, data or infrastructure modifications.

Despite some differences, several common focus areas are apparent among the requirements of different users and stakeholders:

- High-volume routine transport operations are seen as viable candidates for using automated trucks now or in the near future – typically, at-terminal operations, drayage-type operations, and transport along "simple" corridors between internal assets.
- Sustainability, 24/7 operations and new business models are areas in which logistics actors, technology developers and road authorities and operators can align towards goal achievement.
- Despite a need for gradual change, different actors see the need for standardization of physical and digital infrastructure to increase the extent to which automated trucks are interoperable and can be used flexibly.
- All actors see a need for workable models of remote monitoring and functional, usable data interfaces, to be achieved by private and public actors working together on standards and regulations, and possibly on operation.
- Technology developers and road operators recognize the need to develop secure, adequate and reliable connectivity for automated trucks, including adequate signal latency and detail for remote operations.

In conclusion, we have identified initial user requirements from discussions about the value and challenges faced by different logistics actors using highly automated trucks in the most viable logistics use areas. MODI seeks to demonstrate technical feasibility of processes needed to enable each of these use areas (terminal operations, drayage, hub-to-hub, inter-city and international road haulage), so the requirements will be relevant to the design and development of demonstrations and specification of vehicle and infrastructure technology. The value each use case offers should be assessed against user value requirements. Each use case should also assess the requirements, build consensus on how they should be prioritized, and develop them iteratively as solutions emerge. Although calls for standardization and development of regulations and physical infrastructure are evident in user and stakeholder requirements, MODI should also consider exactly which changes to the regulations and which adaptations of the physical infrastructure are absolutely needed, and which changes could be avoided by expending more effort on developing vehicle solutions. Otherwise, requirements analysis suggests that logistics can best be evolved by demonstrating the feasibility of automated trucks in logistics for high-volume routine transport. Demonstrations should explore the potential of new business models and learn which aspects of both vehicles and supporting physical and digital infrastructure must be standardized across operations and geographical borders to give fully interoperable automated truck systems. Viable, safe and secure models of remote monitoring and assist for driverless automated trucks should be developed, specifying new roles and responsibilities. System-engineering approaches are needed to ensure safety and security, to protect against losses from unforeseen interactions among system components, and to integrate automated trucks into digital management systems to exploit potential efficiency gains of digitalized, automated logistics.

1 Introduction

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.
- L4 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

The aim of this Deliverable is to derive requirements for using automated transport for logistics as input for the MODI use cases.

The approach is as follows:

- Review the most relevant existing approaches to eliciting user requirements for automated transport solutions in logistics.
- Identify users and stakeholders, given the ambition of the MODI use cases.
- Interview a wide range of users and stakeholders to identify barriers and drivers for using L4 automated trucks in the type of logistics operations that MODI's demonstration activities will appeal to.
- Derive user and stakeholder requirements from the barriers and drivers identified.

Using this approach, requirements are identified through 60 interviews with users and stakeholders.

1.3 Relation to MODI output

MODI work packages 1 to 4 build towards the demonstration of the five use cases to be conducted in WP5.

WP1 lays MODI's foundation by examining the 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.

Work package 1 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. Defines recommendations for adaptations to be made to infrastructure, regulations and standards, to enable broader deployment of CCAM.

The current Deliverable addresses the first of these by identifying user and stakeholder requirements for automated transport in logistics use areas that appeal to the goals of logistics actors. These requirements will be used to inform use case analysis and development in WP2, including analyses of societal readiness levels, and to identify or confirm constraints for the development of technical solution requirements[1] in WP3 and WP4. Ultimately user and stakeholder requirements will tell us how to make demonstrations optimally relevant for users and stakeholders in WP5. The development of robust requirements will help ensure that subsequent tasks in MODI are built upon a strong foundation based on the needs of users and stakeholders.

[1] See Section 2 for an explanation of solution requirements.

1.4 Structure of the report

The remainder of the Deliverable is arranged in four sections.

Section 2 sets out what we mean by user and stakeholder requirements.

Section 3 goes on to review existing work by EU projects on user requirements identification for automated transport solutions in logistics, and how this has informed the scope of and approach taken to identifying user and stakeholder requirements in MODI.

Section 4 describes the derivation and specification of 48 aggregated user and stakeholder requirements for further development in MODI. It explains how each MODI requirement can be traced back through a larger initial set of requirement statements, to statements from interviews about the drivers, barriers and perceived requirements for use of highly automated transport in logistics.

Section 5 compares the aggregated requirements of different user and stakeholder groups and considers the implication of different requirements for different logistics operations and MODI use cases. It also compares the user requirements identified by MODI with those identified by two most relevant EU projects – AWARD and SHOW – to highlight any discrepancies.

Finally, in Section 6 we make our conclusions and recommendations.

2 What are user and stakeholder requirements?

Multi-level requirements are required to guide the design and development of any complex system comprising multiple users and stakeholders (Davey & Parker, 2015). Whereas high-level requirements guide the development of overarching functions in the system, low-level requirements guide the design and specification of solutions used to perform system functions and achieve system goals. User and stakeholder requirements are identified by the people who together determine the system goals, or the extent to which system goals are valued and can be achieved. They are the people who the system is for (users) and the people who otherwise influence or are influenced by the system (stakeholders). Accounting for user and stakeholder requirements ensures that technical solutions and processes are specified in ways that align with the interests of people in the system, avoiding the development of solutions to non-existent problems. Accounting for user and stakeholder requirements means that people in the system are more likely to use or influence the use of solutions and processes towards the achievement of system goals (Figure 1)[2].

Figure 1: Relationship between user/stakeholder and solution requirements.

User and stakeholder requirements are normally identified prior to solution requirements. Solution requirements describe what solutions or processes must do in order to satisfy user and stakeholder requirements, as well as conditions for how they must do it. These two types of solution requirements are called functional and non-functional requirements (Hull et al. 2005). A single user requirement can lead to many solution requirements, as illustrated recently by the AWARD project (Annex 1).

As large, complex projects are dynamic, it is important to be aware of how non-technical aspects (such as social or political factors) can influence the project, and to ensure that these are considered in requirements elicitation (Katina et al. 2014). This is especially true for CCAM, where user acceptance and the regulatory environment play a major role in the viability of a proposed technical solution using automated vehicles.

Later work packages within the MODI project require the input of user requirements as a foundation to determine the correct solution requirements (functional and non-functional), which will inform the co-creation (WP2) and execution (WP5) of the five use cases to be carried out during the MODI project. The development of robust user requirements will help ensure that these tasks are built upon a strong foundation based on the needs of users.

[2] User and stakeholder requirements comprise transitional (what is needed to get from current system state to new operational systems) and operational (what is needed to operate new systems) requirements.

3 Review of user requirements from similar EU projects and implications for MODI

The area in which an automated vehicle can operate is called its operational design domain (ODD), the extent of which is influenced by both the technology level of the vehicle as well as the infrastructure it interacts with. For example, a shuttle system at an airport can achieve a high level of autonomy though its ODD will be very limited (just a few stops on a short section of rail at low speeds in a controlled setting) because it is reliant on the support provided by the surrounding infrastructure.

A key goal for this Deliverable is to provide user requirements that contribute to identifying and defining useful ODDs within use cases that the users perceive as interesting or in line with their goals. This will help define what highly automated or autonomous vehicles and surrounding infrastructure needs to do or provide in order to be considered useful from the perspective of different stakeholders/users. Mapping user requirements against vehicle capabilities can reveal gaps and allow the more targeted use of resources (such as infrastructure improvements in problem areas) to fill those gaps and fulfill the needs of the user/stakeholder. When introducing vehicles into logistics and traffic systems, other questions are also important to answer, such as: What changes are necessary to existing traffic systems? What would be required of logistics management systems? What regulatory changes would be needed?

Fortunately, several other EU projects have approached the elicitation of user requirements for projects developing automated vehicles (AVs). So that MODI can build on existing knowledge about user and stakeholder requirements for automated transport in logistics, we conducted a review of approaches and user requirements identified by earlier and ongoing EU projects.

3.1 Methods

Relevant completed and ongoing EU projects addressing connected, cooperative and automated mobility (CCAM) in logistics were identified using the databases CORDIS, TRIMIS, ConnectedAutomatedDriving.eu[3] (created by the ARCADE project and maintained by FAME) and the ERTRAC CCAM Roadmap (2022). To capture the most recent developments, the review focused on ongoing projects or projects completed in or after 2018. Using the criteria i) focus on CCAM and ii) relevance for logistics or the envisaged MODI demonstrations, we identified twenty-six relevant projects. Of these, 17 were complete and nine ongoing. Of the latter, five had published Deliverables as of 12/22. For each project selected, deliverables related to user requirements and use cases were reviewed on how they had defined, examined, and elicited user and stakeholder requirements.

3.2 Findings

While many projects offered relevant insights on user requirements and the use of AVs, five were considered especially relevant to MODI as they were both similar in scope and type of use cases studied. Table 1 presents five EU projects that were deemed most relevant for generating user and

[3] https://www.connectedautomateddriving.eu/projects/findproject/

stakeholder requirements for automated transport in logistics. (Other projects reviewed are presented in Annex 3.)

Table 1: EU projects most relevant to MODI.

EU Project	Period	Specific User requirements document	Use cases relevant for MODI	Approach for eliciting user requirements	Stakeholders
AWARD	Jan 21 – Dec 23	Yes	Yes	Stakeholder identification, site visits, interviews, survey, state-of-the-art literature review	Technology developers; Traffic operators and municipalities; authorities; direct process participants (users); indirect process participants
SHOW	Jan 20 – Dec 24	Yes	Yes	Desk research, user opinion discovery, survey of social media, survey iteration	Passengers & road users; umbrella associations; OEMs; Tier 1 suppliers; authorities; researchers
AUTOPILOT	Jan 17 – Oct 21	Yes	Limited - platooning	Survey to understand user preferences, iterated with evaluation from test users.	Not formally categorized
L3Pilot (or highdrive)	Sep 17 – Oct 21	Research questions and data requirements	Limited – SAE L3-4 driver HMI	FESTA-V – Research questions established, followed by hypotheses and requirements logging	Companies, public authorities, users, knowledge institutes
ENSEMBLE	Jun 18 – Mar 22	No	Limited - platooning	Simulation, survey, observation	Shippers, carriers, OEMs, platooning SPs, Insurance companies, Infrastructure management, Regulator

The findings from our review can be summarized as follows:

- **CCAM for logistics has received comparatively less attention than passenger transport**, with only seven projects having an explicit focus on logistics, three of which started late 2022. Many CCAM advances are applicable for automated vehicles (AV) generally. For instance, integrating AVs into Internet-of-Things (IoT) (Autopilot) or how to build user acceptance for AVs (SUaaVe, Trustonomy) are findings that are also applicable for automated trucks.
- **User and stakeholder requirements** identified for use of AVs in logistics are **classified according to user group or themes** arising from thematic analysis. (Different approaches to grouping user requirements by AWARD and SHOW are illustrated in Annex 2.)
- The type of **users and user contexts varies widely**. Some projects focus on the vehicle passenger or pilot as user of the human-machine interface (e.g. L3pilot, Avenue, Hadrian), whereas others consider users as those working or living in systems influencing or influenced by automated transport (e.g. AUTOPILOT, AWARD and SHOW).
- **Requirements evolve iteratively over the course of a project**. Projects employ similar methods to identify user and stakeholder requirement: desk research, user identification and recruitment, user and stakeholder requirements elicitation through surveys, focus groups,

interviews and observations. They vary in when requirements are identified during the course of the project, with some assessing user and stakeholder requirements at the start (e.g. AWARD), some at the end (e.g. Inframix), and several projects using them multiple times to capture user and stakeholder requirements as they change with the evolving project. The latter implies an interdependent relationship between use cases and user requirements.

- **Little** has been done **to explore the requirements created by** the complex **interactions of stakeholder groups** in the field of automated logistics, although AWARD emphasizes the importance of identifying user and stakeholder requirements for automated trucks in the context of factory or hub-based logistics operations (Frölich et al. 2021). In AWARD, requirements were generated from users for real-world logistics use cases (automated forklift, hub-to-hub shuttle, automated baggage handling tractor at airport, trailer transport operations and automated ship loading in port).

3.3 Implications for requirements gathering in MODI

As a result of the above review, we scoped our user and stakeholder requirements identification in Task 1.1 of MODI as follows:

- **We describe preliminary user and stakeholder requirements**. User requirements and use cases are inextricably interlinked – as use cases are developed and specifications appear, the user and stakeholder requirements change. Therefore, we should be prepared to develop user and stakeholder requirements iteratively as use cases evolve during MODI; our aim here at the outset of MODI is to describe only preliminary user and stakeholder requirements.
- **We generate requirements for use of automated trucks in the context of logistics operations.** Logistics actors cannot think about what they need in order to use automated trucks, without thinking about how and why they will use automated trucks in their respective business and operational contexts (McGraw & Harbison, 1997). Our first task was therefore to generate operational contexts for each of the technical demonstrations planned for MODI, so that they become relevant for users and stakeholders to consider. Each of thirteen technical scenarios ("sub use cases") described for envisaged MODI demonstrations (Annex 4), were therefore linked to one or more of five logistics scenarios that users and stakeholders would consider when generating requirements (Table 2).

Table 2: Logistics and technical scenarios considered by users and stakeholders generating requirements for MODI.

Logistics scenario	Technical scenario to be demonstrated in MODI (Annex 4)
Automated terminal/warehouse operations	Gate access (SE1) Driving at terminal (NL1) Terminal maneuvers (NO4) Loading and unloading (SE3) Charging (SE2)
Automated drayage, short-distance terminal-to-warehouse haulage	Gate access (SE1) Drayage service (NL2) Loading and unloading (SE3)
Automated highway transport between two hubs very close to highway	Loading and unloading (SE3) Gate access (SE1) Motorway transition (GE3) Motorway driving (NO3) Charging (SE2) Driving on public (urban) roads (SE4, GE1)
Automated mid-distance inter-city/-town haulage	Motorway transition (GE3) Motorway driving (NO3) Gate access (SE1) Charging (SE2) Loading and unloading (SE3) Driving on public (urban) roads (SE4, GE1)
Automated long-distance international haulage	Drayage service (NL3) Motorway transition (GE3) Motorway driving (NO3) Border crossing (NO1) Customs (NO2) Gate access (SE1) Charging (SE2) Loading and unloading (SE3) Driving on public (urban) roads (SE4, GE1)

User and stakeholder requirements identification in MODI aims to **build on user and stakeholder requirements identified in AWARD** in several ways:

- MODI will consider requirements for the use of SAE L4 automated trucks (see Annex 4 for description of trucks considered) in real logistics systems, considering requirements of the following key system actors:
    - Logistics actors – carriers, wholesalers, terminals, transporters, freight forwarders, third-party logistics actors or logistics platform providers.
    - Road authorities, owners, operators and other regulators (includes port authorities)
    - Technology developers – OEMs, connectivity, data, CCAM or infrastructure providers
- MODI will attempt to advance AWARD by identifying user and stakeholder requirements relevant for the use of highly automated trucks in long-distance international haulage.
- A focus on in-depth interviews on user and stakeholder requirements will give us rich data needed to generate requirements accounting for the interactions between multiple actors in whole logistics systems. Using interviews will also address concerns of variation in respondent understanding and response quality achieved when gathering user and stakeholder requirements from surveys, as well as low response rates. Interviews will also allow us to identify together with actor representatives, types of logistics operation in which use of automated trucks could be of potential interest to them (Courage & Baxter, 2005).

- In addition to focusing on what is needed for highly automated trucks to be accepted by logistics actors, our focus is on what is needed for highly automated trucks to take businesses and society forward. In identifying user and stakeholder requirements, the emphasis is on deriving requirements that will realize the values and solve the problems that public and private actors think about when they envisage using automated trucks in logistics (Hathaway & Hathaway, 2016).
- Finally, in identifying user and stakeholder requirements in MODI we wish to consider how the MODI demonstrations can give logistics companies the information they need to consider the most realistic uses of automated trucks given their business plans and goals. Even though SAE L4 automation of trucks is already possible within limited ODDs, the user requirements will tell us how to demonstrate the use of automated trucks in expanded, business-relevant ODDs so that logistics actors become more interested in using automated trucks. The use of logistics use cases as part of MODI user and stakeholder requirements gathering is an important step in this direction.

4 Preliminary user and stakeholder requirements for MODI

User and stakeholder requirements were collected through individual, group and focus group interviews with potential users of automated trucks, stakeholders involved in developing automated trucks and surrounding technology, infrastructure, procedures and regulations, and subject matter experts in the field of automated transport systems. In line with a workshop conducted at the MODI kick-off meeting, and as a result of our review, emphasis was placed on identifying requirements for the use of highly automated trucks in logistics systems.

4.1 Method

4.1.1 Recruitment of participants

A set of participants representing each user or stakeholder group was identified using i) MODI partner contacts and ii) a preliminary list of members of MODI's stakeholder group. Participants were invited by e-mail to a research interview to gather user and stakeholder requirements for highly automated transport in logistics. Appointments were made with those agreeing to interview. Before interview each participant was sent:

- Information sheet about research ethics (GDPR; in a few cases this was presented orally).
- A description of MODI's envisaged trucks and technical demonstrations (see "Scenarios used in user requirements identification" in Annex 4).
- Company use cases linking technical demonstrations to logistics scenarios (see Table 2).

Participants were asked to read the ethics information, consent to participate if they wished to do so, and read through the project materials prior to the interview. Where relevant, they were asked to focus on one or two of the technical demonstrations that were relevant to their work or interest area, as a basis for discussion during the interview. We also outlined questions that would be asked under interview.

4.1.2 Interview content and process

The semi-structured interview schedule (Annex 6) covered four main themes:

1. Role, experience and nature of business or organization. These questions allowed us to understand participant context and role of their organization in developing highly automated trucks and/or logistics. A review of main activities and assets gave us a better understanding of logistics cases and technical demonstrations that were most relevant, so that subsequent questions could be asked in the context of them.
2. Value from using automated trucks in logistics. Questions addressed reasons for wanting to use automated trucks and measures to assess impact on value. This section also included questions on support, usefulness and usability, in line with Fröhlich et al. (2021).
3. Challenges of using automated trucks in logistics. Problems to be solved are a useful way of identifying requirements that can be difficult to identify through direct questions (Hathaway & Hathaway, 2021).

4. Requirements. Questions here dealt more directly about changes to operations or activities or information that participants would be needed to make automated trucks an acceptable or attractive in terms of goal achievement (Courage & Baxter, 2005).

Questions under each theme were designed to apply to different participant groups, and to be asked in the context of specific logistics cases or envisaged technical demonstrations. In this way, user and stakeholder requirements were elicited in ways that were most relevant to MODI.

The interviews were mostly conducted online using MS Teams. Each interview lasted between 45 and 150 minutes. Three of the interviews were conducted in person, while in three cases participants gave us written answers in response to the interview questions. Most interviews were conducted with two researchers present, one of which took notes, and the sound recorded for transcription or note-checking. Most were individual or group interviews with between one and five participants, while three were international focus group interviews with between five and nine participants. The duration of the individual interviews was 45-90 minutes, group interviews lasted 70-120 minutes, while the duration of the focus group interviews was 120-150 minutes. TOI conducted 40 interviews (of which ALICE observed 5), HZ 7, LSP 6, TNO 4 and SIN 3.

4.1.3 Who did we interview?

A total of 60 interviews were conducted with relevant users, stakeholders and experts in the field. In total, 104 people participated representing over 50 organizations in 15 different countries. Figure 2 shows the number of participants according to the country where they worked.

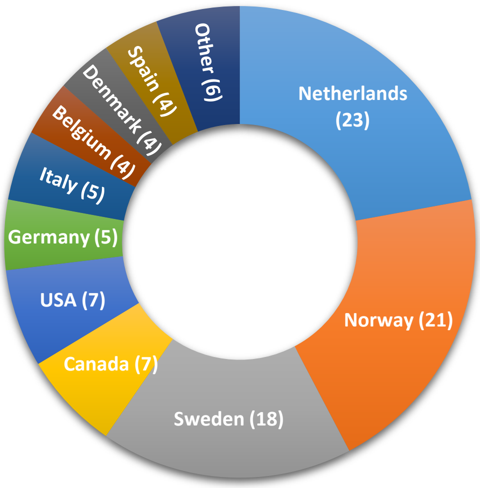

Figure 2: Number of interview participants by country.

Participants represented the following types of organization: freight/terminal/logistics (35 participants), road owners, authorities or operators (30 participants), technology developers (20 participants), subject matter experts (17 participants) and worker representatives (2 participants).

Within the group freight/terminal/logistics actors, representatives from a diverse range of actors were interviewed to capture requirements for use of automated trucks in the use domains that MODI wants to appeal to. These included two large wholesalers with own transport fleets; a European-wide logistics platform contracting third party transport; seven port or canal terminal operators; three large international shippers with their own truck fleets; and nine different logistics actors. Most of the latter had their own truck or vehicle fleets and terminal networks with varying levels of automation at warehouses, and varying nature of transport operations, including at-terminal, drayage, hub-to-hub and international haulage operations. Other actors interviewed included four port authorities, seven national road authorities or operators, five local road owners (municipalities) and one regional road owner, eight CCAM or infrastructure technology providers, three OEM/vehicle providers and two worker unions.

4.1.4 Analysis of notes, transcripts and recordings

Of the 60 interviews, 31 were transcribed and 13 written up under interview as detailed notes using a pre-prepared template. For the remaining interviews, analysis was made of sound recordings. Figure 3 gives an overview of the analysis process. (A detailed account is given in Annex 5.)

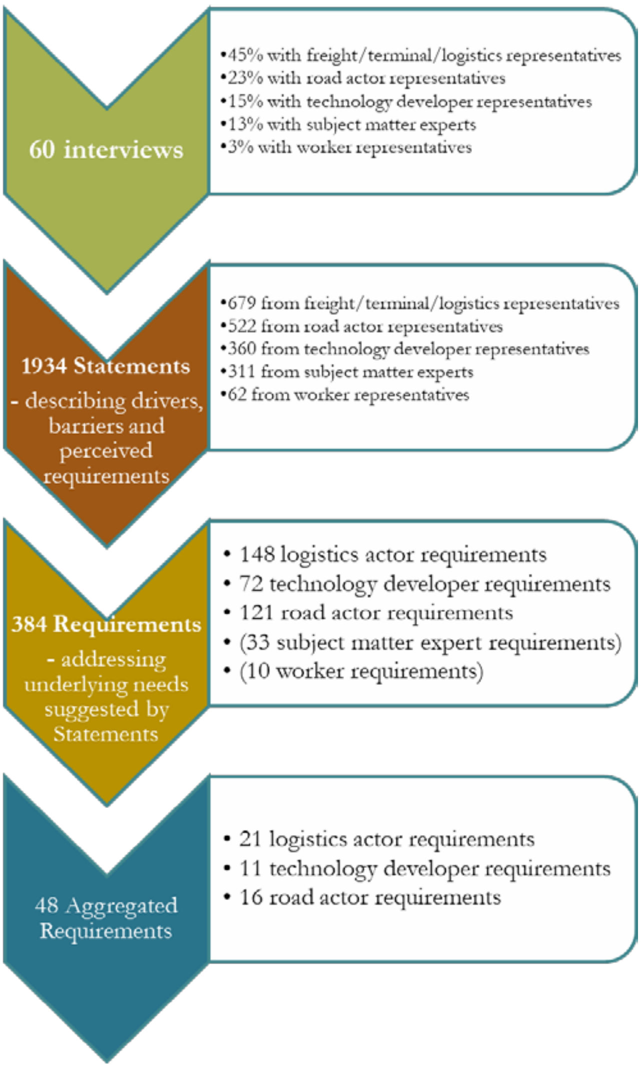

Figure 3: Analysis process used to generate user and stakeholder requirements.

4.2 Specification of user and stakeholder requirements

We identified 48 Aggregated Requirements for the use and implementation of automated trucks in different logistics operations. They comprise 21 user requirements, 11 requirements from developers of automated trucks and surrounding technology, and 16 requirements from road operators and regulators. The requirements have been collected by discussing in depth with representatives of each group, logistics operations that the MODI project has envisaged as relevant for its use cases. The requirements we specify do not describe what users or stakeholders need for demonstrations or pilots involving automated trucks, but what they need for automated trucks to become part of real logistics operations. The requirements should be considered in the design and development of use cases, to ensure that each use case is of optimal relevance and value to logistics businesses and stakeholders.

4.2.1 User aggregated requirements (UAR)

Aggregated requirements for users of automated trucks (transporters, carriers, terminals, wholesalers etc.) are specified on the following page. (They are explained in more detail in Annex 7, which links to the original, unaggregated requirements in Annex 10.)

The 21 requirements can be divided into two groups: 1) requirements for value propositions to be achieved by automated trucks in logstics, and 2) requirements specifying conditions on how value propositions should be achieved by automated trucks in logistics.

Group 1 requirements describe how logistics actors need automated trucks to result in visible cost reductions, increases in efficiency and productivity (partly through better decision making on route planning, use of capacity), and better working conditions for their employees (UAR1-8).

Group 2 requirements describe conditions that logistics actors need to fulfil for automated trucks to achieve their value propositions. These address a need for new business/financing models (see also below), the pace of change, the need for knowledge and skills, and needs for information flows, standardization, reliability, safety, security, technology acceptance and emission cuts.

New financing or business models may be needed to give logistics actors of all shapes and sizes access to automated trucks. While international actors may already be looking to build whole new ecosystems around automated trucks and form closer connections with OEMs or vendor networks (who in turn look to larger outfits to help them scale up automated trucks), there is a concern that actors with limited resources will be excluded from the value that automated trucks can provide. New business models may be needed that could let smaller actors use automated trucks without having to own, maintain or even operate them. New models could also address the financing of infrastructure changes, not only at terminals, but related to teleoperations, service infrastructure, charging infrastructure, port/terminal entrances and holding areas.

Logistics actors also need to think through new processes or how they will have to organize resources differently to exploit the potential that automated trucks give for more extended or 24/7 operations. Alluded to in UAR17, actors want also to see that all formal and informal driver tasks are accounted for where they are taken out of the system. One logistics actor mentioned that it will be difficult to foresee the effects of taking people out of the frontline logistics on long-term customer relations. Other ways of understanding customers and nurturing customer relations may need to be found.

Table 3: Aggregated requirements from potential users of automated trucks (User Aggregated Requirements; UAR).

As a logistics company using automated trucks:

Value requirements	UAR1	Our automated trucks require **fewer person hours** for operation, so we reduce costs per unit transported per km.
	UAR2	We **reduce** erratic driving and the number of sudden braking, near-miss and collision **incidents** per km, which reduces our insurance costs, costs of damage to people, material or cargo, and costs related to fuel/energy and maintenance.
	UAR3	We **save more** from using automated trucks in our operations **than we pay** for implementation, operation and maintenance of automated trucks.
	UAR4	We need fewer operators per truck and see increased truck uptimes so can achieve the **same productivity with a lower number of vehicles and operators**.
	UAR5	We can **integrate** the automated truck **digitally into** our/clients' fleet and logistics **management systems** to give more dynamic and informed planning and execution of operations, with gains for efficiency, reliability and customer satisfaction.
	UAR6	We can increase efficiency by **integrating** automated trucks **with** our/clients' **existing terminal operations**.
	UAR7	We can **increase efficiency by coupling automated trucks with automation** that reduces time taken charge/refuel, transfer goods or pass through borders, customs, gates and inspections.
	UAR8	We can **improve** pay, working **conditions**, health, wellbeing, productivity and the gender balance of our **employees** by training them for other skilled tasks that can be done during social hours and closer to home.
Conditions for value achievement	UAR9	We develop **new** client-friendly **business models** such that logistics actors of all sizes can access the business advantages of automated trucks.
	UAR10	At our **terminals** we have **standardized solutions** allowing us to interface digitally and physically with different internal and external automated trucks, increasing interoperability and flexibility.
	UAR11	We make only **gradual changes** to physical infrastructure at terminals and can receive from the previous link or transfer to next link in the distribution chain, with **few or no modifications** to that link.
	UAR12	We and our clients find that automated truck systems are flexible and adaptive enough to provide **on-time deliveries consistently**.
	UAR13	We develop processes such that automated trucks and interfacing systems execute all process steps **safely at terminals**.
	UAR14	Our automated truck systems allow us to reduce noise and **cut** CO_2 **emissions**.
	UAR15	Integrating our transport operations does not mean that our business outcomes are **unduly affected by unstable digital systems or cybersecurity risks**; use of automated trucks does not make our vehicles or **cargoes less secure**.
	UAR16	Our employees and clients understand, **accept** and trust automated truck technology.
	UAR17	On automating vehicles and systems, we **account for all tasks** previously carried out **by drivers** and other people in the system, reallocating them to technology or other roles; effects on liability are considered.
	UAR18	Our/clients' terminal, fleet and logistics managers, logistics platform provider, forwarders get **logistics information and real-time telemetrics** and about the automated truck, trailer and load, including warnings about maintenance needs or delays, so they can plan and adapt.
	UAR19	Our managers, operators and clients can **easily plan for, deploy, manage, maintain and operate automated trucks**.
	UAR20	We can **assess the effect of automated trucks** on costs, efficiency and productivity using measurable parameters.
	UAR21	We can train, recruit or otherwise have access to the **competence** needed for repair or **maintenance** of automation technology, for **remote** assist/driving **operations**, for **re-gearing** logistics and fleet **management systems**, and for exploiting new possibilities from **24/7 driving** in systems that are less dependent on human control and interaction.

On considering aggregated requirements, the diversity of automated truck users should be considered. For example, some were transporters, some international multimodal logistics operators, some logistics platforms, some wholesalers. Actors we interviewed were also diverse in terms of:

- size of operations and vehicle fleet (from less than 100 to over 1000)
- ownership of fleet (most had own fleet for core operations, but one used third party carriers exclusively)
- cargo handled (break bulk, food, containers)
- level of warehouse/terminal automation (from laser-guided vehicles with moving floors in trucks and warehouse, to dynamic production-responsive terminal operations using manually loaded cargo cages)
- extent to which management systems are digitalized (from paper-based to digital fleet/warehouse/logistics management systems [FMS/WMS/LMS])
- potential use of automated trucks (from dock-to-dock or quayside to container stack terminal operations to long-haul multimodal international haulage).

Diversity is also reflected in approach to incorporating automated trucks in operations, from willingness to test in order to assess and develop potential value, to a need to see prior evidence in terms of comparison on measurable parameters against the performance of traditional trucks (e.g. delivery times, time used for loading, damage to goods).

What most users / logistics actors had in common, however, was a greater interest in the “nodes” of operations rather than what happens out on the roads between nodes (terminals, warehouses etc.). Given this, almost all discussions with users centered on one or more of the five business cases Table 2. In comparison, smaller technical demonstrations were of little interest to the users.

Again, reflecting diversity, terminal operations between two logistics companies are rarely the same, and this needs to be remembered when using requirements to design demonstrations involving terminals. Some actors’ trucks must respond dynamically to changing production operations, and transport needs to be responsive and flexible; transport operations at other terminals are more structured, with some documenting maneuvers that the drivers must be able to do (where the expectation is that the automated truck can do at least the same as the driver).

Diversity may explain an apparent conflict between UAR10, which describes a need for standardized solutions at terminals for interfacing with automated trucks, and UAR11, which describes a need for few or gradual modifications to be made at terminals and transitions. The need for automated trucks to fit with existing and sometimes diverse operations, however, appeared to be universal, implying that automated truck developers need to find ways for automated trucks to interface with a diversity of operations and equipment.

4.2.2 Technology developer aggregated requirements (TAR)

Aggregated requirements for developers of automated trucks or technology needed for automated truck operation (OEMs, CCAM/road technology providers, connectivity providers, mappers) are specified below and explained in more detail in Annex 8, which also links to the original unaggregated requirements in Annex 10.

Table 4: Aggregated requirements from technology developers (Technology developer Aggregated Requirement; TAR).

As technology developers…

Business	TAR1	We can use L4 automation to leverage new business opportunities.
	TAR2	We can start to evolve logistics through the use of automated trucks in high-volume routine, low-interaction use areas where automated trucks have the greatest potential to increase efficiency and productivity.
Technology development	TAR3	We can work towards making trucks smaller, electric, lighter and more aerodynamic to improve the value proposition for logistics actors who are looking to reduce emission levels and energy use and road authorities looking to improve safety.
	TAR4	We can develop the automated truck technology to handle more complex operational design domains, making advanced business cases feasible, by testing, getting feedback from the vehicle, operators and stakeholders, accounting for the behaviour of other road users, accessing external data and making advances in sensor and connectivity technology.
	TAR5	We cooperate with each other and with public data owners and regulators to give teleoperators, fleet managers and fleet/logistics management systems information from the environment (weather, route sensors, closed roads) and vehicle (telemetry, cargo data); and to enable logistics actors and road operators to send instructions to the vehicle.
Dependency	TAR6	We need models for legal and operational handover of remote monitoring and assist, and models of working that give teleoperators adequate situational awareness to monitor several trucks and assist when needed.
	TAR7	We need cooperation and efficient and harmonized processes for testing automated trucks in different use areas and for developing internationally coherent and standardised roads and regulations.
	TAR8	We need adaptations to the physical infrastructure to enable and expand use areas for automated trucks.
	TAR9	We can develop adequate, reliable and internationally coherent satellite and terrestrial connectivity for automated trucks operations.
	TAR10	We have the data we need to develop regularly updated, accurate and standardized HD digital maps (local dynamic maps) for automated truck operations.
	TAR11	We can conduct customer journey mapping of use cases to test latency and network stability and check more unusual connectivity usages.

Business requirements (TAR1-2) describe how developers need to develop new business opportunities from L4 automation technology, which involves starting to engage logistics actors in the technology's potential. Three requirements describe needs for technology development to progress developers towards realizing business opportunities. These address the L4 technology (vehicle, infrastructure, connectivity), information flows and interfaces (with an implicit requirement for diverse actors to share data), and vehicle structure (TAR3-5). Finally, developers have several needs from other actors on which they must depend (TAR6-11), relating to the development of remote monitoring and assist functions, the standardized upgrading of roads and regulations, and the development of adequate connectivity and maps.

4.2.3 Road authorities/operators aggregated requirements (RAR)

Aggregated requirements for road/port authorities, owners and operators are specified in Table 5.

Table 5: Aggregated requirements from road actors (Road actor Aggregated Requirements; RAR).

As road authorities / owners / operators …

Effects	RAR1	The automated truck must remove human driver limitations and **reduce** the number of operator **transgressions** and **serious injury collisions** compared to standard trucks.
	RAR2	We **understand** the **interactive effects** that introducing automated trucks, associated PDI and regulatory changes into existing traffic systems has on safety and traffic flows so that we can **mitigate** new **safety and congestion risks** from automated trucks in traffic.
	RAR3	Society, human road users and transport company/terminal workers see, understand, trust and **accept** automated trucks.
	RAR4	We **assess effects on land use** by reducing curb and parking spaces taken by trucks vs. the need for more parking areas or more hubs or load transfers for last mile deliveries.
	RAR5	We can **meet sustainability goals** by introducing automated trucks to reduce vehicle energy use, NOx/CO2 emissions and noise from heavy vehicles, accounting for life cycle aspects and PDI developments; and we can maintain or improve traffic flows, safety and emission levels while increasing road capacity**.**
	RAR6	The automated truck has technology or support processes so that it can **function to increase safety and traffic flow despite** challenges of the road network and weather conditions of **different EU/EØS countries**.
Data/control	RAR7	We are **warned of** automated truck **stops**, can **monitor assists** and **receive data** for accident **investigations** and **infrastructure improvements**; remote monitors must receive data needed to ensure the robustness and functioning of the truck.
	RAR8	We have an **open dialogue with harmonized manufacturers**[4] **on data we** could provide for automated trucks to ensure efficiency, safety and traffic flows. We can **direct** the automated truck, **control** road accessibility, flexibly set maximum speed limits and orchestrate traffic flows.
Procedures	RAR9	The automated truck always **stops and transitions** between human and automated control **safely**, responds appropriately to incidents in the road or approaching emergency vehicles.
	RAR10	We have **procedures** for traffic and cargo **inspections, controls and border crossings** that work for automated trucks and are at least as efficient and effective than those for traditional trucks.
	RAR11	We **understand** how knowledge, skills, roles, responsibilities, sensor/data possibilities, and needs for information and data integration will **change our traffic center operations,** call-out/rescue and emergency services, who each have information and contingency **procedures** they need to deal with **incidents or road diversions** involving truck with no driver, and can always **access a person** who is **responsible** for and/or can control the automated truck/load.
	RAR12	We are satisfied that **remote assist centers ensure safe and robust system of feedback and control processes**, and we develop certification/**permits to operate** automated trucks remotely – also accounting for cargo. (hazardous).
	RAR13	**Risk management is needed** along with any mitigating measures and procedures to **control** any effects that **loss of data security or connectivity** have on traffic safety and congestion; and to **prevent terrorism, contraband, stowaways, trafficking, theft, vandalism.**
Rules + regs	RAR14	**Regulators** develop and apply internationally standard regulations on who is **liable** for the behaviour, state and content of the vehicle, its technology, quality of data/connectivity provided, data protection, and cargo in different situations of different ODDs where automated truck will be used.
	RAR15	We work internationally with harmonized manufacturers[3] and road operators to learn from demonstrations and, where necessary, **overhaul standards, rules and regulations** on road, vehicle (type approval), road users, cargo, connectivity and data protection in a case-independent way to ease cross-EU functioning.
Roadmap	RAR16	We **prefer** to make **changes** to the physical road infrastructure that **are simple, gradual and absolutely necessary;** and that have been evaluated as safe and effective in tests on private and then public roads; we **need a roadmap for automated truck implementation** to inform us about which critical PDI changes are needed when, so we can consider them alongside other road user and AV needs, make ROI calculations and evaluate alternative financing options.

[4] Harmonized manufacturers = manufacturers who have already come together and agreed on their collective needs.

The requirements are explained in more detail in Annex 9 which also links to the original unaggregated requirements in Annex 10.

Road actor requirements can be grouped according to whether they describe requirements for automated trucks effects, development of procedures, development of rule and regulations or a roadmap for future infrastructure development. Road authorities require automated trucks to fulfil their potential to improve safety and land use and reduce congestion, emissions and energy use for society, without reducing levels of technology acceptance. Several functions that road operators carry out should account for -- and should benefit from -- automated trucks, including traffic monitoring and management, accident investigations, infrastructure improvements and maintenance and inspections. There is a particular need for careful risk management, which should account for system-level hazards; and to consider optimal models for traffic control operations and how these can be shared between the remote functions of road and automated truck operators. Development of diverse standards, rules and regulations will probably be required to account for connected vehicles and roads, and new roles for operators. Finally, road actors require an accessible roadmap that sets out which infrastructural developments are absolutely needed to pave the way for automated trucks, so that they can start planning and prioritizing.

4.2.4 Worker requirements

In this section we summarize pre-aggregated requirements gathered from representatives for worker unions. While worker union representatives were not negative to automated trucks, they described conditions necessary for success:

For long-term acceptance it will be important to engage in gradual development, so that employees and society have time to adapt, re-educate, gain trust, and ensure safe, secure and fair systems (e.g. without surveillance or abuse of technology); increasing the level of automation in manually operated trucks is one way in which this can be achieved.

- Drivers should be engaged in the development of automated trucks as they have unique insight and experience that should be accounted for.
- In helping prepare for the future there should be multi-stakeholder consideration of effects of realistic scenarios on logistics systems, which will require openness from manufacturers and logistics actors.
- To encourage trust and accept, there is a need for openness around the uncertain balance of job gain / loss outcomes – it is not clear whether losses will outweigh benefits of increasing road capacity that automated trucking offers
- Unions need to be engaged to minimize the risk of rejection of automated trucks.

5 Analysis and application of user requirements

5.1 Comparing requirements of different actor types

For all types of representatives that we spoke to, we found requirements for different types of value that automated trucks should provide for their organization. Private actors (logistics actors and technology developers) needed automated trucks to fulfil value propositions aligned with business goals. For logistics actors, automated trucks must help them achieve cost reductions or increased efficiency (e.g. use fewer human resources for same transport work) or productivity (e.g. increased number of deliveries through increased truck availability) (UAR1-8). For technology developers, automated trucks present new business opportunities that must be exploited (TAR1,2), and this requires activities that orient logistics actors towards uptake of automated trucks. According to their own requirements, technology developers need the help of regulators and road authorities/owners, who themselves have goal-related requirements for the use of automated trucks in logistics (RAR1-6). To fulfil their business goals, private actors may need to consider how their tests and implementation activities with automated trucks appeal optimally to the goals that public actors have, for traffic safety, congestion / road capacity, and climate gas emissions.

Technology developers say they need regulators and road authorities to act on several fronts to enable automated truck implementation (e.g. TAR6, 7, 8). Whether such action is an absolute requisite for implementation of automated trucks in logistics is not clear. In theory, automated driving is possible without any involvement of road operators – as long as regulation allows it. When considering user and stakeholder requirements, we should therefore bear in mind that they may be based on the diverging goal-driven interests of the stakeholder group that generated them, and there may be a need to consider further which of the user and stakeholder requirements are absolute requirements in the sense that the underlying issue cannot be addressed in any other way.

Although they are derived from groups with diverging interests, several common interest areas can be identified among the requirements, on which different actor types can align towards goal achievement. For example:

- **Sustainability**: Authorities are interested in increasing the environmental, economic, social and safety-related sustainability of goods transport (e.g. RAR1, RAR5), and this aligns well with the cost-reduction (e.g. UAR2), improved working conditions (UAR8) and efficiency (e.g. UAR5) goals of logistics actors.
- **24/7 operations**: Congestion is a main cause of delayed deliveries for logistics actors, and a challenge to the climate and mobility goals of road authorities. Facilitation of automated transport at night could be in the interests of both actors.
- **New business models**: All actors recognize that automated trucks are a disruptive technology, and new business models not only let technology developers maximize business opportunity their technology provides (TAR1), but might be needed to facilitate financing of infrastructure improvements for road authorities (RAR16) and use of automated trucks for logistics actors (UAR9).

The requirements indicate that technology developers must act as a bridge between users and road authorities. In general, logistics actors accept that the technology is or will be developed to allow automated transport of goods in traffic, and their requirements mostly concern integration of automated trucks at terminals (e.g. UAR10, 11) or transfer points (UAR7). In contrast, the requirements of road/port authorities and operators are concerned with integration of automated trucks into road traffic. Technology developers wishing to develop automated trucks that can deliver hub-to-hub or internationally must develop solutions that satisfy both areas. As they do so they should recognize that both terminal owners and road owners in many cases require that automated trucks can be implemented with only minimal, simple or gradual modifications to their existing physical infrastructure (UAR11, RAR16), which is reflected in a way by worker requirements for trust to be built through gradual automated truck introduction. Developers may also need to help logistics actors and road authorities understand the value of automated trucks by giving them information they need for ROI or socio-economic cost-benefit calculations (UAR3, RAR16), or by easing digital integration of automated trucks into management systems (UAR5). The challenge for developers may be in how they come together to do this. In connection with this, road authorities require technology developers to put on a united front for an open dialogue about regulations, data needs, infrastructure modification etc. (RAR8).

Despite a requirement for automated trucks to fit in with existing operations, all actors see the need for standardization of the physical and digital infrastructure (PDI) to increase the extent to which automated trucks are interoperable and can be used flexibly, across terminal operations, between terminals, from country to country or even cross-modal transfers in the logistics chain (UAR10, TAR10, RAR15). There is lack of clarity, however, about extent of standardization and changes needed to physical infrastructure. While representatives from some road authorities stressed that technology on the automated vehicle needs to be developed to handle a range of complex road environments and situations, technology developers stressed the need for changes to road infrastructure to allow roll-out in the nearer future. Some road actors believe that effort to develop vehicle technology further will prevent the need for expensive and slow changes needed to harmonize road infrastructure – and to some extent traffic regulations – across Europe. Considering this, MODI may need to consider where adaptation of the physical infrastructure is absolutely needed and where on the other hand vehicle solutions could work just as well.

Actors also share a need to progress models of remote monitoring and assist for automated trucks, to start to precipitate ideas on who will carry out this function, how it will pass between companies or regions, and how private and public actors will work together on remote control, both in terms of standards and regulations (permits to operate, interface standards) and actual operations (TAR6, UAR21, RAR11, 12). Common requirements on technical development also apply for data interfaces (e.g. how weather, road data from different sources will be integrated / exchanged to and from the automated truck). On a related note, technology developers and road operators together recognize the need to develop secure, adequate and reliable connectivity for automated trucks, including adequate signal latency and detail for remote operations (TAR11, RAR13).

5.2 Relation to use areas and demonstrations

In this section we compare the Aggregated Requirements on the extent to which they apply for the different cases we presented in Table 2. Table 6 shows that most of the Aggregated Requirements are relevant for each of the logistics cases. Main differences track with the extent to which public road operators are involved. Most terminal operations and many drayage operations happen on private roads, so some of the RARs do not apply there.

Table 6: Relevance for logistics cases of aggregated requirements (AR) from users (U), technology developers (T) and road actors (R). AT = Automated truck.

AR	Short Description	Terminal operations	Drayage	Hub-to-hub	Inter-city	International
UAR1	Fewer operator hours / transport	✓	✓	✓	✓	✓
UAR2	Less incidents / km	✓	✓	✓	✓	✓
UAR3	Save more than we pay	✓	✓	✓	✓	✓
UAR4	Increased efficiency + productivity	✓	✓	✓	✓	✓
UAR5	Digital integration into MS	✓	✓	✓	✓	✓
UAR6	Integration with terminal operations	✓	✓	✓	✓	✓
UAR7	AT coupled to automated processes	✓	✓	✓	✓	✓
UAR8	Improved working conditions	✓	✓	✓	✓	✓
UAR9	New business models so all can use	✓	✓	✓	✓	✓
UAR10	Digital and physical interoperability	✓	✓	✓	✓	✓
UAR11	Few modifications to PI / for transitions	✓	✓	✓	✓	✓
UAR12	Reliable deliveries	-	✓	✓	✓	✓
UAR13	Safe terminal operations	✓	✓	✓	✓	✓
UAR14	Cut CO2 emissions	✓	✓	✓	✓	✓
UAR15	Sufficient cyber/vehicle/cargo security	(✓)	(✓)	✓	✓	✓
UAR16	Employees/clients accept and trust	✓	✓	✓	✓	✓
UAR17	Account for ALL driver tasks	✓	✓	✓	✓	✓
UAR18	Information across logistics chain	✓	✓	✓	✓	✓
UAR19	Easy to deploy, maintain, use	✓	✓	✓	✓	✓
UAR20	Can evaluate effects	✓	✓	✓	✓	✓
UAR21	Know-how to re-gear surrounding systems	✓	✓	✓	✓	✓
TAR1	Leverage new business opportunities					
TAR2	Use for high-volume routine transport	✓	✓	✓	-	-
TAR3	Smaller, lighter trucks	✓	✓	✓	✓	✓
TAR4	Develop AT tech for more complex ODD	✓	✓	✓	✓	✓
TAR5	Information from road environment	-	-	✓	✓	✓
TAR6	Models for remote monitoring and assist	-	✓	✓	✓	✓
TAR7	EU-wide standard roads + regulations	-	(✓)	✓	✓	✓
TAR8	PI adaptations to expand ODD	✓	✓	✓	✓	✓
TAR9	Adequate, reliable connectivity	(✓)	(✓)	✓	✓	✓
TAR10	Data for local dynamic maps	(✓)	(✓)	✓	✓	✓
TAR11	Test connectivity usage	(✓)	(✓)	✓	✓	✓
RAR1	Public traffic safety	-	✓	✓	✓	✓
RAR2	Mitigate interactive effects on safety/flow	-	✓	✓	✓	✓
RAR3	Society/workers trust and accept	✓	✓	✓	✓	✓
RAR4	Assess land use effects	-	-	✓	✓	✓
RAR5	Contribute to sustainability goals	-	✓	✓	✓	✓
RAR6	Functions across EU countries	-	-	-	✓	✓
RAR7	Receive data from AT	(✓)	(✓)	✓	✓	✓
RAR8	Data and control from us to AT	-	(✓)	✓	✓	✓
RAR9	Safe stops and transitions	✓	✓	✓	✓	✓
RAR10	Control/inspection procedures	-	✓	✓	✓	✓
RAR11	New roles for traffic control, emergency	-	(✓)	✓	✓	✓
RAR12	Adequate remote assist operations	-	(✓)	✓	✓	✓
RAR13	Risk management	✓	✓	✓	✓	✓
RAR14	Legal and liable responsibility	✓	✓	✓	✓	✓
RAR15	Overhaul standards, rules, regulations	(✓)	✓	✓	✓	✓
RAR16	Gradual change with roadmap	-	(✓)	✓	✓	✓

Table 7 shows the extent to which each Aggregated Requirement applies directly to the envisaged technical demonstrations in Table 2.

Table 7: Relevance for MODI's planned technical demonstrations of aggregated requirements (AR) from users (U), technology developers (T) and road actors (R).

	Short Description	**Border cross. (NO1)**	**Customs (NO2)**	**M/way (NO3)**	**Terminal (NO4)**	**Gate access (SE1)**	**Charging (SE2)**	**Loading (SE3)**	**Driving on public road (SE4)**	**Terminal (NL1)**	**Drayage (NL2)**	**City roads (GE1)**	**Port area (GE2)**	**M/way transition (GE3)**
UAR1	Fewer operator hours / transport	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UAR2	Less incidents / km	✓	✓	✓	✓	-	-	-	✓	✓	✓	✓	✓	✓
UAR3	Save more than we pay	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UAR4	Increased efficiency + productivity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UAR5	Digital integration into MS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UAR6	Integration with terminal operations	-	-	-	✓	✓	✓	✓	-	✓	✓	-	-	-
UAR7	AT coupled to automated processes	-	✓	-	-	✓	✓	✓	-	-	✓	-	-	-
UAR8	Improved working conditions	-	(✓)	✓	(✓)	-	(✓)	(✓)	✓	(✓)	✓	✓	(✓)	✓
UAR9	New business models so all can use	-	-	-	✓	-	(✓)	-	(✓)	✓	✓	(✓)	(✓)	(✓)
UAR10	Digital and physical interoperability	-	-	-	✓	✓	✓	✓	-	✓	✓	-	-	-
UAR11	Few modifications to PI / for transitions	-	-	-	✓	✓	(✓)	✓	(✓)	✓	✓	(✓)	-	✓
UAR12	Reliable deliveries	-	(✓)	✓	(✓)	-	(✓)	-	✓	(✓)	(✓)	✓	(✓)	(✓)
UAR13	Safe terminal operations	-	-	-	✓	-	-	✓	-	✓	(✓)	-	-	-
UAR14	Cut CO2 emissions	-	-	✓	✓	-	✓	-	✓	✓	✓	✓	✓	✓
UAR15	Sufficient cyber/vehicle/cargo security	(✓)	✓	✓	(✓)	✓	✓	✓	✓	(✓)	(✓)	✓	✓	✓
UAR16	Employees/clients accept and trust	(✓)	✓	✓	✓	(✓)	(✓)	✓	✓	✓	✓	✓	✓	✓
UAR17	Account for ALL driver tasks	-	✓	(✓)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UAR18	Information across logistics chain	✓	✓	(✓)	(✓)	✓	✓	✓	(✓)	✓	(✓)	(✓)	(✓)	(✓)
UAR19	Easy to deploy, maintain, use	-	✓	(✓)	✓	✓	✓	✓	✓	✓	✓	✓	✓	(✓)
UAR20	Can evaluate effects	-	✓	(✓)	✓	(✓)	✓	✓	(✓)	✓	✓	✓	(✓)	(✓)
UAR21	Know-how to re-gear surrounding systems	-	✓	(✓)	✓	✓	✓	✓	(✓)	✓	✓	(✓)	(✓)	(✓)
TAR1	Leverage new business opportunities	-	-	(✓)	✓	-	✓	-	(✓)	✓	✓	(✓)	(✓)	(✓)
TAR2	Use for high-volume routine transport	-	-	✓	✓	✓	✓	✓	-	✓	✓	-	-	✓
TAR3	Smaller, lighter trucks	-	-	✓	(✓)	-	-	-	-	(✓)	(✓)	-	-	(✓)
TAR4	Develop AT tech for more complex ODD	-	-	✓	✓	-	-	✓	✓	✓	✓	✓	✓	✓
TAR5	Information from road environment	-	-	✓	-	-	-	-	✓	-	(✓)	✓	(✓)	✓
TAR6	Models for remote monitoring and assist	✓	✓	✓	(✓)	(✓)	(✓)	(✓)	✓	✓	✓	✓	✓	✓
TAR7	EU-wide standard roads + regulations	✓	✓	✓	-	-	✓	-	✓	-	(✓)	✓	✓	✓
TAR8	PI adaptations to expand ODD	-	✓	✓	✓	(✓)	(✓)	(✓)	✓	✓	✓	✓	✓	✓
TAR9	Adequate, reliable connectivity	✓	✓	✓	✓	(✓)	(✓)	(✓)	✓	✓	✓	✓	✓	✓
TAR10	Data for local dynamic maps	✓	✓	✓	(✓)	-	-	(✓)	✓	(✓)	(✓)	✓	✓	✓
TAR11	Test connectivity usage	✓	✓	✓	✓	(✓)	(✓)	(✓)	✓	✓	✓	✓	✓	✓
RAR1	Public traffic safety	-	✓	✓	-	-	(✓)	(✓)	✓	✓	(✓)	✓	✓	✓
RAR2	Mitigate interactive effects on safety/flow	(✓)	✓	✓	-	(✓)	(✓)	-	✓	-	✓	✓	✓	✓
RAR3	Society/workers trust and accept	-	✓	✓	✓	(✓)	(✓)	✓	✓	✓	✓	✓	✓	✓
RAR4	Assess land use effects	-	✓	-	(✓)	-	(✓)	(✓)	(✓)	(✓)	-	✓	(✓)	✓
RAR5	Contribute to sustainability goals	-	-	✓	-	-	✓	-	✓	-	(✓)	✓	✓	✓
RAR6	Functions across EU countries	-	-	✓	-	-	-	-	✓	-	-	✓	(✓)	✓
RAR7	Receive data from AT	✓	✓	✓	-	-	-	-	✓	-	(✓)	✓	✓	✓
RAR8	Data and control from us to AT	✓	✓	✓	-	-	(✓)	-	✓	-	(✓)	✓	✓	✓
RAR9	Safe stops and transitions	-	(✓)	✓	-	(✓)	(✓)	-	✓	-	✓	✓	✓	✓
RAR10	Control/inspection procedures	-	✓	(✓)	(✓)	(✓)	(✓)	✓	✓	(✓)	✓	✓	✓	✓
RAR11	Know roles for traffic control, emergency	✓	✓	✓	(✓)	-	-	-	✓	(✓)	(✓)	✓	✓	✓
RAR12	Adequate remote assist operations	-	✓	✓	✓	✓	(✓)	(✓)	✓	✓	✓	✓	✓	✓
RAR13	Risk management	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RAR14	Legal and liable responsibility	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RAR15	Overhaul standards, rules, regulations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RAR16	Gradual change with roadmap	-	(✓)	(✓)	-	-	-	✓	✓	-	(✓)	✓	✓	✓

5.2.1 Applying user requirements in MODI

User and stakeholder requirements address what end-users and stakeholders need for transition to automated trucks systems and operation of those systems. In MODI we plan to demonstrate how these needs can be met[5] by considering user and stakeholder requirements in the development of solutions for connectivity, automation technology, user-driver interface development, vehicle adaptation in WP3; and for CCAM interfaces, road PDI and fleet and traffic management systems in WP4. User and stakeholder requirements should be considered within the context of each use case or demonstration activity, in the following steps:

i. Assess and develop user and stakeholder requirements in context of demonstrations, by getting feedback from MODI users and stakeholders. User and stakeholder requirements are often used as the basis for measuring success of project delivery. It is therefore essential to consider for each demonstration, which requirements are viable i.e. are relevant and can be realistically satisfied by the demonstration. It is expected that this work will be done as part of Task 6.1 of MODI.

ii. Where relevant, break down each viable user or stakeholder requirement into smaller, more specific chunks. For example, UAR6 is a user requirement for integrating highly automated trucks with existing terminal operations. This suggests the need for a survey of existing operations at the terminal, along with a consideration of what users will need in order to integrate automated trucks with each operation. For terminal access for example, terminal managers will need information about the truck and load requesting access, a way to communicate approval or rejection of the truck and load, and a means of controlling physical access to the terminal. Breaking down prioritized requirements to ensure they are met by demonstration activities could be part of the co-creation of use cases (WP2) and would help ensure that demonstration activities address user and stakeholder requirements.

iii. Identify the specific actions, processes and features for viable, more detailed user and stakeholder requirements to be addressed. These are the functional and non-functional solution requirements and could be generated by activities in WP2, 3 and 4. Solution requirements should also be reviewed by users and stakeholders.

5.2.2 Relevance of user requirements for use cases

Table 7 serves as initial guidance for individual MODI use cases in selecting which requirements are relevant and viable for each envisaged demonstration activity. Ultimately, the cross-functional team involved in the design and development of demonstration activities are best placed to decide which requirements are relevant and can be met.

To illustrate how viable user requirements can be used to inform the development of technical demonstrations, we can use the example of Table 7 column 1 on border crossing. Borders must be crossed by automated trucks such that there is no increase in the number of driver transgressions or braking incidents (UAR2). This suggests that automated trucks might need to adapt to local road regulations to avoid transgressions, or that connectivity or transition problems must not result in erratic vehicle behaviour. Moving down the list, we see we should try and increase efficiency (UAR4), which could imply a need for digital document transfer. Next on the list we see that digital integration

[5] Making technical solutions palpable for users and stakeholders will also allow them to develop their requirements.

into fleet or logistics management systems (UAR5) could enable information about the border crossing event to be transmitted across the logistics chain (UAR18), and so on.

Taking terminal maneuvers (NL1) in Table 7 as another example, UAR1 suggests that we need to show users that the activity requires fewer operator hours than current activities, after accounting for any non-driving tasks drivers normally do (UAR17) or any need for remote operators. Looking at UAR8, we need to consider what new roles will be created for terminal staff and whether represent better working conditions for employees. UAR21 implies a need for demonstration activities to consider including integration of automated truck activities into existing port or fleet management systems, and so on.

5.3 Comparing requirements from MODI, AWARD and SHOW

As reviewed in Section 3, in developing demonstrations with automated trucks it will be informative to compare the user and stakeholder requirements identified by other EU projects. Here we compare MODI user and stakeholder requirements identified in Section 4, with those identified with AWARD, which like MODI presented specific logistics use cases to develop requirements (but considered mainly short distance transport), and SHOW, which like MODI grouped requirements according to user, technology developer and road authority.

5.3.1 MODI vs. AWARD

Many of the requirements from AWARD (Annex 2) were also captured during our user and stakeholder requirements exercise, but there were also differences. The emphasis through many of the AWARD requirements is on the requirements for performance of the vehicle (e.g. “behaviour…according to road conditions”, “able to operate in public/private areas”, “guarantee…safety of all the people around it”) with somewhat less emphasis on the requirements for automated trucks for use in different aspects of logistics operations.

The following AWARD requirements may be useful to consider in addition to MODI requirements in the development of MODI use cases:

- *Highly qualified personnel shall be available to support/solve problems related to the automated system*. This is partly covered by MODI UAR21 and RAR11, but this AWARD requirement adds that qualified personnel should be available to different actors who understand and have an overview of functioning automated system – the vehicle and infrastructure technology, digitalised management or document transfer systems, links to automated technology and so on.
- *The vehicles shall be equipped with an emergency system, to be stopped and/or intervened by an in-site driver*. This is a vehicle-centered instance of MODI RAR11, which states that there is a need to understand and develop contingency procedures for different actors who are at the scene and must deal with a stopped automated truck.
- *The AGTS shall…prevent misuse by internal unqualified personnel*. This was not picked up in our interviews but could be useful to consider in development of MODI demonstrations.

An added value of the user and stakeholder requirements generated by AWARD is that attempts are made to identify solution requirements for each user requirement (cf. Section 2). In MODI this will be done as use cases are developed in later work packages (WP2,3,4), but the approach taken by AWARD might be useful to review.

5.3.2 MODI vs. SHOW

SHOW gathered requirements for urban/passenger and cargo AVs, but limited requirements found are overall covered by MODI's requirements. For instance, SHOW's users required a usable system (cf. MODI UAR19) and needed proof that AVs would be more efficient and valuable (cf. UAR20). OEM's and road/mobility operators surveyed in SHOW looked to develop business models (cf. TAR1), required interoperability (in MODI, the users and road operators require this), and the development of connectivity (cf. TAR9).

6 Conclusions

We have identified 48 preliminary user and stakeholder requirements for using automated transport for logistics (Tables 3, 4 and 5). These requirements should be assessed and developed to frame and inform the further development of each MODI use case. Accounting for the requirements will ensure that MODI's demonstration activities appeal directly the concerns of end-users, increase their interest in automated transport and their ability and willingness to implement it. In this way the Deliverable helps address MODI's main objective, which is to speed up the implementation and operation of automated transport systems and solutions in logistics.

Requirements were identified after accounting for approaches to user requirements elicitation by EU projects in similar domains. A comparison of requirements finds that we have covered most of the requirements for use of AV in logistics found previously (Section 3) but generated additional requirements for embedding automated trucks as part of real logistics ecosystems.

The requirements we identify concern the use of automated trucks in logistics generally – they are not requirements for use of automated trucks in a specific use case or operational design domain (ODD). Specific ODDs cannot be described at this stage of MODI, so we could not generate user requirements for them. Also, while basic descriptions of MODI's envisaged technical demonstrations are available, it is not easy for logistics actors external to MODI to see how activities attempting to demonstrate L4 technologies relate to logistics operations. What happens during "motorway driving", for example, is interesting for technology developers and road operators, but of little apparent interest to logistics actors. A main aim for us has been to generate knowledge of requirements for use of automated trucks in real logistics systems, so that surrounding logistics systems can be accounted for in MODI demonstrations – and thus make MODI demonstrations more relevant to logistics actors.

Following on from this, we generated user requirements from discussions about the value and challenges faced by different actors using automated trucks in likely logistics use areas. Each of these use areas (terminal operations, drayage, hub-to-hub, inter-city and international road haulage) can be considered as comprising a selection of MODI's technical demonstrations (See Table 2). In this way the requirements we have generated are relevant for the further design and development of MODI demonstrations and specification of vehicle and infrastructure technology. Table 6 supports this, showing all 48 requirements are relevant across logistics use areas, while Table 7 shows that many of the requirements will be relevant to consider in each of the specific technical demonstration activities envisaged for MODI. An explanation of how user requirements can be applied in the design and development of demonstration activities has been provided (Section 5.2).

Preliminary requirements

Because they have been kept broadly applicable, several steps will likely be needed between the aggregated requirements we have identified and the specification of solutions for MODI. An important first step will be to continue our work through a stakeholder workshop in Task 6.1, to assess the viability and relevance of each user and stakeholder requirement in the context of each envisaged demonstration. While we have attempted to generate requirements that address underlying issues that users and stakeholders perceive as important, this is not an exact science, and we have made subjective assessments of what the underlying issues are when generating requirements. In Task 6.1 we should therefore check that the final aggregated requirements address underlying issues and that they "work" in the context of each specific use case; requirements can then be edited and refined as necessary. Co-creation groups (WP2) developing demonstration activities should be involved in this process. These groups may also wish to refine user and stakeholder requirements to omit any that existing regulatory requirements already address (e.g. second part of RAR9). Following initial assessment and refinement, the requirements could be developed into solution requirements as described in Section 5.2.1. MODI could address and account for this process also in developing requirements for vehicle, PDI and connectivity solutions in WP3 and 4. There is also a need for iterative development of the refinements by continual checking against emerging technical solutions are put together in WP2 and implemented in 5. We stress that the requirements are preliminary only – they are not set in stone. Several of MODI's partners are also "users" who will be involved to assess, refine and iteratively develop the preliminary requirements that we have identified, as demonstration activities and ODDs begin to emerge.

Vehicle technology vs. road and regulation development

Calls for standardization of regulations and physical infrastructure are evident in technology developer requirements (TAR7, TAR8), but logistics actors and road actors need limited changes to the physical infrastructure (UAR11, RAR16). MODI and similar projects should therefore consider exactly which adaptations of the physical infrastructure are absolutely needed, and which changes could be avoided by expending more effort on developing vehicle solutions. This will require open dialogue between technology developers and road actors.

Use areas

From requirements interviews it is clear that logistics actors are beginning to consider automated trucks in relation to use areas that are being realized or may be realized soon. In line with ideas of MODI, the following high-volume routine transport operations were seen by most interviewees as viable candidates for using automated trucks:

- terminal operations (at larger facilities or port terminals)
- short-distance, drayage-type operations (e.g. container terminal to nearby warehouse or short-distance between warehouse and nearby production plant across private roads)
- transport along "simple" corridors between internal assets.

We see broad agreement across actors that it will be challenging to use automated trucks for deliveries beyond ring roads to urban areas, and that transport involving several chain links (e.g. cross-docking, cross-modal transfer), demanding routes (many junctions, turns, tunnels) and poor quality roads with extreme weather, are not viable use areas for automated trucks in the short term.

Business models and opportunities

One theme emerging from requirements identification has been that automated truck use will create a need to develop new forms of organization in logistics, with opportunities for new business models in the following interdependent areas:

i. **Fleet ownership and organization**. Fully automated (autonomous) trucks means the vehicle operation function can be delegated to many different actors. Interview comments imply a shift from carriers offering trucks-with-drivers as a service, to a focus on capacity as a service, where a fleet of trucks can be organized to give forwarders the capacity they need without having to consider the many constraints that drivers place on truck use. Autonomous trucks also create opportunities for OEMs to offer transport services directly to forwarders or international shippers, or for port authorities make an automated truck pool available for use by different terminals. Total cost of automated truck ownership will be an important factor in the development of these and other new business models. New models need to help make automated trucks affordable also to smaller logistics actors (UAR9). New models should also consider how highly automated trucks can be organized across different links in the supply chain. MODI's long-distance use case from Rotterdam to Oslo can be performed by a single automated truck, but new systems will be needed for the use of automated trucks in transport in more complex chains involving several transfers between different transport modes.

ii. **Remote automated truck monitoring and assist**. It is not clear to many actors what remote operations will look like (see also TAR6). For some logistics actors remote operations was not a visible or dominant challenge. While technology developers were aware of the challenge, they did not agree on how remote operations might look. While some meant that an "air traffic control" model (overseer responsible for all autonomous truck traffic in a "zone") was likely, others thought that logistics actors would be reluctant to give up operation of their own fleets and that there would be parallel remote operations (several logistics actors agreed). There are technical (e.g. signal latency), organizational (e.g. coordination of different companies or teleoperations providers on same road) and ethical challenges to be resolved to enable remote operations that can cope with obstacles in road or first-time situations without causing delays or risks. These findings underline the need for development and testing of remotely controlled trucks in MODI. Given their experience, road authorities may need to consider what role they should have in ensuring safe remote monitoring, and what challenges involvement with product developments might pose. D2.2 of AWARD provides useful discussion of the potential for integration of fleet management and remote monitoring functions.

iii. **Management systems**. It is useful to consider separately from ownership, organization and physical operation of the fleet, how automated fleets can be managed as part of automated or digitalized supply chains. The potential for efficiency gains from seamless logistics is part of the value proposition of highly automated trucks (UAR5). While the need to monitor automated truck telemetrics for fleet management with fleet management systems (FMS) is relatively clear, it seems less clear how FMS can be integrated with logistics management systems (LMS) for optimal fleet use and organization as part of wider logistics operations. To increase interest in automated trucks it would be useful to demonstrate to logistics actors, how whole management systems – including FMS, LMS and potentially warehouse management systems (WMS) – could work together to increase efficiencies (UAR21). How can existing FMS and LMS be re-geared to exploit efficiency gains from automated dispatch? How can systems be re-geared to maximise fleet capacity by accounting not only for route options, road conditions, weather, but dynamic events in the surrounding supply chain (LMS) or production facility (WMS) or terminal being delivered from (WMS, port management systems)? And how can surrounding supply chain managers respond to events in the fleet such as road delays or abrupt maintenance needs?

iv. **Road PDI**. A common concern among representatives of road operators was the potential expense of development of road infrastructure for automated trucks. Here also, therefore, there may be a need to consider new business models to finance upgrades. Private actors operating toll roads could get increased capacity from daytime traffic backfilling the increased capacity left by trucks using dedicated lanes at night; or logistics centers could help pay to extend a dedicated automated truck lane between the center and the highway.

Technological development

Several interviewees in our study appeared to assume that L4 automation technology is ready, while others – including technology developers – stressed the need for further development to expand the repertoire of ODDs in which SAE L4 automated trucks can function (TAR4). Even if L4 automated trucks are ready for use in some ODDs, the wider logistics systems into which ODD are embedded are not. There is a need to consider carefully the many different physical and cognitive tasks human drivers perform when attempting to automate any part of logistics systems, so that they can be reallocated to technology or people appropriately (UAR17). For logistics actors, the main value proposition of highly automated driverless trucks is that it addresses the driver shortage, which is an increasing threat to capacity and therefore productivity (stated as a requirement in UAR4). It is therefore important to ensure that "driver out" does not mean more people are needed in the system than before, to carry out tasks that drivers used to do.

Systems engineering

Our requirements imply a need for system-level analyses and engineering to avoid loss of safety (RAR1, RAR2) or security (UAR15) and ensure trust. One outcome from such analyses will undoubtedly be that automated truck operators cannot rely only on information from road authorities and should have different sources of information to increase redundancy and resilience.

There is also a need for systems engineering in generating useful models for management of increasingly integrated logistics operations (see 6.2). A holistic approach is needed in which different actors can communicate through a digital infrastructure that is built to support automated transport to the benefit of logistics operations and society. Systems engineers, human factors and cognitive systems engineers could work with technology developers, logistics actors and road operators to develop such systems, with each actor able to interface with the automated truck system in a useful and usable way. Engineering of data interfaces for flows of information about vehicles, roads, surroundings, weather etc., is a key challenge in any systems engineering exercise.

Finally, on a point of ethics, automated systems should satisfy principles of meaningful human control and align with the moral accountability and intentions of operators, users and stakeholders (Santoni de Sio & van den Hoven, 2018).

Roadmaps

In this last section we wish to highlight two dilemmas raised during interviews.

1. OEMs may hold back investment in highly automated trucks until they believe that the required PDI will be ready, but the infrastructure will not be ready until decision-makers influencing the activities of road owners or connectivity providers believe that the automated truck technology is ready.
2. Port container terminals won't invest in interfaces with external automated trucks until they see a demand for them, but there will be no demand unless appropriate interfacing is ready.

The aim of demonstration projects like MODI is to resolve such dilemmas, but collaboration to develop roadmaps for system development would also help. While logistics actors concerned about an increasing driver shortage, want to operate with "driver out" as soon as possible, it is hard for them to see a clear path forward. Both logistics actors and road operators may be willing to start investing in the PDI changes they need to make, but they may need evidence that these changes are absolutely necessary and not the result of attempts by vehicle technology developers to save on development time and costs. Identification of PDI and regulatory changes that are critical as they cannot be addressed by vehicle technology development, would help logistics and road actors assess what actions they need to take for a future with automated trucks. This in turn would require that OEMs unite to present their collective needs and share knowledge on the limitations and potential of their technology. An important outcome of such activity would be a roadmap calling for practical feasible changes to PDI that different actors must make to pave the way for highly automated trucks in logistics.

6.1 Recommendations

We wish to highlight the following recommendations for MODI project partners:

- Use user and stakeholder requirements to inform the development of activities demonstrating the use of highly automated and/or connected trucks in logistics.
- Assess the relevance and viability of each user and stakeholder requirement in the context of each envisaged demonstration activity; develop and prioritize the requirements accordingly.
- Assess the value each use case offers against users' / stakeholders' value requirements.
- Consider how to requirements could be developed iteratively as use case solutions emerge.

The user and stakeholder requirements should be useful outside the MODI project for those looking to develop automated transport or automated solutions for logistics. The following recommendations are therefore aimed at external technology developers and road authorities, operators and owners, in addition to MODI partners:

- Consider exactly which adaptations of the physical infrastructure are absolutely needed, and which changes could be avoided by expending more effort on developing vehicle solutions.
- Evolve logistics by demonstrating feasibility of automated trucks in logistics for high-volume routine transport in low-interaction situations.
- Organize demonstration activities to learn about aspects of vehicles and supporting PDI that should be standardized across operations, regions and countries to give fully interoperable highly automated truck systems.
- Explore new business models for highly automated truck fleet operation and ownership.
- Develop viable, safe and secure models of remote monitoring and assist for highly automated (driverless) trucks, specifying possible roles and responsibilities.
- Technology providers should work together with each other and with logistics actors and road authorities on roadmaps for the future development of automated truck operations logistics, outlining absolute requirements for PDI investment and development.

The following recommendations are aimed at those carrying out future projects and demonstrations:

- System-engineering approaches are needed to protect against losses from unforeseen interactions among system components.
- System approaches are needed to integrate automated trucks into integrated digital management systems that exploit potential efficiency gains of digitalized, automated logistics.

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See also Annex 3

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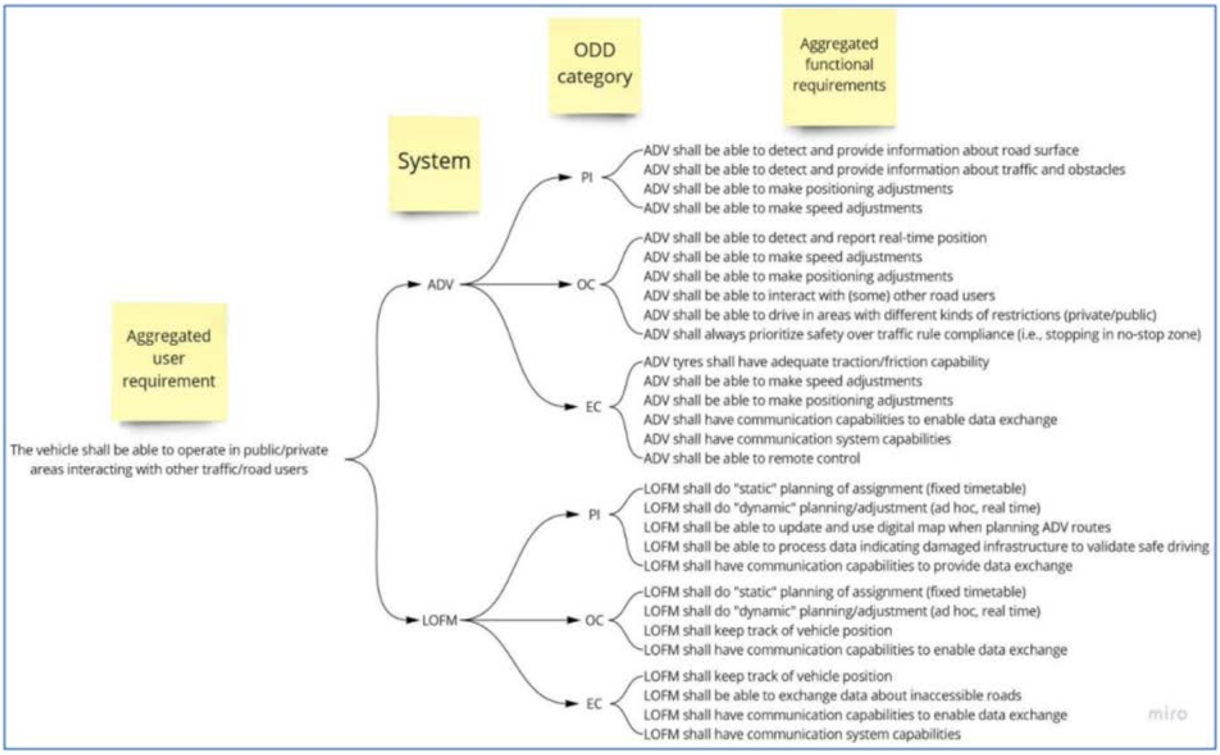
Annex I: User and solution requirements (AWARD)

The figure below is taken from EU project AWARD's Delivery D2.2 (Fröhlich, P., 2021), and shows how a user requirement can lead to many functional (solution) requirements.

Annex 1: User and solution requirements (AWARD)



Annex 2: User requirements identified in AWARD and SHOW

AWARD (Frölich et al., 2021) identified the following aggregated user requirements for use of AVs in logistics:

Personnel

- Highly qualified personnel shall be available to support/solve problems related to the automated system.
- Working unions help shall be required for acceptance of the automation process.
- For the acceptance of the automation process, there shall be clear information about the impact on working conditions (employment, qualification, tasks, etc.) as well as new job opportunities.
- Training for personnel directly/indirectly involved shall be carried out.

External conditions

- The vehicles shall be able to operate in public/private areas.
- interacting with other traffic/road users.
- AGTS operation shall be adapted to different weather conditions.
- The vehicles shall guarantee at all times the safety of all the people around it.
- The behavior of the vehicles shall be adjusted according to the road conditions: area (public or private), surface (pavement, concrete), relief (slope, flat), and geometry (curve, line).
- For the implementation of the AGTS, the opinions / suggestions / requirements of the people who will interact with the vehicles on public roads shall be considered.
- The vehicles shall be able to interact with the available digital/physical infrastructure.

Vehicle fleet operation

- The vehicles shall be eco-friendly (low noise, low CO_2/GHG emissions).
- The vehicles shall be equipped with an emergency system, to be stopped and/or intervened by an in-site driver.
- A recurring physical inspection of the vehicles shall be done.
- The vehicles shall inform the control system (LOFM) about its movements (actions, positioning, longitudinal and lateral motion, etc.) and status (sensors, tires, fuel/energy, etc.).
- The user interface shall be easy to use.
- The vehicles shall allow remote intervention / control at any time.

Reliability

- The AGTS shall be able to define a detailed route before starting operations, as well as modify it in real-time if necessary (for example, under the presence of an
- obstacle/accident).
- The AGTS shall be robust to face external attacks (e.g., cyber-attacks), as well as prevent misuse by internal unqualified personnel.
- The AGTS shall be reliable and fault tolerant.
- A delay time shall be considered for the implementation of the AGTS to achieve the desired performance.
- The AGTS shall be integrated with existing systems avoiding any interference

Business model

- The AGTS shall be standardized to simplify its implementation in logistics use cases.
- Automation shall result in higher profitability, coming from higher productivity (24/7 operability), higher transport capacities, and optimization of movements/time (and therefore, reduction in fuel/energy consumption).

- Tasks around the vehicles shall be automated.

Ethical and legal scope

- A regulatory change shall be made to consider the presence of automated vehicles.
- Ethical and social implications shall be studied.

SHOW identified the following stakeholder priorities:

Passengers and other road users (includes umbrella associations/non-profit organisations)

- Easy to use and friendly systems and apps
- Evidence on the efficiency of automated mobility solutions
- Transfer of control between the vehicle and driver / operator and vice versa.
- Behaviour control of vehicles in relation to other road users.
- Clarification of the impact on societal values.

OEMs, Road/mobility operators and Tier 1 suppliers, telecom operators, technology providers, and services company

- Operational interoperability
- " Establishment of legal framework in order to allow
- for development of technological solutions. "
- Development of business models and partner agreements.
- Environmental and economic sustainability and connectivity

Authorities (Cities, Municipalities, Ministries), policy makers, municipality agency and road operators

- Road, system and telecommunication infrastructures and networks with operational interoperability and accessibility.
- Holistic approach solutions through integrated initiatives from private domain.
- Operational excellence of monitoring and controlling systems and mixed schemes with passengers and cargo delivery by common automated vehicle fleet, under vehicle sharing concepts.

Research and Academia

- Projects funding to provide evidence on efficiency, safety and security of vehicles, systems and services, encouraging user acceptance and promoting accessibility for all.
- Inter-partner agreements

Annex 3: Overview of projects and articles reviewed

The following Table is an overview of EU project reviewed in preparation for T1.1 MODI.

Project	Purpose	Period	Topics	Methods for requirements elictiation	Identified stakeholders	Relevant deliverable	Requirements
SHOW (Shared automation Operating models for Worldwide adoption)	Advance sustainable urban transport by deploying automated vehicles	2020-2024	Business models, CAD functions, user acceptance, logistics	Desk research, user acceptance survey, interviews before and during pilots,	6 primary stakeholder groups, 10 sub groups	D 1.1 Ecosystem actors needs, wants & priorities & user experience exploration tools, D1.2 Use cases	Called ecosystem needs, wants, and priorities- 14 needs, 12 wants identified for freight transport.
5GMED (Sustainable 5G deployment model for future mobility in the Mediterranean Cross-Border Corridor)	hastening EU goal of cross border 5g connectivity for CCAM in Mediterranean core network corridor	2020-2023	5G,CCAM, infrastructure, sensors	literature review, data collection from other WPs,		D2.1, Definition of use cases, D4.1 Requirements and initial design for Automotive test cases; D5.1 - functional and non-functional requirements	Focus on functional and non-functional requirements
AWARD (All Weather Autonomous Real logistics operations and Demonstrations)		2021-2023	CAD functions, sensors, logistic	stakeholder workshop, site visits, contexutal interviews, survey, literature review, automated road transport logistics acceptance model (ARTLAM)	3 primary groups, 14 sub-groups, 60 specific stakeholders	D2.2 User and Stakeholder Requirements; D8.1 Market opportunities, barriers, and solutions	26 aggregated requirements for the 4 usecases. Requirements divded into 6 topics- Ethical and legal scope, Business model, Reliability, External conditions, Personell
HiDrive (Addressing challenges toward the deployment of higher automation)	Extend operational design domain of autonomous vehicles by making driving automation robust and reliable.	2021-2025	ODDs, CAD functions	FESTA - process methodology for field operational trials		4.2 Data for evaluation (1st deliverable available on website)	
Inframix (Road Infrastructure Ready for Mixed Vehicle Traffic Flows)	Prepare road infrastructure for the coexistiance of conventional and automated vehicles	2017-2020	infrastructure, platooning	desk research, interviews, workshops	Freight companies	D 2.1 requirements catalogue	Functional, Non Functional, and Feasibility requirements defined for each use case
Aeroflex (Aerodynamic and Flexible Trucks for Next Generation of Long Distance Road Transport)	support vehicle manufacturers and logistics industry increase efficiency of vehicles	2017-2021	infrastructure, logistics	desk research, interviews, workshops			22 stakeholder requirements for Cost, Operations, Infrastructure, Loading/unloading, Other
AVENUE (Autonomous Vehicles to Evolve to a New	Full scale demonstrations of autonomous	2018-2022	public transport, CAV, V2X,	survey, interviews	7 discussed- Traditional Transport Operators,	D2,1 Passenger needs and analysis, D2.7 Stakeholder	Requirments for safe passenger exchange, inside andoutside the

Urban Experience)	mini-buses in 7 cities.		acceptance, accessibility		Legislators, Tech providers, Municipalities, Assessment agencies, New competitors, End users	analysis, D2.10 Regulatory Requirements	vehicle. 26 user generated requirements,
ARCADE (Aligning Research and Innovation for Connected and Automated Driving in Europe)	to coordinate census building across stakeholders	2018-2022	Consensus building	Stakeholder workshops		D3.7 Society thematic areas: challenges and scenarios (complementary reports vailable on systems & services as well as Tech & vehicles	
Head-Start (Harmonised European Solutions for Testing Automated Road Transport)	Validate safety and security requirements for CAD	2019-2021	CAD functions, testing and validation	Interviews with stakeholders, online surveys, workshops	5 stakeholder groups (OEMs, automotive suppliers, policymakers and member states, consumer organisations, research institutes)	D1.2 Stakeholder and user needs	
L3Pilot (Piloting Automated Driving on European Roads)	Pilot study SAE level 3 (and 4)	2017-2021	CAD functions	FESTA V-process methodology for field operational trials	4 groups - companies, public authorities, users, knowledge institutes	D3.1 From Research Questions to Logging Requirements; D7.2 user experiences; 1.6 Deployment strategies and business models, 3,3	
ICT4CART (ICT Infrastructure for Connected and Automated Road Transport)	Provide ICT infra to enable transition to road transport automation	2018-2022	Infrastructure, 5G, ICT	desk research, interviews, workshops	7 stakeholder groups (Automotive companies, IT companies, Cyber security providers, Road Network operators, Mobility Service providers, Policy Makers	D2.1-Specification of use cases; D2.2 Analysis of market needs (needs of end users)	performance requirements for 6 different markets
TransAid (Transition Areas for Infrastructure Assisted Driving)	Develop traffic management procedures and protocols for conventional and autonomous vehicles in transition areas (at the edges of ODDs)	2017-2021	ODD, infrastructure, CAD functions, ICT	workshops for stakeholder consultation		D2.1 Use case definitions, D2.2 Scenario definitions and modelling requirements, D8.1 Stakeholder consultation	
Levitate (Societal Level Impacts of	Create an evaluation framework to	2018-2022	CAT evaluation	Literature Review. Goals proivded to		D3.1, D 7.1 Defining the	

Connected and Automated Vehicles)	assess impact of CAT on mobility and society			stakeholders to revise in iterarivei process.		future of freight transport	
PASCAL (Enhance driver behaviour and Public Acceptance of Connected and Autonomous Vehicles)	Address issues of users in or near CAVs	2019-2022	User acceptance, CAD functions	survey, literature review		D 3.1 User centered recommendations	
Trustonomy (Building Acceptance and Trust in Autonomous Mobility)	Raise safety, trus, acceptance of Avs with a focus on request to interverene scenarios	2019-2022	User acceptance, CAD functions	Questionnaires, interviews, focus groups, field/simulator observation, systematic reviews, q sort method		D1.2 Trustonomy Requirements	Divide into 4 levels - Must, Should,Could, Would
Autopilot (Automated driving progressed by internet of things)	Involve vehicles, road infrastructure and surrounding objects in IoT	2017-2022	ICT, IoT, infrastructure	surveys based on scenarios		D4.7 User Requirements Analysis	Users asked to rate different requirements from 1-7 in terms of importance
Drive2thefuture (Needs, wants and behaviour of Drivers and automated vehicle users today and into the future)	Prepare drivers, travellers and vehicle operators to adopt CCAM. Focus on HMI	2019-2022	User acceptance, HMI	Interviews and questionnaires (targeted survey) on six topics- use cases, safety, testing, type approval, consumer testing, testing goals for Key Enabling Technologiess	5 stakeholder groups, vehicle manufactures, auto suppliers, polic makers/member states, consumer organisations, research institutes	D1.1 User clusters, opinion, research hypotheses and use cases towards future autonomous vehicle acceptance- specifically table 11	Users defined as anyone who uses Autopilot services
Ensemble (Enabling Safe Multi-Brand Platooning for Europe)	Pave the way for the adoption of multi-bran trcuk platooning	2018-2022	Platooning, logistics	stakeholder survey, desk research	Shippers, carriers, OEMs, platooning SPs, Insurance companies, Infrastructure mgmt, Regulator,	4.4. use cases, 4.3 economic and environmental impacts	elicited from use case description
MAVEN (managing automated vehicles enhances network)	Develop infrastructure assisted platoon organization and negotiation algorithms	2016-2019	platooning, infrastructure	workshops, stakeholder consultations	(4 identified)Cities, Vehicle drivers and road users, Vehicle makers (OEMs), Infrastructure service providers,	D2.1 User needs, conceptual design and requirements	16 use cases defined. User Requirements elicited from stakeholder group, workshops, and surveys
SUaaVe (Supporting acceptance of automated vehicle)	Achieving social reliability and acceptance towards CAVs through greater user awareness and ethics	2019-2022		focus groups (n=70) survey (n=3783)		D1.2 Model and guidelines depicting key psychological factors that explain and promote public acceptability of	

						CAV among different groups	
Adaptive (Automated Driving Applications and Technologies for Intelligent Vehicles)	Testing automated technologies (SAE) 1-3 to make vehicles safer while looking at drivers needs and the regulatory enviornment	2014-2017	acceptance,			D4.7 User Requirements Analysis	

Ongoing projects with no Deliverables on requirements yet: ForFreight, MultiRELOAD, FAME, Roadview, Ultimo.

Annex 4: Envisaged technical demonstrations

1

A LEAP TOWARDS SAE L4 AUTOMATED DRIVING FEATURES

A leap towards SAE L4 automated driving features

Scenarios used in requirements identification

20th January 2023

This document contains a description of scenarios that MODI plans to demonstrate. The scenarios are not meant to be finished descriptions of activities to be demonstrated but have been prepared for the purposes of identifying user and stakeholder requirements to inform design (Task 1.1).

Original content was prepared or coordinated by MODI WP5 use case leaders, based on questions designed by WP1, WP2, WP3.1 and WP3.3 leaders. Content has been edited for the purposes of user requirements generation, by TØI, who have also added a description of L4 vehicles to be used in MODI.

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Co-funded by the European Union

Overview

MODI aims to demonstrate how the following 13 transport activities can be carried out **autonomously**:

As shown above, each demonstration activity has been given a code to indicate the country in which the activity may be demonstrated. Thus, for example **NO1** activity number 1 in Norway, **SE2** is Sweden activity number 2, and so on; **NL** = Netherlands, **DE** = Germany. Since the activities will be designed developed further before demonstration, we refer to the activities as **scenarios** for the purposes of identifying user and stakeholder requirements.

What about the trucks?

The scenarios contain little description of the vehicles to be tested. The main reason for this is that the vehicle, connectivity with surrounding infrastructure / traffic, and other aspects of the automation set-up will be designed and developed during MODI and demonstrated in 2025. The reason for identifying user and stakeholder requirements is to inform this development process.

We do know, however, that the MODI project will test and evaluate **Level 4 autonomous vehicles**. These can navigate autonomously within a defined area without human intervention. If there is an unexpected event or error that exceeds the vehicle's capabilities, such as construction on a road stretch that alters lane markings, it can respond appropriately and autonomously to achieve a minimal risk condition (e.g. pulling to the side of the road and stopping). A human operator can then resolve the issue, either in person or remotely, to return the vehicle to a state where its autonomous features can take over again. If the change in driving environment that exceeds the autonomous vehicles capabilities is more predictable (e.g. a planned departure from a highway into an urban area), the handoff to a human operator can take place before the vehicle takes the initiative to enter a minimum risk state.

Level 4 autonomy is conveyed by a set of on-board autonomous driving features bounded by an operational design domain (ODD), which is the physical and digital context (infrastructure, conditions etc.) within which the vehicle can operate. There may be varying degrees of connectivity between the vehicle and its context (e.g. traffic lights, road surface, other vehicles etc.)

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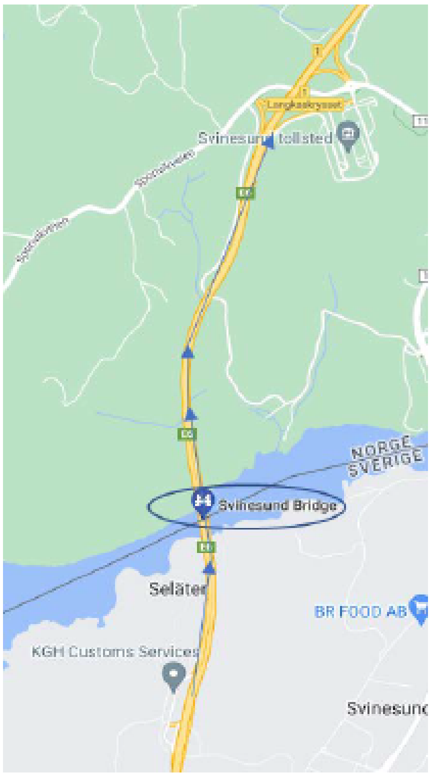
3

Border crossing (NO1)



Activities to be demonstrated. Autonomous driving from Sweden on E6 to Norway, crossing the Svinesund bridge without the need to stop (see map). This includes switching between providers of precise positioning data (real-time kinetic correction) and between providers of connectivity, as well as getting permits in two countries. Automated driving system will probably need to handle cut in/overtake by other vehicles, exit/enter highway and safety critical failures. The speed will be ca. 60 km/h[1].

Potential users. Transport service / vehicle providers, Owners of cargo to be transported cross border, Technology providers (identified gaps and solutions might spark business opportunities), Standardization bodies.

Technology and physical objects. Autonomous vehicle, Remote Interface, Positioning services with GNSS correction[2], high density maps and/or point clouds for navigation purposes, Cellular communication on both sides of border, AutoPASS tag (needed for automated tolling on Norwegian roads), and C-ITS for V2X communication.

Potential impacts. Improved traffic safety (e.g. enforcing speed limits, no driving under the influence), new office-based job opportunities, increased share of female employees in logistics, more efficient and environmental driving style, removal of operational constraints due to rest time regulations so more efficient transportation. Authorities may enforce stricter and higher standards on vehicles, and they may get more information from vehicles in real-time.[3]

Constraints. Lack of light at night, poor visibility, poor weather, winter conditions, congestion, tunnels. Borders can be congested road segments.

Regulatory and technical challenges. Operator of remote interface likely to be in one country, yet the vehicle will require a permit to drive from the authorities of two different countries. Going from one country to another, the mobile coverage may be interrupted while switching from one operator to another. This may create some time without network connectivity. It hard to predict in advance where/when the switch will happen. It may occur in a critical moment in relation to information flow needed to safely and correctly pass the customs. Similar challenge from need to change RTK correction operator. Switch between Swedish and Norwegian maps may create confusion about map datums, height systems etc. C-ITS based messages (CAM, MAP, DENM, etc) all use WG84 coordinates and mostly assumes a two-dimensional surface (no roads on top of each other).

[1] See also description in the motorway case.
[2] e.g. SWEPOS/CPOS

[3] Further impacts on mapping. Companies that do not have position and mapping as their core service can provide autonomous vehicles. Several companies or authorities do data capture in the same areas. If this work can be harmonized to produce better quality high-density maps and point clouds these products will be produced at lower cost and save the environment. More frequently updated high-density maps and point clouds would lead to safer navigation and traffic.

4

Customs (NO2)

Activities to be demonstrated. Driving an autonomous truck through the Norwegian customs when crossing the border between Norway and Sweden at Svinesund. See map.

The set up could look like this:

1. Transport service provider to register as a digital user with Norwegian customs.
2. Shipping documents will be declared and paperwork processed ahead of time using a digital customs (Norway's "Digitoll") portal.
3. The customs will do the proper document inspection, including inspection of the Remote Operator (a person)
4. Demo of "green light" scenario: Vehicle may proceed through customs site without stopping.
5. Demo of "red light" scenario:

a. Pull the vehicle over in the red zone (potentially high density of traffic)
b. Park (potentially high density of traffic)
c. Customs officer need to be able to communicate with the Remote Operator via an intercom
d. Remote Drive or high-level command to the scanning hall

6. At the scanning hall, customs officer needs to be able to open the vehicle port to the cargo hold (or possibly to have it opened remotely)
7. Leave Customs

Potential users. Custom authorities in the EU, Transport service or vehicle providers, Owners of cargo to be transported cross border.

Technology and physical objects. Autonomous vehicle, Remote Interface, C-ITS (traffic light, C-ITS communication[4]), and Norwegian Customs service on site and declaration service.

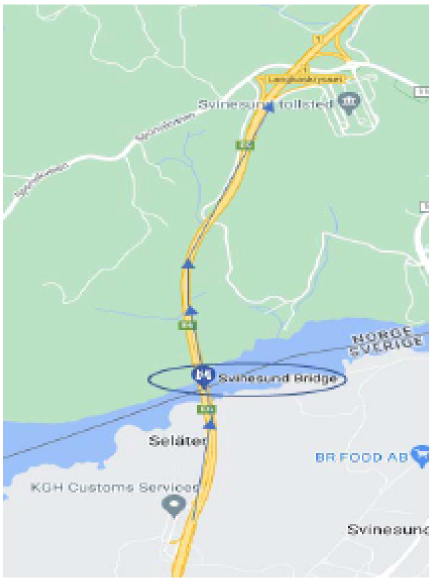
Potential impacts. Efficient customs handling is key for efficient international logistics. For autonomous vehicles to reach their potential in making transportation more cost-efficient, a reliable, efficient and standardized automated border crossing is needed in different EU/EØS countries. This means that the customs process itself needs to be digital and autonomous, which would also increase the efficiency of customs processes generally. This would have socio-economic benefits such as a more predictable logistics services.

Constraints. Lack of light at night, poor visibility, poor weather, winter conditions, congestion. To autonomously drive up on a ramp for the cargo hold to be scanned can be a problem.

5

Motorway driving (NO3)

Activities to be demonstrated. Autonomous driving on E6 highway will be demonstrated[5]. The driving will take place either: 1) across the border between Norway and Sweden, at Svinesund (map on left), or 2) only on the Norwegian side, probably in the area of the Patterød intersection (map on right).



Potential users. Transport service providers, Vehicle providers, Owners of cargo to be transported on the motorway, Terminal owner (driving on motorway enables more possibilities for hub-to-hub transport), Technology providers (identified solutions and gaps might spark business opportunities), Standardization bodies.

Technology and physical objects. Autonomous vehicle, Remote Interface, potentially C-ITS (traffic light, C-ITS communication[6]), AutoPASS tag to drive on Norwegian road, Positioning services with GNSS correction (e.g. SWEPOS/CPOS, and high-density maps and/or point clouds for navigation purposes).

Potential impacts. Improved traffic safety (e.g. enforcing speed limits, no driving under the influence), new office-based job opportunities, increased share of female employees in logistics, more efficient and environmental driving style, removal of operational constraints due to rest time regulations so more efficient transportation. Authorities may enforce stricter and higher standards on vehicles, and they may get more information from vehicles in real-time.[7]

Constraints Night, poor visibility, poor weather, winter conditions, congestion, and tunnels.

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[5] The final solution of this set up will be determined in the application process, including possible solutions like full speed (90 km/t) or reduced speed with appropriate safety measures like closing down the road or one lane for the demo, car following, using a vehicle with safety driver instead of the driverless vehicle etc.

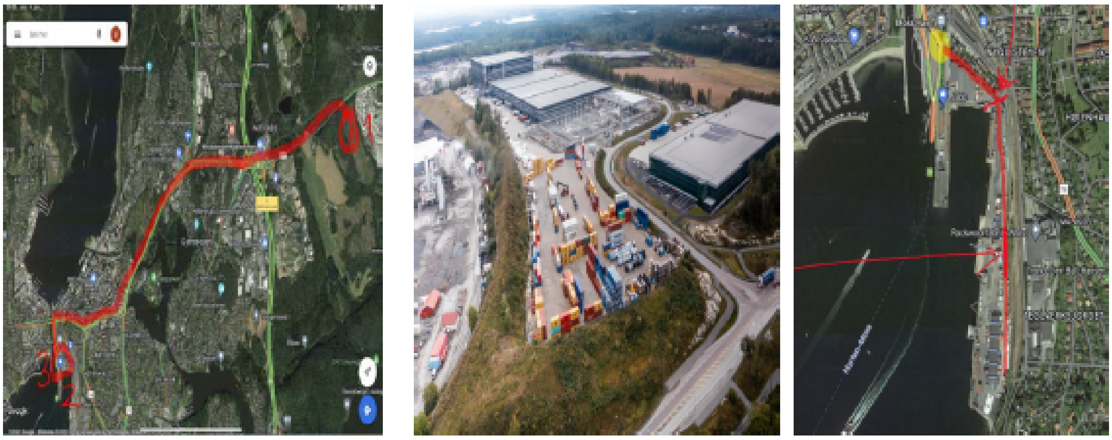
[6] e.g., SPaT/MAP messages

[7] Further impacts on mapping. Companies that do not have position and mapping as their core service can provide autonomous vehicles. Several companies or authorities do data capture in the same areas. If this work can be harmonized to produce better quality high-density maps and point clouds these products will be produced at lower cost and save the environment. More frequently updated high-density maps and point clouds would lead to safer navigation and traffic.

6

Terminal manoeuvres (NO4)

Activities to be demonstrated. The port demonstration can consist of different options: 1) Dry port, 2) Container port, and 3) Sea drone port. The options are shown in the maps below.



From left to right: Dry port, Container port, Sea drone port (Asko).

Potential users. Owners of goods, Logistic companies, terminal operator at ports, Shipping companies.

Technology and physical objects. Automated gate at port (to access the port area), Autonomous vehicle (to drive in the port area), Sea drone (to transport goods over the fjord), and Automated terminal tractors (to move goods on the port area).

Potential impacts. More efficient operations (around the clock operations possible due to reduction in noise, less restrictions on working hours). Less accidents in the port area (loading/unloading a risk for workers, which will be eliminated). Less noise in the urban port area (due to electric vehicles/operations). Environmental impacts: automated transport from port gate across Oslo fjord could enable reduce the need to drive by road via Oslo city centre. At full capacity the two sea drones are expected to do 8 trips over the fjord each day, and a reduction of 5000 tons of $CO2$ is estimated. Since the sea drones are electric, short sea transport will be made more competitive by demonstrating the feasibility of automated, zero emission transport chains.

Constraints. Issues due to different regulation of confined area versus public roads.

7

Gate access (SE1)

Activities to be demonstrated. Autonomous truck-trailer combinations given access from public roads to a confined area through gate access services including request, confirmation and passing based on proper document handling.

At ports and other closed off areas there are often gates and different kinds of physical and digital barriers to handle to be able to enter the site. Depending on the site we will investigate the demands for access control and find a solution to be able to handle that specific demand. The demonstration will cover the full scenario of planning and timing, routing to correct gate, queuing and waiting, entering, and exiting gate area.

At a private site in the Gothenburg region "Proper document handling" could mean that the proper contract is set up between the site owner and autonomous vehicle owner, that the vehicle owner as transport service provider has access to the code or tag used, or that the Automatic Number Plate Recognition (ANPR) system has knowledge about and accepts the autonomous vehicle number plate. This will be analysed further when the site is decided.

The actual test set up could be: 1) The transport service provider is allowed access to the site in advance; 2) The vehicle drives up to the gate/entry point; 3) The Access control service accepts the vehicle and opens the gate; 4) The vehicle passes the gate.

For entering and exiting the gate, the following data exchange needs to be considered:

- Driver access (if relevant): what firm they are coming from, ID, name – information sent to port. Can we register the driver pre-hand before the gate? What happens if there is no driver in the truck?
- Transport booking (purpose on terminal). At the test site (Gothenberg RoRo terminal) you can book a time, pickup and drop off a trailer digitally – "Entry Code" to be send to DFDS. Receipt (from kiosk) sent to truck.
- Customs? To be investigated together with DFDS Logistics.

Potential users. Transport service providers, enclosed site or terminal owners, logistics companies, traffic management.

Technology and physical objects. Autonomous vehicle and Remote Interface, On-board/Vehicle equipment, Gate / access control solution (system opening the gate), Back-end system (IT service that the access control system by the gate could communicate with), Mobile networks, Cloud systems, Web services, etc. Physical parking and gate areas, Reference objects for autonomous vehicles (concrete blocks, lightpoles etc.), Railway barriers / physical barriers, Shark teeths, yield signs, line markings, traffic lights.

Potential impacts. Unauthorized deliveries or people need to be kept out of closed or fenced areas.Creating a solution which works for autonomous vehicles could contribute to continuous traffic safety at the site. An autonomous access control solution is also efficient from a logistics perspective (e.g. efficient turnaround for ships using planning and digital tools) and is needed to help build a sustainable business model for autonomous transports. Potential negative impacts include potential stowaways / tailgating.

Potential constraints. Poor weather and winter conditions (snow, rain, fog, wind, sun, temperatures). Particularly snow where line markings are covered will be challenging. Other challenges are traffic lights (if snow, then sensors may not work), merging lanes, and construction planned in port area.

8

Charging (SE2)

Potential users: Site owners, transport service providers, road authorities.

Activities to be demonstrated. There may be two demonstration sites, but will probably include a fenced off area in the Gothenburg region much like the Gothenburg RoRo terminal.

Two scenarios will be demonstrated:

1. Planned autonomous electric charging in standard operations.
2. A proprietary remote interface operation enabling charging to be replanned based on logistical changes or challenges encountered (e.g. extra charging while waiting for traffic jam, loading delays).

In both scenarios, a charging location will be allocated, and the slot confirmed on-premises.

Technology and physical objects. Autonomous vehicle (truck and trailer), Onboard/Vehicle equipment, Remote Interface, and Autonomous charging solution and station, Power grid provider, Physical parking, Connectivity systems, Mobile networks, Cloud systems etc., possibly Gate systems. The technical solution for autonomous charging that will be tested has yet to be determined.

Potential impacts. Implementing an autonomous charging solution in an autonomous logistics chain is important in order to eliminate the need for a driver or human attendants on site, and reduce congestion around charging stations through increased efficiency. It is thought that this will be beneficial not only for the business case but also from a safety and security perspective.

Constraints. Winter conditions.

Challenges. Individual vehicles will require different amount of energy (kWh) depending on need, cost, and available time for charging. The charging station need also to handle the overall energy need and in addition handle the power balance. The financial transactions such as payment, subscriptions will also need to be managed. The physical power transfer connection using different means to connect the vehicle to the charging station will also be demonstrated.

9

Loading and unloading (SE3)

Activities to be demonstrated. The site of the demonstration is not yet decided but will probably take place at a fenced of area in the Gothenburg region much like the Gothenburg RoRo terminal. The aim is to test one solution for autonomous loading and unloading at a cargo bay.

A provisional plan of the test is to:

1. Dock the vehicle at the cargo bay (and possibly restrain vehicle).
2. Open the door to the cargo hold
3. Communicate that the vehicle is docked and ready to be loaded, either manually (through a Remote Interface used by personnel) on site, or digitally with the customer's Enterprise Resource Planning (ERP) system.
4. Autonomously load the vehicle in accordance to the agreed loading scheme
5. Receive information that the vehicle is loaded, either manually (through personnel on site using a Remote Interface), or digitally (e.g. through the customer's ERP system.
6. Automatically secure the load and check that it is secured.
7. Close the door to the cargo hold.
8. Drive autonomously to loading bay for unloading, repeat step 1, 2, 3.
9. Autonomously unload the vehicle in accordance to the decided unloading scheme
10. Receive information that the vehicle is unloaded, either manually or digitally as above.

Potential users. Site owners, transport service providers, and road authorities.

Technology and physical objects. Autonomous vehicle, Solution for autonomous loading and unloading, and probably an ERP-system.

Potential impacts. Will potentially reduce the need for "vehicle hosts" or on-site personnel. This would be beneficial for the business case as well as from a safety perspective.

Constraints e.g. winter conditions.

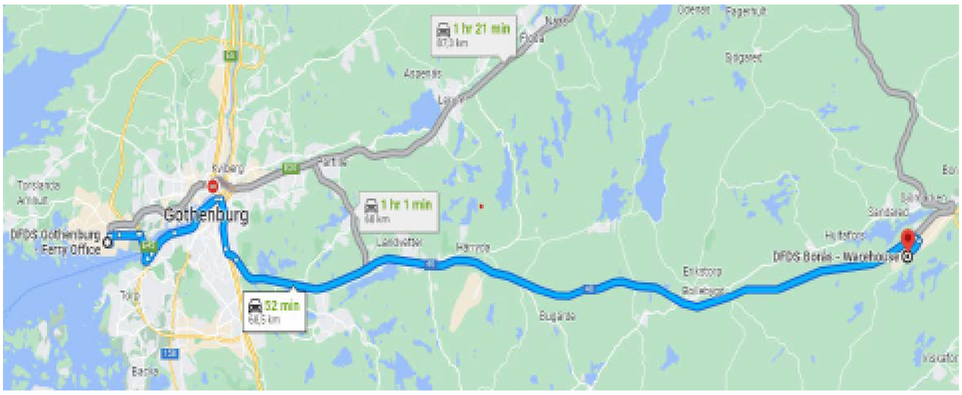
10

Driving on urban roads (SE4)

Two scenarios involving driving on public roads will be demonstrated in Sweden, one involving a driverless vehicle, and one with a safety driver on board:

1. Vehicle drives in restricted area
2. Vehicle access public road through gate
3. Vehicle drives on public road with mixed traffic
4. Vehicle access private road through gate

The demonstrations will focus on the services where trucks and trailers are in operation in mixed traffic on public roads. In one demonstration, the public roads between the DFDS port in Gothenburg and a DFDS warehouse in Borås in Sweden are the planned site for the demonstration. See map below. The roads may be equipped with additional C-ITS Road Side Equipment (RSE) and the vehicles will be equipped with C-ITS capabilities. There will be a selection of C-ITS services according to what is feasible and practical to demonstrate also with the perspective of future highly automated driving functions.



The site for the second demonstration (with driverless truck) has not been chosen, but a public road with a speed limit of 30 km/hour will be selected, and the vehicle will drive at least 15km/h.

Potential users. Cities, transport companies, terminal owners.

Technology and physical objects. Main components are automated truck and trailer, Remote Interface, Physical and Digital Road network, Connectivity systems, On-board/Vehicle equipment, Mobile networks, Cloud systems, Web services, etc. Depending on the stretch of road and the possible C-ITS solutions it contains, the demonstration could include testing of that technology as well.

Potential impacts. Reduced congestion, reduced waiting times, improved just-in-time operation, reduced energy need etc. due to improved planning, scheduling, routing, and logistics operation. This will be of benefit for the road operator and for the logistics operators.

Constraints. Poor visibility, poor weather, winter conditions, congestion, and tunnels.

11

Driving at terminal (NL1)

Activities to be demonstrated. The route and series of events for automated driving at the APM terminal in Rotterdam are depicted in figure below.

The demonstration will start before the gate (point 0 in figure above) where the truck driver can get out of the truck to take a rest. The vehicle will drive the sequence as indicated, which involves the following driving tasks:

1. LOW SPEED: Low-speed precision entry (0->1)
2. STOPPING POINT: Driving to a stopping point (e.g., 1->2 and 6 ->7)
3. MERGING: Merging in a lane (e.g., at 3 and 8]
4. ROUNDABOUT: Entering a roundabout (at 4 and 11), driving on roundabout(4->5 and 11->12)
5. ROAD FOLLOW: Follow the road driving (e.g., 5->6 and 8->9)
6. REVERSE POINT: Pick-up container (9->10) to reversing point
7. REVERSING: Reversing into docking bay
8. DEPARTURE: Merging from container pick-up (10->11)
9. LEFT TURN: Left-turn from lane (7a)
10. CROSSING: Railway crossing (8a)

The demonstration will involve driving in mixed traffic, interaction with roadside systems for traffic regulation, automated container pickup, and gating procedures.

Potential users: Service could be used by truck drivers, transport companies and logistic operators.

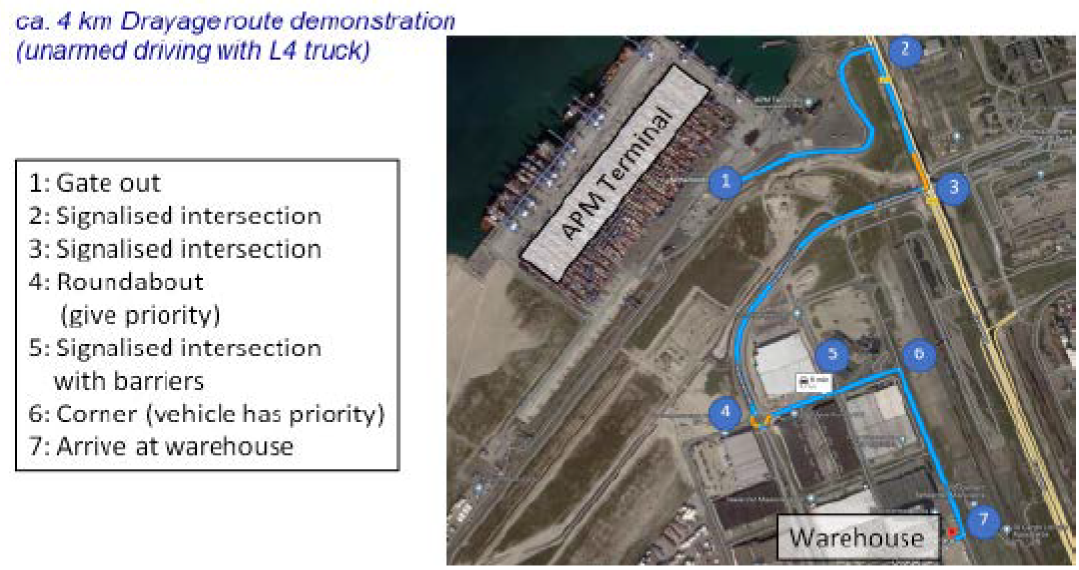
Other technology and physical objects. The truck will be coordinated to drive around the terminal using a "control tower" concept. Add-on devices will be fitted to the trucks for communication and positioning. Several communication units will be installed at the terminal, as well as several systems for detecting the whereabouts of trucks (including manual driven non-connected trucks). A positioning system at the terminal will support the driving tasks. A system will support the positioning of the trailer within the docking bay when reversing. It is envisaged that drivers will not be present to intervene.

Potential impacts: 1) the truck driver can take a rest while the truck is delivering and picking up a container, 2) automated driving can potentially reduce accidents and damages, and improve the energy efficiency of the driving, and 3) optimization of the logistic processes on the terminal with an increasing share of automated trucks.

Constraints: Lack of light at night, poor visibility, poor weather and congestion.

Drayage service (NL2)

Activities to be demonstrated. The route and series of events for a service for short-distance transport between terminals or warehouses at a port (Drayage) are depicted in automated driving sequence indicated in the figure below.



The focus is to assess the business case, including considering feasibility of / investments required for adapting existing road systems, traffic regulation and vehicle functions. The demonstration will start just before exiting the gate (at point 1) and driving the route to the warehouse where communication and sensing systems for automated driving are active. On the route, various situations are encountered which are also present at the APM terminal (e.g., traffic lights, roundabout, cf. scenario *NL1 Terminal manoeuvres*). The data collected from the vehicle (sensing and communication) provides an assessment of the technical capability of the vehicle, and requirements on information provision from future road-side infrastructure. The procedures for entering and exiting the terminal are not automated but will be assessed for the potential of automating them.**Potential users.** Transporters and terminal operators.

Technology and physical objects. Truck automation technology, existing infrastructure (physical and digital) along the route. No additional systems will be installed for this demonstration. The objective is to assess the need for additional systems.

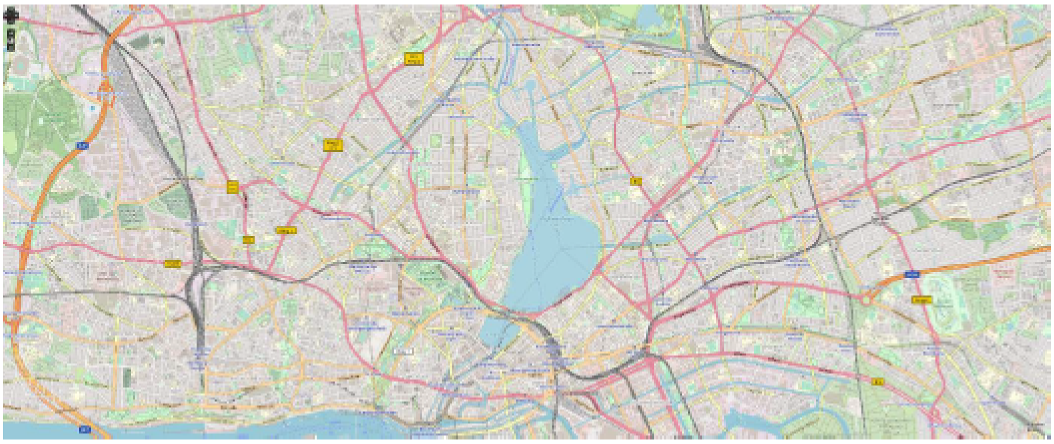
Potential impacts. The methodology can then be applied for other locations, and there is business potential in automated vehicle operations on a public road.

Constraints. Lack of light at night, poor visibility, poor weather, congestion, and tunnels.

13

Driving on city roads (GE1)

Activities to be demonstrated. Transition from confined area, such as terminal, into city-streets (likely in Hamburg area see map).



This will require a smooth transition to blend in with surrounding traffic. Depending on the route, there may be a need to drive over high bridges subject to wind and/ or tunnels with congested traffic. There may also be driving on narrow, slow speed roads in congested city traffic high in traffic, and driving may feature left and right turns.

Potential users. Transport service providers, vehicle providers, road owners, owner of related infrastructure (e.g. port, terminals) standardization bodies.

Technology and physical objects. Autonomous vehicle (Volvo, DAF), Positioning services with GNSS correction (e.g., SWEPOS/CPOS), HD-maps and/or point clouds for navigation purposes (FHH-(LSBG&LGV), C-ITS for V2X communication Infrastructure, Services (FHH-(LSBG & HHVA & ITS Mobility), Confined Area, permit to drive on closed roads (to be decided).

Potential impacts. Reduce overall queuing through precise routing and speed advisory, reduce driver workload and driving hours, reduced risk of accidents in specific situations, e.g., taking a sharp turn, crossing a bicycle path, implementation of VRU and citizen feedback into development cycle to increase confidence in interaction with automated systems on the road.

Constraints. The roads are often busy and prone to disruption. Only limited changes to infrastructure can be made with regard to C-ITS roll-out. Scheduled and unplanned roadworks can severely interfere with a MODI demonstration. Weather conditions etc.

Annex 5: Analysis to generate requirements

Transcripts, notes or sound recordings were analysed to identify from each interview a set of **Statements**. One statement was entered per row of an Excel spreadsheet (one spreadsheet for each interview). Data was entered under five columns: “Interview theme”, “Statement number”, “Statement”, “Scenario” and “User/stakeholder group”. Under “Interview theme” statements were categorized using a drop-down menu according to whether they identified a potential value from using automated trucks in logistics, a potential challenge, an information need or general requirement. Under the column “Scenario” any specific technical demonstration or logistics cases (cf. Table 2) being discussed at the time the statement was made were identified from a drop-down menu. Each statement was also assigned a user/stakeholder group indicating the type of organization to which the participant making the statement belonged. An average number of 33 statements were identified per interview, with most interviews generating 25 to 50 statements.

Interview statements were then collected into a single Excel “Statements” file containing a single spreadsheet. A column was added to this spreadsheet to indicate interview number from which each statement originated. The resulting spreadsheet contains 1,934 statements.

We went through each statement and started writing user and stakeholder **Requirements** based on the formula “As a [stakeholder / group] we can/cannot do/know/have something to achieve [goal/objective]” (Hathaway & Hathaway, 2005). To convert “Challenge”, “Value” or perceived requirement statements to Requirements, the researchers considered the underlying need to be met in order to identify a requirement (Hathaway & Hathaway, 2005). Similar requirements were grouped into a single summary Requirement.

As each Requirement was identified, it was entered into a row of a new “Requirements” Excel file. The new file contained five worksheets, each worksheet containing requirements for each main user or stakeholder group: Logistics actors, Technology developers, Road authorities, owners or operators, Subject matter experts and Workers. Note that requirements for one actor type could be derived from statements given by any of the other actor types, although this was not usually the case.

Each new requirement identified was given a unique code according to the user group who had identified it and the order in which it was identified. (For example, S4 was the fourth Requirement identified by a Subject matter expert; L23, the 23rd requirement derived from a Logistics actor and so on.) The unique Requirement code was also assigned to the statement(s) from which it was derived, so that each Requirement can be traced back to Statements, and from Statements to interviews.

The final Requirements file contained a total of 384 Requirements: 148 logistics actor (user) Requirements, 72 technology developer Requirements and 121 road authority, owner, operator Requirements. Most subject matter expert and worker statements identified Requirements for the other actors, but 33 and 10 unique Requirements were also identified for subject matter experts and workers, respectively (not shown in Figure 3).

To identify **Aggregated Requirements** for each user or stakeholder group, items in the Requirements file were then analyzed to identify similar themes and merged to make new Aggregated Requirements in a third Excel file. Original Requirements were collected into the single cell to the right of each Aggregated Requirement, to inform descriptions of each final Aggregated Requirement. Codes for Requirements from which each Aggregated Requirement was made were also entered alongside, so that final aggregated requirements could be traced back through Requirements to Statements to the interviews from which they are derived.

Annex 6: Interview schedule

Interview questions were developed somewhat during the first series of interviews, although questions eliciting requirements remained essentially the same. The following questions are taken from the final version, version 3.

Schedule (60-90 min)

1. You and your organization
   a. Can you start by telling us *briefly* about your current role and experience?
   b. Can you tell us about your organization? [what is the business / customers] [*what do you do for who?*]
   c. What are [your organization's main goals / the main goals in your work?]
   d. Which main activities [do you / does your organization] need to perform to reach these goals?
   e. Which assets / resources are most important [in your work / to your business]? Main partners, suppliers?
   f. What role does goods transport play? (*If not addressed yet*)
2. Value
   a. Would you [business/organization] want to use auto-trucking [in this scenario]? Why? What would improve?
   b. What would need to happen for auto-trucking to be **useful** [in this scenario / in other ops]?
   c. What would need to happen for auto-trucking to be **easy to use** [in this scenario / in other ops]? **Support**?
   d. How could automated and connected transport affect logistics KPIs / affect your organization?
3. Challenges
   a. What challenges do you see for you / your [business/organization] in these scenarios? Other actors?
   b. Would integration of auto-trucking into logistics systems require changed processes? What would need to be done / what would new systems look like?
4. Requirements
   a. What requirements would automated transport system in these scenarios need to meet in order to be accepted by [you / your organization]? Can this be measured?
   b. What would make you like it / not like it? Can this be measured?
   c. What would you be need to change in order to accommodate the automated transport system in these scenarios? [e.g. surrounding systems, other aspects of logistics, physical/digital infrastructure, rules and regulations, standards…] What would you want / not want to change?
   d. Can you think of changes other actors would need to make?
5. Information
   a. What information would be needed about the automated transport system? Who would need it? *[Cues: about vehicle, cargo, surroundings, people on site, by people elsewhere in logistics chain]*
   b. What information would the automated transport system need? Who would give it? *[Cues: to vehicle operator, to people surrounding it, about events elsewhere in logistics chain]*
6. Real and unusual situations
   a. What unusual situations might occur and cause problems (*cues: roadworks, ambulance/police, use of hard shoulder, weather*)
   b. What informal/social/cultural aspects need to be considered in these scenarios?
7. Gender issues

Annex 7: User aggregated requirements (UAR)

The notes attached to each aggregated requirement derived for logistics actors are derived from the full set of 148 unaggregated Requirements. Codes in bold denote original Requirements from which each aggregated requirement (AR) us derived.

*UAR1 Our automated trucks require fewer person hours for operation, so we reduce costs per unit transported per km. [**L1, L24**]*

It is expected that there will be less need to pay driver hours for truck operation, either because there will be less need to pay drivers for rest hours (rest regulations are relaxed and/or driver can rest in vehicle), or because a driver will not be needed. In either case qualified persons will still be needed to monitor or assist the automated truck remotely. The unit transported can be at a terminal or between terminals, but in either case it is likely that most costs will be saved for routine transport tasks requiring most driver hours. Given the current state of technology, costs may be saved sooner for high volume, routine transport on simple, dedicated and road stretches between terminals or transfer sites that are close to the road. In such cases, platooning may lead to increased savings. At terminals, there is a need to save costs by freeing up shunting drivers or allowing external drivers to rest while their truck drives automatically to deliver their load at the terminal, e.g. from port entrance to the terminal or from terminal gate to dock. Comments from actors, however, that drivers would be free to be reallocated to more skilled functions would mean that they would still be paid. Calculating the net cost savings in such cases will be complicated – see also R3.

*UAR2 We reduce erratic driving and the number of sudden braking, near-miss and collision incidents per km, which reduces our insurance costs, costs of damage to people, material or cargo, and costs related to fuel/energy and maintenance. [**L17, L23, L27, L50, T43, S21, S33**]*

L4 technology informed by data from surrounding traffic and road ahead will lead to smoother driving and less abrupt braking or turning. This will lead to safer and more economic driving. Logistics actors want to know how much they will save on insurance or material/person injury costs and on fuel or energy. More aerodynamic, lighter trucks (driver out) may improve energy savings and safety further. Net costs savings will be reduced, however, by extra energy used by onboard computers (estimated by one respondent to be 10% extra energy use) and technology maintenance – though the latter will be offset by less wear and tear on parts (brakes, tyres etc.). Safety also is a value in its own right, independent of costs saved.

*UAR3 We save more from using automated trucks in our operations than we pay for automated truck implementation, operation and maintenance. [**T22, L130**]*

Logistics actors want to know if the reduced dependence on drivers that can be achieved by L4 automation, will reduce their net costs. This involves considering several factors:

1. How much they pay to use the automated truck will depend on the automated truck financing or business model, which may be new. Some actors wish to understand the total cost of ownership advantages or disadvantages before deciding on a financing model, and they will need information to be able to do this.
2. Direct (see AR1, AR2) and indirect savings. The latter requires considering potential business advantages to such as increased capacity afforded from availability of trucks at more times of the day.
3. Direct and indirect costs. In addition to financing the automated truck, actors must consider support and training activities required, the need to staff and equip remote operations, new tasks for people during anti-social hours to make trucks available at more times of the day, changes to terminal PDI, automation/staffing of charging or loading, need for extra parking, customer service.

Knowing this means that all needs (e.g. infrastructure requirements, new roles) and costs related to automated truck implementation, operation, maintenance, depreciation are made clear. Logistics actors also wish to know how much time will be needed to change operations such that automated truck can be implemented for full cost savings.

*UAR4 We need fewer operators per truck and see increased truck uptimes so can achieve the same productivity with a lower number of vehicles and operators. [**L21, L90, L3, L15, L36, S13, L28, L14, L8, L86, R23**]*

For some logistics actors, truck availability (uptime) is constrained by lack of access to qualified drivers in many EU countries (driver shortage); where drivers are available truck uptimes are limited by maximum work periods, social hours or other driver needs (e.g. EU regulations state drivers must stop for 45 min rest every 4,5 h). At the same time actors see increasing demand for cargo transport (e.g. from e-commerce) especially on long-distance routes. As a result, companies want to be able to run trucks using less qualified-driver hours. Some want to run extended/24-7 operations at or between automated terminals, especially on high-frequency routine runs on private or dedicated roads (“maximise time as resource”), and some are interested in night-time operations that allow them to avoid congestion, which is often the main threat to delivery times. Actors see that automated truck can be available at more times of day and year (no holidays) and that they will more easily be able to juggle between trucks, adapt capacity in the face of fluctuations in demand or lack of access to competent drivers from sickness or strike action; delays will not be made worse by having to consider rest times, and they will be able to spread deliveries so our/customer terminals can increase efficiency by using less resource to cope with intense periods of loading / unloading. Large (port) terminals are interested in increasing capacity by operating internal automated trucks 24/7. Such operations will require new processes to minimize staffing required during non-social hours. Operating routinely and frequently between internal assets along simple or dedicated road stretches, at more times of day and night, disconnecting and connecting container/cargo at each end, with automated gate access and docking, is an attractive proposition. Where automated operational flows already exist at warehouses and terminals actors are interested in streamlining operations by integrating with automated trucks as a step towards 24/7 automated operations. In the long-term actors want to digitalize more comprehensive, intermodal supply chains with more integrated operational data (involving e.g. port, warehouse, fleet management systems to maximize efficiency and exploit the 24/7 capacity of the truck (see N5).

*UAR5 We can integrate the automated trucks digitally into our/clients' fleet and logistics management systems to give more dynamic and informed planning and execution of operations, with gains for efficiency, reliability and customer satisfaction. [**L6, L18, L20, L48, L60, T21, S20, S39, L51, L14, L117, L8, L42**]*

Some logistics actors see that efficiency gains could be achieved through dynamic planning if they has the data, systems and competence necessary to i) digitally track, program/direct and interrogate the automated truck and its trailer(s) and load, and ii) interface with external traffic, road and weather data for re-planning or route optimization. Full integration of the transport function with FMS, with further couplings to WMS and LMS offer exciting possibilities for efficiency gains in logistics operations. Automated truck and cargo location and flows could be clearly visible in real-time to operators, logistics platform providers, forwarders, truck owners, terminals who could track through fleet/logistic management systems where the truck is, cargo information, when it has left/entered port/terminal, expected time of arrival, where it is going (next), how they need to organize connecting operations (e.g. load/unload), and are warned of delays, in order to increase efficiency in supply chain. Information should flow seamlessly through the chain of involved parties. How such systems are used can depend on priorities e.g. automated truck delivery could be coordinated with surrounding operations for optimal energy use. Through AI systems, optimal routes can be planned accounting for rush hour, weather forecasts and conditions that may affect the safety of the service or fuel consumption, such as strong headwinds. Seamless logistics would mean that automated trucks could be redirected optimally in the event of order cancellations or if a delivery destination is closed or there are delays along the route. Dispatch could be automated (streamlining/organization of truck movements / back office automation and seamless connection) to exploit increased availability of trucks and maximize use of load capacity. Actors would save time by departing on time and planning trips using routes that are optimal for the business without having to account for the human needs of the driver. Such seamless logistics could lead to shorter more transparent, predictable delivery times, and easy-to-manage disruptions = customer satisfaction.

Some important caveats to consider are

- Actors need to know how to set up the "back-room" planning infrastructure that gives orders to truck or control room - how to operate the total business? What new physical and digital systems and processes will they need to integrate automated trucks as part of seamless logistics?
- Many smaller logistics actors will not have necessary digital or automated systems, so automated truck developers should also consider how automated trucks can be interfaced with manual operations.
- At port terminals the systems may be simpler, e.g. automated truck will need to know where the container to be fetched is, its number, confirmation that it is ready, and a way to validate collection and report validation.

*UAR6 We can increase efficiency by integrating automated truck with our/clients' existing terminal operations. [**L40, L42, L108, L53, L62**]*

At the terminal the automated truck will increase efficiency through automated interactions with the gate for access in and out, automated driving through traffic, junctions etc., reversing or using approach ramps to park or dock in the correct position automated (un)loading of cargo/container; automated charging and couple/decouple trailers (fifth wheel, kingpin, support legs, air and light connections); and connection of itself and/or the trailer/chassis to warehouse electricity and communication systems. Interfaces should be standardised and interoperable (see N10).

At terminals (e.g. quayside crane to stack, port reception to terminal), the automated truck could park/reverse/dock with or without remote control (tower on- or off-site). Terminals need to verify that it the right vehicle is entering or collecting or is bringing the right goods. Gate clearance in absence of driver needs also standardized information about licence plate, correct container, automated vehicle of approved type; could also be done by remote tower. Digital document transfer will be required. At terminals operators also wish to control entry and areas in which automated truck can move e.g. through geofencing.

Optimal efficiency will require sufficient digital maturity at yards to allow remote control parking or terminal maneuvres.

*UAR7 We can increase efficiency by coupling automated truck with automation that reduces time taken charge/refuel, transfer goods or pass through borders, customs, gates and inspections. [**S23, R79, R81, L62, L105, T45**]*

To avoid the need for extra staffing in the absence of drivers, process bottlenecks should be automated and interoperable with different automated trucks. Information about the process situation digitally integrated with dispatch/transport planning systems so that stops can be scheduled and coordinated with other automated trucks to avoid queues and increase truck availability. Some logistics actors stressed a need reduce charging time for electric vehicles during potential uptimes, or else to use hydrogen / HVO.

Digital document transfer will be necessary. Operations will require clear processes clarifying who is legally and liably responsible for what at different times in the process.

There is a need for automated truck or logistics companies to work with road or port authorities on different models for costing implementing charging infrastructure at strategic locations on highways, at ports, terminals and warehouses.

*UAR8 We can improve pay, working conditions, health, wellbeing, productivity and the gender balance of our employees by giving them other skilled tasks that can be done during social hours and closer to home. [**L2, L10, L11, L9, L30, W3**]*

Logistics actors want to offer employees increased health and wellbeing by reducing physical and mental workload of drivers. This could be achieved through less loading, less working at anti-social hours, away from home or at short notice e.g. to fill in for sick colleagues. There will be reduced need for temporary staff, salaries could be improved through upskilling. One worker representative commented that drivers will no longer have to experience being robbed, injuring others / suicide attempts.

To achieve the potential benefits, extended or 24/7 operations afforded by automated trucks must not mean more personnel do shiftwork – "you can't solve the current personnel problem by saying some people have to work at night". This raises questions about how the safety of night operations with automated trucks can be ensured with minimal personnel, or who will pass orders to vehicle, who will fill the orders?

*UAR9 We develop new client-friendly business models such that logistics actors of all sizes can access the business advantages of automated truck. [**L100, T22, S19, L64, L58, L45, L113**]*

As stated under N3, logistics actors need information to assess TCO advantage/disadvantage. The high purchase cost of automated truck technology (higher costs through redundancy related additions to vehicle design) and CapEx for automated trucks could mean that new business models need to be developed through stakeholder analysis (who pays what, who need to change what, who earns what, who gets what benefit etc). Potential new business models are uber freight or capacity as a service, the operator as a service, and there may be investment opportunities in automated truck/CaaS developers, freight transfer hubs in combination with automated truck fuel/charging networks, or new-generation cloud TMS developers. Logistics service providers that can use automated truck for own-terminal network transport could consider cutting out any third-party carrier and dealing directly with manufacturer/automated truck provider who would execute the journey, to cut costs.

While largest logistics actors or terminals may look to partner with OEMs, build new ecosystems and upscale automated trucks internally, most are too small and have tight profit margins, and will need subsidies or incentives to invest in technology and competence needed to develop automated trucks as part of operations - especially if step changes are required. For management of a highly automated vehicle pool at port, a new entity - possibly a rental company – could be needed for distribution, operation and maintenance of vehicles, in which case terminals need a process to book what they need in advance.

Finally, the consequences for automated truck on warehouse and (port) terminal network design should also be considered in terms of effects on current business models.

Business models must be **client-friendly** in the sense that clients / shippers should not be faced with extra costs and demands (e.g. loading) that they do not appreciate the benefit of.

*UAR10 At our terminals we have standardized solutions allowing us to interface digitally and physically with different internal and external automated trucks, increasing interoperability and flexibility. [**L16, S29, L46, L132, L26, L35, S55**]*

Logistics actors want automated trucks that can be used flexibly, to pick up/drop off at various locations within and between terminals (own or clients'), across different operations, routes (public/private roads), trailers or load types and load handling procedures. There may also be a need to cope with diverse loading/unloading processes or levels of loading automation. This implies interoperable automated trucks with standardized technology for docking, loading/unloading, charging, battery swapping, as well as interoperable digital solutions for linking to management systems. This would reduce costs for logistics actors and leave them free to choose between automated truck suppliers. It seems inevitable, however that some existing solutions may not be compatible with automated trucks (trailers, swap bodies, containers, etc.), so some actors wanted to know which systems were likely to become the interoperable standard.

Also of interest:

- Actors wish to know what loading/unloading equipment, trailer access solutions etc. will be compatible with of the future so they can plan to invest in it.
- Forwarders need carriers to use interoperable automated truck systems - compatible with each other's and forwarder's systems.
- Digital infrastructure and IT system requirements at terminals that transporters need to comply with must be standard (analagous to toll systems).
- LTL carriers working for different clients will need very flexible automated truck solutions.
- Port terminals and other terminals need standardized external automated trucks so that they can use same system to interface with them all.
- Port operators need process for port access and situation awareness (with live tracking) on ingoing / outgoing trucks and their container number and cargo.

*UAR11 We make only gradual changes to the physical infrastructure at our terminals and can receive from the previous link or transfer to next link in the distribution chain, with few or no modifications to that link. [**L38, L47, L58, T35, T34, L39, L113, S31, L55**]*

Several actors wanted automated truck solutions to cope with their existing infrastructure, which in some cases was a complex busy terminal environment in which driverless automated trucks must be able to "see round corners, behind stacks". One actor did not think it was possible to dedicate a lane for automated truck use at terminal, because the environment was too busy. At their production terminals, automated trucks need to fit as much as possible with existing traffic (i.e. must operate in mixed traffic) and and the physical, digital and operative infrastructure and procedures. Ideally they would replace existing tractors with autonomous ones that run on the same physical infrastructure as now, so autonomous trucks would need to be able to reverse and turn left etc. In contrast a representative for a logistics company with a more structured and predictable warehouse operations did not think dedicating lanes to automated truck operations or making simple modifications to signage, for example, would be a problem. So there seems to be a variation in willingness to change terminal infrastructure depending on the nature of the existing terminal operation.

One actor represented that changes could not be made for handover to manually operated trucks or vans for last-mile delivery into the city (e.g. supermarket delivery). Another stated that automated trucks would ideally be compatible with the operations of third party carriers (where they are needed to increase capacity), without requiring changes to third-party systems. For some actors at least automated trucks "need to deliver in the same way as the old vehicles did", so companies can "use the same kind of KPIs and have the same kind of reliabilities".

There seems to be a need for technologies that can automate significant chunks of current operations, without fundamentally changing current operations. Gradual change is desired, with clear steps that logistics actors can plan to integrate automated truck with PDI at different links of the transport route, including cross-dock/consolidation from container to pallets, from 44 t automated truck to 3,5 t manual truck for city legs, and to manage the needs and actions of multiple players.

For long-haul transport, fully autonomous trucks must not have low interoperability between modes (causing "differential operational instances") or reduce flexibility in choice of route on longer trips.

*UAR12 We and our clients find that automated truck systems are flexible and adaptive enough to provide on-time deliveries consistently. (***L43, S16, L91, L7, L22, S23, L5, S22, L45, L61, L84, T23, L89, L102**)

Logistics actors want to know that highly automated trucks will not be so slow that they reduce transport times at or between terminals or annoy other road users, because they stop too often, cause stoppages, default to "slow mode" or are unable to cope with situations that conventional trucks already deal with: variable lighting, extreme weather, complex/new traffic situations, or obstacles in the road, and so on. At terminals one representative expected some failures but emphasized a need to know how to understand and manage them with e.g. on-site manual override function for transit or cargo loading operations or to steer to safe parking area on technical failure ("minimum risk manouver"). One representative highlighted a need to prioritize automated truck at slip roads, roundabouts, junctions in terminals and on public roads, due to a possible "politeness" problem – i.e. people will be reluctant to let a highly automated truck into the flow of traffic.

The implication is that autonomous trucks need to anticipate roadworks or queues, get round obstacles and choose alternative routes to protect delivery times in the event of incidents or traffic flow problems. A good support infrastructure will be needed to avoid human intervention in the event of unplanned stoppage to protect delivery schedules. Actors seemed uncertain if increased specification and organisation of streamlined systems would give the requisite flexibility or decision-making power to cope with the variety of situations drivers normally face.

*UAR13 We develop processes such that automated truck and interfacing systems execute all process steps safely at terminals [**L107, L19, L88, L120, S76, L106**]*

One actor stated that the highly automated truck would need to come with a guarantee it will execute all required process steps safely and correctly. Others pointed to a need to support automated trucks as part of a safe system with overhauled rules, procedures, technology and infrastructure that ensure safe interactions and processes and establish adequate situational awareness in people operating and interacting with the automated truck. As part of this, automated trucks must comply with road rules or local safety rules or other regulations at terminals or port roads. Road users, crane operators, forklift operators and other staff and visitors (including foreign language speakers) at logistics / clients' terminals must have adequate situational awareness of automated trucks while they are parked, driving or maneuvering ("what is it doing now, why, and what will it do next"). This may involve attending to external HMI and use of geofencing. A well-designed interface for remote operators overseeing or assisting operations will be required.

*UAR14 Our automated truck systems allow us to reduce noise and cut CO2 emissions. [**L27**]*

Several logistics representatives stated that highly automated trucks presented leverage for increased electrification of truck fleets. Information about potential emission cuts is needed based on life-cycle analyses.

*UAR15 Integrating our transport operations does not mean that our business outcomes are unduly affected by unstable digital systems or cybersecurity risks; use of automated truck does not make our vehicles or cargoes less secure. [**R60, L81, L82, T70, S14, W4**]*

Here "operations" are likely to involve digital integration of the transport function with port, fleet and logistics management systems. Some actors wanted to know how to protect cargo physically from theft, whether the automated truck and its load could be made tamperproof or immobile. Gate processes and geofencing are important to access security and preventing automated truck from "being driven" digitally to an unplanned destination. One representative meant that the automated truck should come with advanced security features (sensors, cameras, real-time monitoring) and warn teleoperators of threats to security.

*UAR16 Our employees and clients understand, accept and trust automated truck technology. [**L2**]*

Understanding can involve a role-appropriate working mental model, giving people the insight they need to gain situational awareness of the automated truck, which itself should also be "explainable", appropriately supported and easy to use. There were comments from several representatives that employees feel their jobs are threatened by automated technology, which could lead to reduced trust and accept.

*UAR17 On automating vehicles and systems, we can account for all tasks previously carried out by drivers and other people in the system, reallocating them to technology or other roles; effects on liability are considered. [**L59, S76, L31, L49, L123, L4, T23, L92, L105, L109, L110**]*

Several representatives highlighted the need to account for all tasks that drivers and other employees perform before attempting to automate. They need to see that cognitive and physical operations and tasks achieved by human interaction and control in existing systems are fully understood and reallocated to new roles (e.g. remote operations) or technology (e.g. digital document transfer). Drivers will be essential in imagining the situation whereby an automated vehicle is active in a logistics operation and then see what sort of things are encountered in order to make it work. Finally, this requirement also includes a need to know which person or organization is liable for cargo (currently with carrier), at what point in operations cargo liability transfers, that there are processes for this, and it clear who is responsible for what in relation to inspections.

The following is a list of some of the driver tasks mentioned in interviews that need to be considered:

- Customers
  - Respecting customer expectations and finding workarounds to satisfy customers, adjusting delivery times to suit customers
  - Problem-solving for customers
  - Maintaining business/social relations with customer
  - Helping customers with informal tasks
  - Informing customers e.g. about how goods are sorted on truck, incidents en route
  - Relating customer needs to managers
  - Loading, unloading or carrying for customers
- Checking and controlling (tyres, brakes, warns of delays, quality of goods before validating receipt, checking number of pallets tallies with order)
- Dealing with traffic emergencies or tipped loads
- Sensing tipping, road friction
- Providing diagnoses, prognoses for technical problems
- Clearing road
- Fixing technical issues
- Deterrent for thieves, contraband, stowaways
- Connecting containers to tractor/warehouse
- Charging/fueling
- Check truck and cargo are roadsafe before departure
- Checking oil, loose straps that must be tightened
- Cleaning sensors
- Putting on chains when icy weather
- Identifying need for, planning and driving alternative routes, choosing to deviate from advised routes to avoid schools, or noise in neighbourhood late at night,
- Gathering information from other drivers via chat etc.
- Checking cargo integrity, temperature
- "Feeling" and reporting likely effect of abrupt stops and turns on cargo
- Checking light cable, air cables
- Opening tail lifts, doors, landing gears,
- Logging subtle cues indicating technical issues
- Exchanging paperwork when entering / leaving a site
- Closing and opening twist locks, opening trailer doors, cooperating with inspectors
- Connecting and disconnecting the tank container to filling station
- Placing and removing of stopping blocks under the trailer
- Announcing arrival at terminal with CargoCard – a "triggering of the logistics process" at yards or terminals.
- Adjusting the chassis (for 20ft or 40ft containers)
- Putting stickers on the container
- Adapting at controls "In approximately 20% of cases exceptions occur and truck drivers have to get out of their cabin to obtain/ exchange additional paperwork and/or certificates"
- The truck drivers are the "eyes" on the terminal, e.g. via a "dead man`s switch" drivers indicate to cranes at the stack that containers can be put on the chassis
- Regarding long-haul automated driving on highways and in hub2hub transport, the "eyes" of the truck driver are needed to make vehicle checks, fix flat tyres.
- Customers can ring drivers to find out ETA, will need to be at least as satisfied with new automated systems
- Provide proof of delivery at agreed destination for insurance purposes (e.g. take photo of cargo with mobile phone).
- Replanning and adaptation: "We need good processes and planning so that operations at more dynamic terminals to account for loss of adaptability of drivers."
- How contracts and agreements will be made? For example, can receivers reject an automated (or remote operated) truck at the gate?
- Port/yard workers must be able to communicate with the automated trucks without a driver inside. Do they need to contact the control tower and/or should they be able to digitally get info by using phone/device to take photo of QR-code or RFID on the vehicle?

*UAR18 Our/clients' terminal, fleet and logistics managers, logistics platform provider, forwarders get logistics information and real-time telemetrics and about the automated truck, trailer and load, including warnings about maintenance needs or delays, so they can plan and adapt. [**T39**]*

Fleet managers are interested in e.g. information on battery/fuel level, tyre pressures. Terminal managers are interested in automatic warning from automated truck (e.g. via FMS) on stoppages with reasons, upcoming need for vehicle charging or maintenance. Others in the logistics chain may be interested in cargo state or progress/delays. Preferably the vehicle would be able to charge, maintain or fix itself automatically.

*UAR19 Our managers, operators and clients can easily plan for, deploy, manage, maintain and operate automated trucks. [**L116, T28, L79**]*

Truck operators need to interface with information from vehicle, road or other sensors in usable and useful way. This will require a well-designed human-machine interface for the operator overseeing the operations so that they can keep track of the operations done automatically. This requirement also implies successful integration with FMS and LMS so that human operators can oversee maintenance, dispatching etc.

*UAR20 We can assess the effect of on costs, efficiency and productivity using measurable parameters. **[L25, L12, L13, L2, T24, T32, L32, L33, L59, L61, L83, L96, L104, S30, L56**]*

While representatives for some (larger) logistics actors seem to want to drive change and learn about value by becoming involved in pilots with automated truck providers, others would like a roadmap on technology readiness, how viable use areas for automated truck will develop, evidence that L4 trucks can improve their business outcomes, and information on time for implementation and scalability. An ability to compare highly automated trucks with existing trucks on key operational measures would seem important, e.g.

- delivery times
- time used for loading
- time for procedure at origin
- time for unloading
- time for procedure at destination
- driving time
- payload
- damage to goods (nr, frequency, relevance)
- damage to vehicle (number, frequency, relevance)
- maintenance (frequency, relevance)
- insurance costs.

Actors need competence, tools and information to assess the cost-benefits / ROI of automated truck and any accompanying value-chain PDI (logistics and fleet management systems; dedicated lanes at terminals) changes required. They need to know which characteristics give existing use areas and operations potential for increased business value through automated truck solutions, and how eventual integration with existing or new digital/automated systems could be done in order to fully exploit the potential of automated truck solutions in logistics.

On assessing effects they need to know which use areas are most likely/unlikely to be viable first so they can plan for their unique operation and context (LA are diverse), they need to see how highly automated truck accounts for their economic reality (especially SMEs). While actors can accept that whole logistics chains cannot function without drivers in short term, and that L4 should be considered as driver support in a first phase, they might need to see that driver can be replaced in second phase on major legs of transport in order to start planning and implementing automated trucks.

Concerning remote operations, some actors will be reluctant to hand over control of remote operations to a third party - especially if this costs money or time - as they see this as part of our logistics role.

Actors see human drivers as hardest to replace in urban logistics where people are better than digital solutions on routing in real life and where there are many variables to be considered. National chains delivering to cities might therefore look first to standardize automated truck delivery from warehouse to ring for cross-docking with standardized solutions.

UAR21 We can train, recruit or otherwise have access to the competence needed for repair or maintenance of automation technology, for remote assist/driving operations, for re-gearing logistics and fleet management systems, and for *exploiting new possibilities from 24/7 driving in systems that are less dependent on human control and interaction. [**S7, T48, S40, L34, L60, T64, L122**]*

Logistics actors need to be able to recruit or train current drivers as support drivers using L4 automation, as remote operators, to work at staffed transfer points, as automated truck maintenance or call-out personnel, or to do more challenging driving (e.g. exceptional loads) or back-office tasks. Solutions that simplify integration of automated trucks in logistics systems would be useful, so that the competence we need to loan, hire, recruit or train for establishing seamless logistics is limited.

Nationwide logistics actors might consider integrating some aspects of remote teleoperations with existing national fleet monitoring but will probably look to outsource safety operations. Remote operations need to be included as part of new business models. Ownership of control towers, responsible for management, monitoring, predictive maintenance scheduling, etc., should be clarified and services interconnected with carriers' traffic departments for proper coordination of services.

Annex 8: Technology developer aggregated requirements (TAR)

The notes attached to each aggregated requirement derived for technology developers (OEMs, CCAM / signal-from-road providers, connectivity providers, mappers) are derived from the full set of 72 unaggregated Requirements. Codes in bold denote original Requirements from which each aggregated requirement (AR) is derived.

*TAR1 We can use L4 automation to leverage new business opportunities. [**S66, T56, S6, S63**]*

The emerging technology will disrupt, creating new roles and business models. Human intervention (mainly the driver, normally part of the haulier's staff) will not be necessary to the same extent, so that the operation of the vehicle can be "delegated". Technology developers see opportunities for new business models e.g. automated truck providers who also execute transport as a service themselves, or who park automated truck tractors for hire at charging sites, owners can sell data collected from automated truck to help make high-quality maps for less. Change of truck ownership or ways of using trucks will require clarification of tasks or elements for which users will be responsible.

*TAR2 We can start to evolve logistics through the use of automated trucks in routine, predictable, low-interaction use areas where automated trucks have the greatest potential to increase efficiency and productivity. [**T2, T27, T11, T12, T26, T41, T42, T47, T57, T61, L77**]*

A main aim for OEMs and other developers of automated truck technology are to mature the technology such that enough logistics see that they need automated trucks in order to compete. Regular, routine, predictable, low-interaction operations (simplest ODD) performed with a relatively simple sensor/radar set were seen as the most high-impact, feasible near-term use areas for automated trucks, and would also make automation of surrounding operations simpler – they may therefore need to be prioritised.

To evolve logistics, technology developers might also need logistics actors to consider new models, change location of assets or operations to exploit near-feasible use cases - this could mean running highly automated trucks in dedicated lanes between assets; In drayage situations it might be feasible to make a high quality dedicated track for 24/7 automated trucks.

OEMs we spoke to were reluctant to work on more complex parts of logistics chain such as last mile urban deliveries, although this is might in part be due to the large size of trucks being automated in MODI.

It is important for technology developers to know which segments of value chains need humans and which can be automated (link to UAR17).

One representative claimed that ports are complex situations in which to implement automated trucks, require specialised automated truck with limited sales potential (units to be sold), and here infrastructure-based automation is more feasible. The advantage of terminal usage is that only a confined area needs to be considered and the onset of 5G connectivity in some ports makes them attractive for automated truck trials. In comparison ODDs involved in hub-to-hub solutions are more open but they can be simple. They may require, however, human drivers for first/last mile between hub and parking place near motorway (but drivers could work nearer home). Hub-to-hub cases would require operation in mixed traffic, conditional on dedicated lanes and some limited changes to infrastructure (e.g. line continuity, sensors, possibly extension of dedicated lane from highway to freight village).

One representative stated that different vehicles and technology are needed for highway vs. operations on logistical network roads or terminal yards, since the technology for highway driving will likely not be sufficient for the complexity of yards or logistic network roads, in which several junctions and crossings may be involved.

Some automated truck solutions will require drivers, but the main goal for technology developers is driver out.

*TAR3 Driverless trucks can be made smaller, electric, lighter and more aerodynamic to improve the value proposition for logistics actors who are looking to reduce emission levels and energy use, and road users looking to improve safety. [**T1**]*

*TAR4 We can develop the automated truck technology to handle more complex operational design domains, making advanced business cases feasible, by testing, getting feedback from the vehicle, operators and stakeholders, accounting for the behaviour of other road users, accessing external data and making advances in sensor and connectivity technology. [**T5, T4, T13, T17, T20, S10, S12, T29, S38**]*

Bot technology developers and subject matter experts stressed the need to develop technology, so that automated trucks can for example:

- adapt to merge into traffic streams, especially across lanes
- travel at speed in keeping with traffic flows / expectations of logistics actors
- handle diverse/new objects in the road
- handle extremes of weather and lighting conditions
- discern real objects from pictures
- cope with uniform environs (tunnels)
- drive in mixed traffic, with VRUs around the automated truck
- operate with less energy demand from computing
- navigate in cities
- account for the unpredictable behaviour of other human (and technical) road users
- be monitored and assisted remotely with sufficiently low signal latency.

Some of these developments require in turn developments in sensor technology, processing power, and 5/6G connectivity. Data from the vehicle (e.g. performance in changing weather/situations) and feedback from users and stakeholders would progress technological improvements, and this in turn requires pilot projects. One representative highlighted the need for a living lab enabling automated truck testing while being able to control parameters, gradually "complexify" the situation and prove the feasibility of advanced business cases. This implies the need for automated truck testing and evaluation in real logistics systems.

Technology developers can also progress by mapping, understanding and developing solutions for situations in which human driver/operator needs to intervene; or by tracking vehicles on size of deviations from intended path (sit in lanes well). Signal-from-road providers need to learn how to instrument tunnels. Developers also point to a need for dynamic data they can use to inform the automated truck about collisions, emergencies or other changes to the environment, in order to sufficiently develop their technology (see TAR5).

*TAR5 We cooperate with each other and with public data owners and regulators to give teleoperators, fleet managers and fleet/logistics management systems information from the environment (weather, route sensors, closed roads) and vehicle (telemetry, cargo data); and to enable logistics actors and road operators to send instructions to the vehicle. [**T24, T38, T49, T54, R107**]*

To develop automated trucks as part of seamless logistics with increased value for logistics actors, technology developers need cooperation and time with different chain actors. Several mentioned that they need to track automated trucks on vehicle progress, give warnings on traffic disruptions, traffic cameras, but data protection issues can be a hindrance. Mappers expect automated truck manufacturers / users to share data they can use to update maps, assuming automated truck will be able to generate sufficient coverage. Importantly, there is a need for road authorities/operators/owners, mappers, OEM or other data providers to work together on developing **standard joint data exchange interfaces** for V2X connectivity and two-way data flows.

*TAR6 We need models for legal and operational handover of remote monitoring and assist, and models of working that give teleoperators adequate situational awareness to monitor several trucks and assist when needed. [**T51, R82, T71, R61**]*

There is need for technology developers, regulators, researchers road operators with traffic control centres and logistics actors/ fleet operators to work together to explore and develop models for the legal and operational handover between interoperable remote-control towers within or between municipalities and countries or between private and public roads (e.g. from Sweden to Moss havn). More fundamental questions may also need to be answered: Where will the "towers" be? How many will there be? Who will run them? How? Is there a need for an overseer of different automated truck fleets? Developers would like to see regulatory challenges related to remote teleoperators in one country controlling automated truck in another resolved. How will operators be licensed and who will educate them? To ensure safety and avoid congestion, remote control operations shall not limited by signal latency or reliability; and should receive a feed that is sufficiently detailed and reliable so as to ensure the robustness and function of each automated truck being monitored or assisted remotely.

*TAR7 We need cooperation and efficient and harmonized processes for testing automated trucks in different use areas and for developing internationally coherent and standardised roads and regulations. [**T6, T7, T8, T10, T15, T16, T18, T26, S2, R27, L64, T69, R83, R98**]*

Developers expressed frustration in being able to get permits from road authorities for automated truck operation in confined ODDs, to be able to test to validate / develop safety that road authorities need to see before they will start work on necessary EU regulations. Slow processes or lack of legislative policy to support automated trucks in EU can slow down and restrict testing. Developers also see that regulators are reluctant to change the rules of the road – but anticipate that road markings and signage will have to be adapted. There is need for regulatory frameworks that support automated trucks such that developers know that the potential of automated trucks will not be limited, for example by restrictions on trucks on key roads at certain times of day or week.

Developers want also

- to be able to test the safety and performance of automated trucks against measures that road authorities agree are important
- to know that road authorities will invest in and harmonize infrastructural changes now to prepare for a future with highly automated trucks
- road authorities to develop/identify high-quality simple stretches of roads that are interesting for logistics actors.
- to work with regulators on the need for procedures for "what-if" routes (e.g. where automated trucks may need to break road rules by speeding to avoid a risky situation) or cross a line to avoid object in road. (Road authorities would like automated trucks to fit in with normal truck traffic but this could mean breaking the highway regulations!)

One representative stated that developers can take risks to develop technology and drive change but public-private collaboration required to achieve societal and economic/business goals. Amongst other things this requires that authorities nationally and internationally work together to develop standardized supplier-independent PDI that enable automated trucks to be used everywhere and which produce predictable road-vehicle interactions / variations on data coverage and quality between countries on weather, road status.

Regulations that encourage electrical trucks would also motivate investments in automated trucks. Different countries need also to agree on standards for maps and GPS coordinates.

TAR8 *We need adaptations to the physical infrastructure to enable and expand use areas for* automated trucks*. [**T9, S3, S8, S9, T25, T30, T62, T52**]*

Developers may require changes to the physical infrastructure at terminals with automated loading/unloading, to enable effective and efficient coupling. Port/road operators or terminal owners may also be asked to make and maintain infrastructural adaptions such as regularly placed sensors in road (e.g. every 250 m for ML algorithms to predict traffic flows), dedicated lanes, high-quality asphalt or lines, add or modify road-signs or symbols, or improve line and lane continuity or so that the vehicle can handle merging situations or drive on-off motorway. There may also be a need for regularly placed safe stopping places or mode transition zones for automated trucks. Developers also need to work with road operators on using road sensors to remove limitations of the vehicle sensor suite's ability to handle spiralling roads, blind corners, or sudden rises or falls. In uniform environments road operators may be asked to supplement roadside furniture with symbols or reference markers or barcodes on the wall - especially those with GPS differences like tunnels. Generally, a more continuous, dedicated, sensored or increased quality road environment is desired. Although L4 technology cannot depend on infrastructure if it is to work everywhere, changes to infrastructure can simplify the problem faced by L4 technology developers, and especially if they can be used by different vehicle operators. Simplified infrastructure / dedicated lanes could also enable highly automated trucks at night and passenger AV in the day. Developers may also need to develop road sensor maintenance standards with road operators. Finally, an emission-free charging / fueling infrastructure will also need to be in place that can work with highly automated trucks.

TAR9 *We can develop adequate, reliable and internationally coherent satellite and terrestrial connectivity for automated truck operations. [**T14, S64, L80, T50, R61, T65, T66, T68, T67, S37, S36**]*

Connectivity providers need to be engaged to develop 5G or 6G for V2V (ensure safe braking), V2I, V2Cloud, for higher data rates and lower latency than previous wireless networks = better safety through faster transfer of data for decisions, reduced computational load on vehicle, improved navigation and situational awareness to navigate more complex environments. Developers need a coherent, harmonized connectivity across borders for international automated truck use to be achieved through cooperation of providers from different countries authorities and connectivity providers to plan for completely reliable cross-border connectivity.

A representative of one connectivity provider underlined a need to consider whether dedicated connectivity would be needed to ensure adequately robust and reliable connectivity for automated truck – so-called network slicing: We need to provide automated trucks or AV with an exclusive 5G/6G network to ensure reliability since automated trucks must work all not most of the time, and there is a need to ensure that the automated truck onboard system knows where the automated truck is located within an operational geofence at all times. In particular, remote control operations cannot be limited by reliability, or signal latency, and need a detailed feed to ensure the robustness and function of the truck.

Developers also need to help authorities or decision-makers consider ROI and who will pay for costly 5/6G connectivity that may need to be exclusively available to automated trucks - what is the business case? Will society pay to get the benefit? Costs will vary by area in terms of achieving global coverage necessary for resilient, robust automated trucks in areas with poor wifi/terrestrial coverage; for weather and traffic information; for global positioning for navigation.

*TAR10 We have the data we need to develop regularly updated, accurate and standardized HD digital maps (local dynamic maps) for automated truck operations. [**T19, T47, T31, S47, R72, R83**]*

Autonomous trucks need regularly updated, accurate and standardized high-density digital maps. Local dynamic maps are a static map with layers added on top to position objects of interest, boundaries for digital traffic rules, and information about road condition, lights, signs, weather, hindrances. Developers need access to solid HD maps and reliable and accurate internationally standardized data from different private and public parties to construct highly accurate dynamic maps covering wide areas. In return for providing developers with the data they need for 3D maps (static maps, object or traffic rule layers), road operators could receive more regularly updated HD maps (e.g. every day instead of every year). Developers need different countries to agree on standards for maps and GPS coordinates.

*TAR11 We can conduct customer journey mapping of use cases to test latency and network stability and check more unusual connectivity usages. [**T69**]*

Building on the issues discussed in TAR10, there is a need to test whether connectivity is adequate for automated truck use in real logistics operations, and whether any less than normal connectivity uses (e.g. video feed or other data from vehicle) may strain the network.

Road authority / owner / operator requirements

Annex 9: Road authority/owner/operator aggregated requirements (RAR)

The notes attached to each aggregated requirement derived for Road authorities / owners / operators are derived from the full set of 121 unaggregated Requirements. Codes in bold denote original Requirements from which each aggregated requirement (AR) is derived.

*RAR1 Automated trucks must remove human driver limitations and reduce the number of operator transgressions and serious injury collisions compared to standard trucks. [**R1, R3, R12, R20, R26, R45**]*

Road authorities want data to support that L4 automated truck with safety driver or remote assist will reduce the number collisions with serious injury outcomes involving trucks in the ODD in which it will be used, in comparison with trucks with lower automation levels. There should be fewer or no transgressions performed by the automated truck system and its human operator(s). There should be no speeding, dangerous driving or risky maneuvers, and human monitors or operators should not be fatigued or under the influence of drugs or alcohol. Since many collisions can be linked to human driver limitations e.g. fatigue, DUI, speeding, attention, they should be reduced. The absence of "driver in" enables the design of lighter vehicles that exert less force and give way in collisions with VRU, so injury outcomes should also be improved. Automated trucks should be involved in less near miss or hazardous situations than trucks with human drivers.

*RAR2 We understand the interactive effects that introducing highly automated trucks, associated PDI and regulatory changes into existing traffic systems has on safety and traffic flows so that we can mitigate new safety and congestion risks from automated trucks in traffic. [**R11, R2, R28, R44, R52, R64, T55, R61, R8, R62, R82**]*

New risks can be created from e.g. increased traffic volumes (more vehicles on roads, decreased distance between vehicles), congestion caused, or effects of altered “new vehicle behaviour” or PDI on other road users (e.g. wide berth on overtaking, automated trucks drive at speed limit in roundabouts, nobody lets automated trucks into traffic causing congestion (“politeness problem”), unpredictable abrupt stopping, lack of social negotiations in traffic, too slow driving for speed limit / conditions). They want to see that highly automated trucks can handle normal complex "social" traffic situations involving interactions with human road users such as braking for (real) obstacles, pedestrian crossings, roundabouts. Interactive effects of automated trucks in mixed traffic should therefore be understood and accounted for, and they expect that trials of one or two automated trucks, consider the ramifications of having many more automated trucks operating.

Road authorities want to see that new PDI does not reduce safety for human drivers before it is rolled out, and how to keep other traffic from using lanes dedicated for automated trucks. They want to know that new PDI and roll-out of automated trucks increase not reduce traffic flow and reduce delays for other road users and cargo thus increasing road capacity/efficiency and reliability. Effects of increased numbers of automated trucks queueing around charging stations should also be considered.

*RAR3 Society, human road users and transport company/terminal workers see, understand, trust and accept highly automated trucks. [**R5, S41, R126, R53b**]*

We should know that society, human road users and transport company/terminal workers feel safe in traffic with automated trucks, because they trust and accept automation technology; they have a simple, correct mental model of how the technology works and its abilities and limitations; the technology is usable, visible, predictable (external HMI) and reliable in practice, and useful (beneficial for society). This will require transparent systems and openness and honesty about the technology from automated truck suppliers and logistics actors. We know that automated trucks will not decrease traffic flows and acceptance by other road users by operating at lower speeds in mixed traffic. To maintain trust, citizens should be informed of what is happening before highly automated trucks is implemented in their society. Other road users should know that a truck is automated and have adequate situational awareness of automated trucks.

*RAR4 We assess effects on land use by reducing curb and parking spaces taken by trucks vs. the need for more parking areas or more hubs or load transfers for last mile deliveries. [**S71, R9, R13, R105**]*

Municipality road owners want to see that automation technology reduces parking. loading or waiting transgressions and therefore congestion on perimeter roads, terminal roads etc. The net effects of automated trucks on land and energy use should be assessed, e.g. need for more parking areas or more hubs or load transfers for last mile deliveries.

RAR5 *We can meet sustainability goals by introducing automated trucks to reduce vehicle energy use, NOx/CO2 emissions and noise from heavy vehicles, accounting for life cycle aspects and PDI developments; and we can maintain or improve traffic flows, safety and emission levels while increasing road capacity. [**R30, R70, R78, R33, R51**]*

In return for any infrastructure changes, road operators expect more efficient use of the road network -- better capacity -- from less stop-and-go phenomena, closer safe driving distances, fewer trucks using roads in rush traffic since they can operate 24/7 (applies also to port road networks). It is expected that these effects are stronger on roads where larger shares of vehicles are trucks. Toll road operators are interested in generating increased income by dedicating lane for overnight use by automated trucks, due to backfilling during day. Road authorities need to help develop regulation needed to support potentially positive effects of automated trucks on daytime traffic volumes or emissions.

RAR6 *Automated trucks have technology or support processes so that they function to increase safety and traffic flows despite challenges of the road network and weather conditions of different EU/EØS countries. [**R25, R63**]*

Countries with particular road network characteristics (e.g. Netherlands dense network, many port roads; Norway many tunnels, tight bends and inclines) or geography or climate (e.g. winter driving conditions in Scandinavia) might require more extensive testing of automated trucks before roll-out, and may require more support from infrastructure (e.g. more sensors in tunnels) or maintenance (snow-clearing of road sensors).

RAR7 *We are warned of truck stops, can monitor assists and receive data for accident investigations and infrastructure improvements; remote monitors must receive data needed to ensure the robustness and functioning of the truck. [**R4, R56, R48, S49, S63, R91, T58, R88, R142, R18, R42, R80, R89**]*

Road authorities need digestible real time and historical data from automated trucks, e.g. for the creation of braking/swerving "heat maps" or queuing for road investments/improvements, optimization of salt use. They can learn about missing signs from differences between HD maps and perceived objects. Remote assist must receive the detailed real-time data it needs for continuous monitoring to ensure the robustness and functioning of the truck, and road authorities would like to see operator response time to incidents involving automated trucks measured - how long before blockage removed?

The road operators' traffic center shall be warned immediately that an automated truck has stopped due to engine/tyre/brake/cargo trouble.

Need to think through how traffic management by road authorities might change e.g. visualize and respond to vehicle movements in real time.

Port authorities need traffic management system for automated trucks using its roads that coordinates movements for optimal flows.

RAR8 *We have an open dialogue with harmonized manufacturers on data we could provide (digital signage, regulations) for automated trucks to ensure efficiency, safety and traffic flows; in return we can direct the automated truck, control road accessibility, flexibly set maximum speed limits and orchestrate traffic flows. [**R36, R49, R140, R48, S49, R50, S45, S59, R35, R46, R74, R77**]*

Public highway authorities have an open dialogue with harmonized manufacturers on data they can provide for automated trucks onboard client or FMS to improve road safety and flows. Data supplied could be on planned changes, information that roads are clear of snow, state of road network, hazardous incidents, weather, route planning, road characteristics, friction, speed limits (variable) or other "digital road signage", advisory speed limit, queues, adverse weather, lane closure, roadworks, obstacles and so on. Standard data format and criteria and provisions for reliable, robust data supply should be developed. AVs should behaves appropriately given data received but should not depend on it for safety. There should be redundancy, since road authorities will not be responsible for data flaws. Likewise, road authorities need know that the truck will stop safely or safely transfer control to an alert human driver when safety in the operational geofence is not guaranteed (RAR9).

Road authorities support orchestration (e.g. V2V connectivity) of automated trucks that helps traffic control centres manage traffic flows and incidents. Port road operators expect to be able to direct vehicle successfully. If road operators discover that a road is not drivable (e.g. flood) they want to be able to withdraw digital permission for vehicle to drive. Road authorities could discuss considering digital speed limits that match optimum energy use by engine. Super-control of different remote operations of automated trucks using the road might be needed and will require open data sharing from manufacturers and truck operators, probably regulation for this too.

*RAR9 The automated truck always stops and transitions between automation levels safely, responds appropriately to incidents in the road or approaching emergency vehicles. [**S42, S53, R10**]*

If in difficulty the highly automated truck needs to stop in a way that is safe and predictable for other road users, does not cause congestion and parks in a safe location. Transitions between manual and automatic operation also need to happen safely. Road authorities need to know that autonomous trucks will not stop in road, or otherwise cause congestion when faced with harmless objects (dead birds, becomes "tricked" by e.g. oil spills) or due to technical faults, weather or unusual traffic situations, such that they cause hazards or congestion to other road users.

*RAR10 We have procedures for traffic and cargo inspections, controls and border crossings that work for automated trucks and are at least as efficient and effective than those for traditional trucks. [**R41, R128, R15, R17, R47, R50, R58, R65, R68, R74, R108, R55**]*

Road authorities need to be clear about the legal requirements for automated trucks, expect manufacturers/operators to follow them and can check them. Road authorities need to receive vehicle data from companies to simplify inspection of vehicle maintenance and safety standards – and this may become enforced by legislation. Customs may also need to interface with, control and access the automated truck. Authorities need to be able to locate, communicate with / interrogate and direct the autononomous truck, and get the digital information and physical access they need to inspect the automated truck and cargo at borders or control stations. It must be possible to stop the truck in order to check it. Remote interrogation should result in relevant, digestible information (e.g. dashboard) the content of which should be developed with authorities. Examples are company safety record, vehicle inspection history, type of cargo, cargo owner/supplier/customer, mode, technical status, origin, destination, disengagements, hard braking, speed.

Authorities should take the purpose and functions of the border crossing and inspection stations and translate them for automated trucks in development with stakeholders with reliable processes for information exchange (e.g. between customs, the customs broker, importer and exporter) and physical checking. At inspection stations they must be able to talk to a person who is responsible for and has situational awareness of the vehicle and contents as and when we need to.

Road authorities should be able to withdraw digital permission for the vehicle to drive.

Traffic police should differentiate and target addressing and controlling of AVs vs. human drivers.

*RAR11 We understand how knowledge, skills, roles, responsibilities, sensor/data possibilities and needs for information and data integration will change our traffic centre operations and call-out/rescue and emergency services, who each have information and contingency procedures they need to deal with incidents or road diversions involving automated trucks, and can always access a person who is responsible for and/or can control the automated truck/load. [**R16, R21, R22, R31, T31, S40, R66, S15, S25, R53a, R14, R15, R17, R47, R50, R58, R65, R68, R74, R108, R55**]*

Contingency procedures may need to be overhauled to account for fully automated trucks in breakdowns, tunnel fires, floods etc. including insurance clarification. Criteria might need to be developed for when autonomous trucks can attempt to evacuate from tunnel fire. The road operator's traffic control centres might need to develop new diversion processes by sending data to autonomous trucks on stationary/mobile roadworks, lane/roundabout/road diversions; they need to know what to do when an autonomous truck cannot be diverted outside of its ODD. Traffic control centres and other call-out centres need to be warned of problems and be able to contact a person responsible for autonomous trucks. Road operators need to have analysed system scenarios and mitigated risks e.g. need to open dedicated lane when crash in non-trucking lane. Information will be needed on hazardous cargo. Responders may need to communicate with remote assist through the vehicle.

*RAR12 We consider any role we might have in helping remote assist centers ensure safe and robust system of feedback and control processes, and in developing certification/permits to operate autonomous trucks remotely – also accounting for cargo. [**R67, T58, T37, R101**]*

Road operator need to be engaged in the development of remote assist centres, to understand how they will work alongside their own traffic control centres -- data sharing, flows, procedures. For example, if a truck is controlled remotely after an incident, the road operator needs to know that safety is ensured, and that the remote control has full situation awareness of site events (e.g. oil spill) and does not interfere with operations on site - this will require cooperation with traffic control centre on other traffic. ("In case of an obstacle, the most difficult part for the autonomous vehicle is to check if the environment is safe (that is why you would need a human being) so you need to have a way to collect data on the environment and traffic around." As a result of this work regulators and authorities will have a better understanding of needs for certification or qualifications required by remote operators and/or remote operating systems, to inform any issuing of permits. Advanced permits may be required for remote operations of oversized or hazardous cargo.

*RAR13 Risk management is needed along with any mitigating measures and procedures to control any effects that loss of data security or connectivity have on traffic safety and congestion; and to prevent terrorism, contraband, stowaways, trafficking, theft, vandalism. [**R52, T68, R59, R37, W9**]*

There is a need to develop necessary regulations on cybersecurity affecting autonomous trucks, they need to be implemented and controllable and ensure secure V2V, V2I and V2TCC connectivity. These should encourage understanding and mitigating the risks (probability and consequences) of data / connectivity systems needed for autonomous trucks / other AVs dropping out or being sabotaged. Work must be done to understand and mitigate any system-level risks (assess risks in interactions between components, not just individual components). Opportunities for or consequences of terrorist attacks should be reduced and there should be no increased risk of harm in society, due to e.g. cyber-attacks or GPS spoofing.

*RAR14 Regulators develop and apply internationally standard regulations on who is legally and liably responsible for the behaviour, state and content of the vehicle, its technology, quality of data/connectivity provided, data protection, and cargo in different situations of different ODDs in which the automated trucks will be used. [**R32, L114**]*

Clear delineation of legal responsibility and liability of teleoperators, on-site AV operators, automated truck owner, data providers, infrastructure providers is needed for different modes and phases of automated truck operation. Who will be liable for collisions or inspection outcomes? "The entire legal path is important". This concerns also new players eg IT manager, OEM. Ideally there should be EU-wide agreement on responsibility.

*RAR15 Authorities work internationally with harmonized manufacturers and road operators to learn from demonstrations and overhaul standards, rules and regulations on road, vehicle (type approval), road users, cargo-handling, connectivity and data protection in a case-independent way to ease cross-EU functioning. [***S5, R52, R39, S27, T63, R87, R100, S28**]

Homologation. Regulatory overhauls should account for vehicle technology modifications and maintenance (e.g. sensors, LIDAR). There are many different private and public road operators within and across countries and sectors (port), and they need to be harmonized towards standardization of PDI needed to enable crossing regions and borders to accommodate automated trucks (signs, lane markings etc.). The transport system depends on interoperability - so road owners - and EU projects - need to collaborate and specify data/interface standards, and standards for infrastructure, customs, tolls, charging, parking, and vehicles and platforms. “Big companies must not develop exclusive platforms and ecosystems around automated transport as this may lead to poor interoperability and suboptimal automated truck systems in traffic”. Evidence-based development of legislation so that EC ultimately will be able to demand changes to highway codes to accommodate automated trucks.

*RAR16 We (RAO and port terminals) prefer simple gradual changes to the physical road infrastructure that are evaluated as beneficial for other road users in tests on private roads that can be rolled out as short term pilots with simple ODD on public roads; we need a roadmap for automated truck implementation to inform us about what PDI changes might be expected when, so that we can consider them alongside other road user and AV needs, make ROI calculations and alternative financing options. [**R7, R19, R24, T59, R63, R75, L57, R109, R38, R39, R43, R43, R99**]*

The following comments summarize road authorities’ and owners’ needs for automated trucks development:

- Need OEMs to present “a united front” and be willing to share data.
- For now, will consider only minor changes to the physical infrastructure but prefer intelligent vehicles over intelligent roads. Road and port road owners will make only simple minor and gradual changes to infrastructure to accommodate automated trucks due to budget priorities, the time it takes to plan larger changes, and from a need to maintain standards for other traffic (which will increase acceptance of automated trucks). Where C-ITS (e.g. warning of light changes) can be used they will be prioritized over expensive physical changes to infrastructure to reduce congestion.
- Will provide data for digital maps and provide information needed about dynamic road conditions.
- Look to for preliminary testing on private roads (e.g. port or freight village road networks) before testing on simple public road ODDs – preferably at night.
- Need to know what infrastructure changes are needed through open dialogue with harmonized automated truck providers and political decision-makers on steps/roadmap to the future and “our role in automated trucking”: what physical infrastructural changes should road owners be planning for in the short term (e.g. modified signs, high-quality lines, overhead lights, ensure continuity, dedicated lanes) or long term (e.g. wider roads, stopping areas/transition zones where automated trucks can change mode or be rescued)?

- Need data for ROI / socioeconomic cost-benefit of PDI investments calculations, develop business models (who will pay? In ports, for example, port terminals together pay port for PDI improvements like new gates) - this will include accounting for effects on safety, the need to maintain any new technology etc., any changes to service infrastructure, mapping out roads, automated charging stations and tele-operations.
- There is a need to know how long the changes we make will last and how they can be kept up-to-date for developing technology.
- Positive to dedicating one lane of a specific multi-lane highway for testing where we can see clear potential benefits to users of that road and where political will and regulations allow. Infrastructure modifications, dedicated lanes, approval for trials e.g. at night require political decisions.
- Modifications will need to work for different types of automated trucks and possibly AV so there is a need for standards.
- In countries with lower standard infrastructure the quality upgrade that automated trucks demands will be more difficult.
- Evaluating which infrastructure changes make a difference in the end in terms of effectiveness & efficiency will be important, and learnings can be applied by adapting infrastructure.

Annex 10: List of 384 pre-aggregated requirements

In the following table codes can also be used to find which of the 1,934 value/challenge/requirement statements collected each requirement has been derived. For example, Requirement L1 links to 31 statements in our original Excel file derived from logistics actors, and these statements have been labelled L1. AT = Automated truck.

		As a logistics company
L	1	We can save on driver costs to achieve reduced transport costs per unit shipped or moved (port) and therefore we see most value in simple routine tasks requiring many driver hours
L	2	We know our employees/drivers trust and understand automated truck technology and in their new roles experience increased health and wellbeing by reducing driver physical and mental workload from less loading, anti-social hours / away from home / at short notice
L	2	We need evidence that any proposed use of AT will work, how long it will take to "train-up" the technology, it is scaleable and that it accounts for our economic reality (especially SMEs)
L	3	Maximise time as resource: By transporting between or within nodes 24/7 with no need to stop for 45 min rest every 4,5 h, preferably with dedicated lanes, we can reduce delivery times and maximize use of truck capacities, by avoiding congestion (main threat to delivery times); at large (port) terminals we can increase capacity by operating internal AT 24/7. Will need new processes to minimize staffing required during non-social hours.
L	4	We understand and work internally/with partners to implement changes to procedures (gates, docking etc.) at terminals/hubs/warehouses so that they are less dependent on human control/interaction to maximise efficiency gains of automated trucks
L	5	Our AT (with help of FMS where relevant) can anticipate roadworks or queues, get round obstacles and choose alternative routes to protect delivery times in the event of incidents traffic flow problems
L	6	Tracking and dynamic planning: AT and cargo location and flows are clearly visible in real-time to operators, logistics platform providers, forwarders, truck owners and our nodes who can track (e.g. through integrating terminal/warehouse with fleet/logistic management systems) where the truck/load is, cargo information, when it has left/entered port/terminal, ETA, where it is going (next), how they need to organize connecting ops (e.g. load/unload), and are warned of delays, in order to increase efficiency in supply chain
L	7	We can spread deliveries so our/customer nodes can increase efficiency by using less resource to cope with intense periods of loading / unloading
L	8	We have procedures to instruct or direct an automated vehicle *en route* or about to depart (fit with FMS)
L	9	We can improve gender balance and increase opportunities for employees with restricted movement in logistics
L	10	Employees accept need for change and do not feel their jobs are threatened by automated truck technology
L	11	We can reduce need for temp staff, improve salaries, work conditions, wellbeing and productivity by using people in more skilled jobs nearer home for tasks that people are best at; 24/7 operations must not mean more personnel do shiftwork - You cant solve the current personnel problem by saying some people have to work at night - so how to ensure safety of night ops worth automated vehicles? Who will pass orders to vehicle? Who will fill the orders?
L	12	We have the competence, tools and information we need to assess the cost-benefits / ROI of automated trucks and the new PDI (logistics and fleet management systems; dedicated lanes at terminals) they require in our value chain
L	13	We know which use areas are most likely/unlikely to be viable first so that I can start planning for my unique operation and context (LA are diverse)
L	14	We improve customer service partly with more reliable, shorter delivery times; easy to create visibility and predict service level (e.g., arriving time). easy to manage disruptions and reschedule
L	15	We can apply automation in cases where we run trucks routinely and frequently between internal assets, or between terminal and asset, along simple or dedicated road stretches, at more times of day and night, disconnecting and connecting container/cargo a each end
L	16	At warehouses, terminals, nodes we need standardized solutions for interfacing with external automated trucks - includes both ends i.e. digital infrastructure / IT system requirements at terminals that transporters comply with must be standard (analagous to toll systems)
L	17	We see that collision/sudden braking levels are reduced so that I can reduce costs due to material/cargo damage
L	18	We need information to flow seamlessly through the chain of involved parties on when cargo will arrive, action that needs to be taken etc. (overarching logistics system) / order for shipment should go directly to TMS and then from TMS, which accounts for optimal energy use in schedule, to automated truck, with pick, pack, loading, truck tracking
L	19	Our node staff or customer node staff -- including visitors and foreign-language speakers, crane operators, forklift operators -- need full situational awareness of automated trucks while they are parked and manouvering at the node (external HMI)
L	20	We can redirect AT in the event of order cancellations, inaccessible destination terminal/node/warehouse, delays along the route
L	21	We can act strategically so that our ability to meet extra demand for cargo transport (e.g. from ecommerce) especially on long-distance routes, eventually will no longer limited by access to qualified drivers (driver shortage)

L	22	We can more easily adapt our capacity to meet demand in the face of fluctuations in demand or in availability of competent drivers from sickness, strike action
L	23	We can save costs by saving fuel/energy and on wear and tear from more economic driving afforded by AT
L	24	In the short to midterm we can use AT with support driver on long distances as long as rest regulations are relaxed and/or driver can rest in vehicle; alternatively platooning
L	25	We need evidence that L4 trucks can improve efficiency and other business outcomes they achieve with their current trucks (examples of measures given in statement #339)
L	26	Ideally AT can be used flexibly, to pick up/drop off at various locations within a node, across different operations, routes (public/private roads), load types and load handling procedures
L	27	Reduction in risks due to human factors in vehicle operation (R1)
L	28	We can use AT in highly competitive but routine drayage operations accepting the need to cross public roads and that a high degree of human interaction and control needs to be accounted for
L	29	In our long-haul operations time spent at terminal is small so AT use at terminals has relatively low value proposition
L	30	With AT we can (re)allocate drivers to other functions to increase operational effectiveness
L	31	We need to provide proof of delivery at agreed destination for insurance purposes
L	32	We accept that whole logistics chains cannot function without drivers in short term, and that L4 should be considered as driver support in a first phase, but to invest we need to see that driver will be replaced in second phase on major legs of transport
L	33	We see human drivers as hardest to replace in urban logistics where people are better than digital solutions on routing in real life and where there are many variables to be considered
L	34	We have the equipment and competence we need to maintain or repair new trucks and automation technology
L	35	We need AT that can move around different trailers at warehouses and cope with diverse loading/unloading processes or levels of loading automation
L	36	Where we already have automated operational flows at warehouses and terminals we are interested in streamlining operations by integrating with AT - aim being 24/7 automated operations
L	37	We know how much AT can reduce CO2 emissions and save fuel or energy in our operations
L	38	We prefer few or no changes to physical infrastructure at terminals or maintain infrastructure so AT solutions should ideally cope with existing infrastructure, and complex busy terminal environment ("see round corners, behind stacks")
L	39	We can ideally replace existing tractors with automated ones that run on the same physical infrastructure as now so can reverse and turn left - variation in willingness to change terminal infrastructure depending on indvidual situation
L	40	We can direct AT to do complex driving or docking manouvres at nodes, which container no. to fetch at terminals, where the AT system should park, use approach ramps/park at docks etc. such that the side or back can be loaded/unloaded, couple/decouple trailers (fifth wheel, kingpin, support legs, air and light connections) and connect itself or the trailer to electricity and communication systems
L	42	We need seamless interoperable standardized gates, docks and connections between AT and goods delivery, container movements etc. at our terminals/terminals or customers'/suppliers' nodes
L	42	We can find/lozalize the AT when we need to - within terminals/warehouses or out on roads
L	43	AT must not be so slow that they reduce operation and transport times at or between terminals or annoy other road users
L	45	We can overcome unexpected challenges that inevitably arise in the uniques contexts in which we will use AT (at and between nodes)
L	45	While largest LA and terminals look to partner with OEMs, build new ecosystems and upscale AT internally, most LA have tight profit margins and the large number of smaller actors especially may need subsidies or incentives to invest in technology and competence we need to develop AT as part of operations - especially if step change required. Cost of tech increase (through redundancy related additions to vehicle design). CapEx for automated trucks will also be higher.
L	46	We know what loading/unloading equipment, trailer access solutions etc. will be compatible with AT of the future so we can plan to invest in it
L	47	Some operations require delivery into city (e.g. supermarket) where driver might need to take over for last mile
L	48	We can free up shunting drivers (or rest external drivers while their truck drives automatedly) with AT dock to dock or for container/cargo manouvres at larger terminals (quayside crane to stack, port reception to terminal) - the AT must be able to park/reverse/dock with or without remote control (tower on site) - need to know where it must go, which containers to pick up and where to drop them again
L	49	We have good processes and planning so that operations at more dynamic terminals to account for loss of adaptability of drivers
L	50	Save costs of damage to material and cargo
L	51	We need to know how to set up the "back-room" planning infrastructure that gives orders to truck or control room - how to operate the total business? What new physical and digital systems and processes do we need for the vehicle?
L	53	Some of us want the truck to park, load, unload itself or enough digital maturity at yards to allow remote control parking or terminal maneuvres
L	54	We may require dedicated parking for AT e.g. for hubless goods or mode transfer for city deliveries

L	55	AT must not have low interoperability between modes (cause "differential operational instances") or reduce flexibility in choice of route on longer trips
L	56	First use may be large volume routine repetitive transport rather than the extremely flexible AT solutions would be required that can cope with several mode and node transfers where nodes have different owners in different countries
L	58	Those of us who subcontract in carriers to cope with periods of high demand need to change are business model or our new system must be compatible with subcontracter equipment and systems
L	59	Customers who previously rang drivers to find out ETA etc., need to be at least as satisfied with new automated systems
L	59	National chains delivering to cities might look first to standardize AT delivery from warehouse to ring for cross-docking with standardized solutions
L	60	We need to learn how to leverage data driven operations as we see it can bring lots of benefits in term of efficiency, predictability, flexibility
L	60	As nationwide actors consider integrating some aspects of remote teleoperations with existing national fleet monitoring but safety operations probably outsourced
L	61	We see a good support infrastructure needed to avoid human intervention, unplanned stoppage, unplanned charging, and therefore protect delivery schedules
L	61	LTL carriers working for different clients will need very flexible AT solutions
L	62	We need clear processes for legal and operational goods handover to customers or third party carriers
L	65	We need reduced charging time if we need to charge electric vehicles during potential uptimes, or to use hydrogen / HVO
L	79	We can easily operate AT systems
L	81	The vehicle should come with advanced security features (sensors, cameras, real-time monitoring) and warn teleoperator of security issues
L	82	We know how to protect cargo from theft e.g. tamperproof, make immobile
L	83	We need AT providers to be honest about the maturity of the technology
L	84	We are not certain if increased specification and organisation of streamlined systems will give us requisite flexibility or decision-making power to cope with the variety of situations drivers normally face (T23)
L	85	At nodes/terminals we need to control entry and areas in which AT can move e.g. through geofencing; terminal gate clearance in absence of driver needs standardized information about licence plate, correct container, automated vehicle of approved type; could also be done by remote tower
L	86	Hubs or freight villages near motorway gets dedicated lane extended from motorway to hub
L	87	Port terminals and other terminals need standardized external AT so that they can use same system to interface with them all
L	88	Safety rules at nodes and terminals are revised to account for AT, which must also abide by them
L	89	Need procedures to redirect AT to holding area in event of terminal closure
L	90	Same or higher productivity with lower number of vehicles - we see increased uptimes for our vehicles
L	91	Where AT + human drivers may need to prioritize AT at slip roads, roundabouts, junctions due to "politeness" problem - in terminals and on public roads
L	92	We know which person or organization is liable for cargo (currently with carrier), at what point in operations cargo liability transfers and have processes for it; applies also for role in relation to inspectors
L	93	We can work with RAO, port authorities on different models for costing implementing charging infrastructure at strategic locations on highways, at ports, terminals and warehouses, using solar power where possible
L	95	For management of an automated vehicle pool at port, a new entity - possibly a rental company - is needed for distribution, operation and maintenance of vehicles
L	96	For some of us we can assess value best through testing involving multiple stakeholders
L	100	To cope with the expense of AT and change in TCO advantage/disadvantage, new financing models and options for costing short-term investments needed for long-term cost reductions. Important to do a good stakeholder analysis incl business model (who pays what, who need to change what, who earns what, who gets what benefit etc.); Potential new business models are uber freight or capacity as a service, the operator as a service, new generation cloud TMS, and investment opportunities in freight transfer hubs in combination with AT fuel/charging networks.
L	101	Terminals would like their needs to be accounted for in advance in event that terminals share pool of AT
L	102	May be need for manual override of some automated operations at terminal, depending on cargo
L	104	We need to insure our AT simply and for a reasonable cost
L	105	We need digital document transfer
L	106	Consider local regulations e.g. photo ban in terminal areas
L	107	Terminals would like external AT to enter, park in designated spot, load/unload, and drive out again while following local road and safety rules
L	108	Terminal/node gates/infrastructure are able to verify that it is the right vehicle, the right driver and the right goods - a lot of admission for shunting at port terminals is done manually - see L105

L	109	Port/yard workers must be able to communicate with the autonomous trucks without a driver inside. Do they need to contact the control tower and/or should they be able to digitally get info by using phone/device to take photo of QR-code or RFID on the vehicle?
L	110	Ports need to have a control tower with a fleet management system from where they can see all trailers and a GTMS logistic system from where they can see truck filling degree and available parking's
L	112	We can cost, find ways to finance modifications to the terminal environment: entrances, loading/unloading bay
L	113	Consider consequences for AT on warehouse and (port) terminal network design
L	116	AT easy to plan for, deploy, manage, operate
L	117	Terminal would need to know that the AT has received the latest map and has confirmed its ability to execute against it
L	120	The automated vehicle would need to come with a guarantee it will execute all required process steps safely and correctly.
L	121	Need for technologies that can automate significant chunks of current operations, without fundamentally changing current operations
L	122	We need to know what we should do so that we are ready to use AT when we assess that the benefits outweigh the risks and costs
L	123	How contracts and agreements will be made? For example, can receivers reject an automated (or remote operated) truck at the gate?
L	130	All needs (e.g. infrastructure requirements, new roles) and costs related to AT implementation, operation, maintenance, depreciation must be clear.
L	131	Clients like to be associated with innovation, company reputation
L	132	Forwarders expect carriers to use interoperable AT systems - compatible with each other and forwarder's systems
R	60	Our (clients') cargo is secure throughout the journey
R	79	We can schedule charging time to maximize AT resource use
R	81	At port terminals the truck knows where the container to be fetched is, its number, confirmation that it is ready, and a way to validate it and report validation
S	7	We have the knowledge and resources to re-gear logistics and fleet management systems to exploit new possibilities from 24/7 driving and that are less dependent on human control and interaction
S	11	We know efficiency will not be reduced if a responsible person becomes unavailable to assist L4 technology if needed
S	13	We can in the longer term digitalize more comprehensive, intermodal supply chains with more integrated operational data (involving e.g. port, warehouse, fleet management systems) to maximize efficiency and exploit the 24/7 capacity of the truck
S	14	We know our business will not be vulnerable to the cybersecurity consequences of digitally integrating our operations (involving e.g. port, warehouse, fleet management systems)
S	16	We know efficiency will not be reduced because of AT inability to cope with dark, extreme weather, complex/new traffic situations, obstacles in road
S	19	as LSP we can use AT for own-terminal network transport we will consider cutting out carrier and dealing directly with manufacturer/AT provider who would execute the journey, to cut our costs
S	20	More predictive traffic management: We save time by departing on time and plan trips using routes that are optimal for the business without having to account for the human needs of the driver; through AI systems, optimal routes can be planned accounting for rush hour, weather forecasts and conditions that may affect the safety of the service or fuel consumption, such as strong headwinds, ...Logistics software providers require quality data to develop this
S	21	We know how much we save energy or fuel expended on driving (optimal eco-driving) and more aerodynamic, lighter trucks (driver out) after accounting for increased energy use from e.g. computing power (estimated 10% extra energy use), maintenance
S	22	We can cope with delays, queues by driving as long as needed without having to consider driver needs / rest regulations
S	23	We will not have staff and will in any case save time by planning passes and passing more quickly through charging/fueling stations, borders, customs, gates and inspections more quickly (due to digitalized approval processes integrated with our dispatch/transport planning systems)
S	23	We expect some failures but need to know how to manage them and which are more likely so we can prepare for them, this includes default slowing and/or remote operators that can steer to safe parking area on technical failure ("minimum risk manouver)
S	29	We can streamline / achieve optimal efficiency by interfacing AT with existing or new automated procedures at charging stations, terminals (port quayside cranes to container stacks etc.) or loading docks
S	30	We have highly automated procedures that allow cargo to be moved between AT and other modes in order to increase efficiency of our intermodal operations
S	31	We need clear processes to integrate AT with PDI at different links of the transport route, including cross-dock/consolidation from container to pallets, from 44 t AT to 3,5 t manual truck for city leg, and to manage the needs and actions of multiple players
S	32	We find AT to be more reliable than current trucks, and more flexible in that they are available for goods movements at all times of day and year / The number of stoppages due to automated vehicles must be limited
S	33	Using the AT in our operations reduces the number of persons injured in work and traffic accidents involving our trucks (R1)
S	39	We need to be able to tell the AT where to go and what tasks to do next, flexibly, safely, securely, reliably and easily, either manually or using management systems to ensure seamless operations

S	40	New skills: We can recruit or train our current drivers as support drivers using L4 automation, as remote operators, to work at staffed transfer points, AT maintenance or call-out personnel or to do more challenging driving (e.g. exceptional loads) or back-office tasks
S	55	We need regulations to be harmonized across borders (e.g. weight limits)
S	56	Logistic companies look to long-distance automated transport as a long-term possibility but can be interested in more realistic short term solutions depending on their needs
S	60	AT gives us the continuous transport that we need to win orders from other long-distance modes
S	64	Our clients / shippers should not be faced with extra costs and demands (e.g. loading) that they do not appreciate the benefit of
S	70	We prefer to use own trailers, swap bodies, containers, etc. to be picked up and moved by the automated tractor/chasis; urban logistics want standardized containers in all sizes that can be plugged into one another
S	74	We can work with RAO to increase efficiencies e.g. inspect while charging at terminal
S	76	Goods receivers need to know how trucks operate, understand external HMI and how to act on damage goods
T	21	We can streamline and possibly automize dispatch by connecting AT to logistics management systems, to exploit increased availability of our trucks and maxmise use of load capacity / limit empty loads by streamlining/organization of truck movements / back office automation and seamless connection
T	22	We must see that benefits outweigh effots, costs, risks, ROI: We have information we need to assess TCO advantage/disadvantage and if use of "safety driver" or "driver out" can reduce our costs overall after accounting for business/financing model and advantages (increased capacity) and disadvantages (the proposed vehicle and support, that drivers may wait more, more expensive people, training, need to staff and equip remote operations, new roles at anti-social hours, changes to our own PDI, autocharging/loading, parking, loading, customer service - and how long it will take us to get there?
T	23	We can no longer "let the driver finish the design" - we need to specify more in our planning (automation) or get people in other roles to do all the things a driver does: we see that cognitive and physical operations and tasks achieved by human interaction and control in existing systems are fully understood and allocated for (e.g. deals with emergencies, respects customer expectations so finds workarounds, driver checks tyres, brakes, warns of delays, quality of goods before receipt, checks number of pallets, provides diagnoses, prognoses, maintains business/social relations with customer, adjusts delivery times to suit customers, problem-solves for / informs customer e.g. about how goods are sorted on truck, incidents en route,social account to managers of customer needs, loads/unloads, carries for customer, clears road, fixes technical issues, detterent for theives/contraband/stowaways, connect containers to tractor/warehouse, charging, check AT and cargo are roadsafe before departure. charging/fueling, oil, loose straps that must be tightened, clean sensors, put on chains when icy weather, identifies need for, plans and drives alternative routes., gleans information from other drivers via chat etc., checking cargo integrity, temperature, feeling and reporting effect of abrupt stops and turns on cargo; light cable, air cables, opening tail lifts, doors, landing gears, couple trailer, choose to deviate from advised routes to avoid schools, or noise in neighbourhood late at night, log subtle cues indicating technical issues, exchange of paperwork when entering / leaving a site, closing and opening of twist locks, connecting and disconnecting the tank container to filling station, placing and removing of stopping blocks under the traile). Imagining the situation whereby an automated vehicle is active in a logistics operation and then see what sort of things are encountered in order to make it work. Driver announces arrival at terminal with CargoCard - so a digital triggering of the logistics process is needed.adjusting the chassis (for 20ft or 40ft containers) and putting stickers on the container. In approximately 20% of cases exceptions occur and truck drivers have to get out of their cabin to obtain/ exchange additional paperwork and/or certificates. The truck drivers are the "eyes" on the terminal, e.g. via a "dead man`s switch" drivers indicate to cranes at the stack that containers can be put on the chassis; Regarding long-haul automated driving on highways in hub2hub transport, one misses the "eyes" of the truck driver to make vehicle checks, fix flat tyres, snow chains
T	24	We have identified a use area and developed a business case
T	28	Truck operators need to interface with information from vehicle, road other sensors in usable and useful way
T	32	We may be reluctant to handover control of remote ops to third party - especially if this costs money or time - as we see this as part of our logistics role
T	34	At terminals and node, AT need to fit as much as possible with existing traffic (i.e. must operate in mixed traffic) and physical, digital and operative infrastructure and procedures
T	35	The new vehicles need to deliver in the same way as the old vehicles did, so companies can have the same kind of KPIs and the same kind of reliabilities
T	36	Need of a human interface for the operator oversees the operations in order to keep track of the operations done automatically
T	39	We need realtime telemetrics on battery/fuel level, tyre pressure etc., and automatic warning from AT (e.g. via FMS) on stoppages with reasons, vehicle charging, maintenance, tyre pressure needs; preferably with the vehicle able to charge, fix itself automatically
T	43	Reduced insurance costs through reduced risk of collision
T	45	We require automated charging/battery swap for longer shunting operations or distances over 4-500 km
T	46	We need interoperable AT with standardized technology for docking, loading/unloading, charging, battery swapping, and interface/digital solutions - this will reduce costs and leave us free to choose between AT suppliers
T	48	We need new seamless solutions that simplify integration of automated trucks in logistics systems
T	64	Ownership of control towers, responsible for management, monitoring, predictive maintenance scheduling, etc.,should be clarified and services interconnected with carriers' traffic departments for proper coordination of services
T	70	Our vehicles are safe from cyberattacks

T	92	We can charge our trucks when and where we want to
W	4	Our operations do not suffer from the effects of unstable digital systems

As OEM/Technology provider developing useful products

T	1	We can focus on making highly automated trucks smaller, electric, lighter and more aerodynamic to improve the business case for logistics actors who are looking to reduce emissions and energy and land use
L	64	We would like regulators to regulate for electrical trucks to motivate investments in automated trucks
L	77	It will be easier to start with automated transport systems in confined areas
L	80	The onset of 5G connectivity in some ports makes them attractive for AT trials
L	114	Accountability of downtime
R	27	We need RAOs nationally and internationally to develop standardized supplier-independent PDI that enable AT to be used everywhere and which produce predictable road-vehicle interactions / variations on data coverage and quality between countries on weather, road status
R	61	Remote control operations are not limited by signal latency or reliability and receive a detailed feed to ensure the robustness and function of the truck
R	72	We can give RAO updated HD maps if we get data we need from them to help build our 3D maps
R	82	We can resolve regulatory challenges related to remote teleoperators in one country controlling AT in another
R	83	We need different countries to agree on standards for maps and GPS coordinates
R	107	Need to work with RAO, municipalities, mappers, OEM or other data providers on standard joint data exchange interfaces and V2X connectivity
S	2	We can work with regulators on need for procedures for "what-if" routes (e.g. where AT may need to speed to avoid a risky situation) or need to cross line to avoid object in road
S	3	We can work with ROA on using road sensors to remove limitations on vehicle sensor suite (spiralling roads, blind corners, sudden rises or falls)
S	6	We want to offer remote monitoring and support of vehicles including performance monitoring ("one stop shop")
S	8	We can work with RAO on need to supplement roadside furniture symbols or reference markers or barcodes on the wall in uniform environments - especially those with GPS differences like tunnels
S	9	We can work with RAO on need for more continuous, dedicated, sensored or increased quality road environment (we knowL4 cannot depend on infrastructure if it is to work everywhere, yet changes to infrastructure (e.g. physically spearated lane with high quality markings, lighting, sensors every 250m) can simplify the problem, be used by different vehicle opeartors)
S	10	We track and understand situations requiring human driver/operator interventions
S	12	We track vehicles on size of deviations from intended path (sit in lanes well)
S	24	We need authorities and connectivity providers to plan for completely reliable cross-border connectivity
S	35	We understand local regulations concerning AT and can adapt to them dynamically
S	36	We work with RAO to give human (tele)operators, fleet managers, FMS, LMS data in digestible form on vehicle progress, warnings from road authorities about traffic disruptions, traffic cameras
S	36	We need to ensure that the AT onboard system knows where the AT is located within an operational geofence at all times
S	38	We need dynamic data to inform the AT about collisions, emergencies or other changes to the environment
S	47	We need reliable and accurate internationally standardized data from different private and public parties to construct highly accurate digital maps covering wide areas
S	48	Our AT depend also on computer vision for information about e.g. light status
S	62	It is essential that sensors are checked, cleared and maintained
S	66	We will search for new business models e.g. execute transport ourselves, park AT tractors for hire at charging sites…
T	2	To start evolving logistics we offer AT for a few regular, routine, predictable, low-interaction operations(simplest ODD) with relatively simple sensor/radar set are the most high-impact, feasible near-term use areas for automated truck technology, they make automation of surrounding operations simpler, and should be prioritised
T	3	We see that users need to trust and believe in automated driving technology
T	4	We need further development so that AT can adapt to merge, travel at desired speed, handle diverse/new objects in the road or lighting conditions, discern real objects from pictures, uniform environs, mixed traffic, with VRUs around the AT, and poor weather, navigate in cities, and this may need sufficient sensor tech, processing power, and 5/6G connectivity (T14) and energy use by onboard computers
T	5	We account for the unpredictable behaviour of other human (and technical) road users
T	6	We need to test to confirm safety so do not want to wait for permits to test or operate automated trucks from authorities (who may not have necessary internal processes ready). Slow legislative policy to support AT in EU – slowing down and restricting testing. Reluctane to change the rules of the road – although it is anticipated that road markings and signage may have to be adapted.

T	7	We need regulatory frameworks that support AT, e.g. we know that the potential of automated trucks will not be limited by restrictions on trucks on key roads at certain times of day or week
T	8	We can work with RAO to test the safety and performance our trucks against agreed measures
T	9	We require RAOs or terminal ownes to make and maintain infrastructural adaptions such as sensors in road, dedicated lanes, high-quality asphalt, lines, roadsigns/symbols, continuity, or so that the vehicle can handle merging situations e.g. on-off motorway, or have regular safe stopping places / mode transition zones
T	10	We know that all RAOs will invest in and harmonize infrastructural changes now to prepare for a future with automated trucks
T	11	We do not work on more complex parts of logistics chain such as last mile urban deliveries
T	12	We know which segments of value chains need humans and which can be automated
T	13	We get data from the vehicle (e.g. performance in changing weather/situations) and feedback from users and stakeholders for technological improvements
T	14	As connectivity providers we need to be engaged to develop adequate, reliable and internationally coherent terrestrial connectivity for AT - 5G or 6G may be needed for V2V, V2I, V2Cloud, for higher data rates, lower latency than previous wireless networds = better safety through faster transfer of data for decisions, reduced computational load on vehicle, improved navigation and situational awareness to navigate more complex environments (T66)
T	15	We see that cross-border RAOs cooperate on permits for AT
T	16	We need RAOs to accept automated trucks are safe so that they work on necessary EU regulations
T	17	We need a living lab enabling AT testing while being able to control parameters and gradually complexify the situation and prove feasibility of advanced business cases
T	18	We need RAOs to develop/identify high-quality simple stretches of roads that are interesting for LA
T	19	AT need regularly updated, accurate and stadardized digital maps (local dynamic maps) a static map with layers added for objects, digital traffic rules, and information about road condition, lights, signs,weather, hindrances
T	20	We can develop technology on automated trucks for nighttime use
T	24	We are not hindered by data protection issues so we can enable tracking of automated trucks
T	25	We (mediator companies) can work with RAO to simplify the infrastructure to enable AT at night AV day - dedicated lane, sensors with ML processed data on road ahead, improved quality road markings
T	26	In drayage situations it can be feasible to make a high quality dedicated track for 24/7 automated trucks
T	26	We can take on risk to test technology and drive change but public-private collaboration required to achieve societal and economic/business goals
T	27	We want LA to consider new models, change location of assets or operations to exploit near-feasible use cases - this could mean running AT in dedicated lanes between assets
T	29	We as signal-from-road providers can learn how to instrument tunnels
T	30	We can work with RAO on road sensor maintenance
T	31	We have access to solid HD maps
T	38	We can develop the FMS to receive info from the environment (weather, route sensors, closed roads) and vehicle (telemetry data) and send instructions to vehicle (from logistics systems)
T	41	Ports are complex situations in which to implement automated trucks, require specialised AT with limited sales potential (units to be sold) and infrastructure based automation may be feasible - ODDs involved in hub-to-hub solutions can be simple in comparison but may require human drivers for first/last mile between hub and parking place near motorway (still work nearer home).
T	42	Some AT solutions require driver in but main goal for all is driver out
T	47	A sufficient number of LA see that they need AT in order to compete
T	49	To develop AT as part of seamless logistics with increased value for LA we need cooperation of all chain actors
T	50	We can help ensure safe braking reducing risk of collision using V2V
T	51	We can generate models for legal/operational handover between interoperable remote control towers within or between countries, municipalities or between private and public roads (e.g. from Sweden to Moss havn) or models of working that give teleoperators adequate situational awareness to monitor several trucks and operate those needing assistance. Where will the towers be?
T	52	In yards with automated unloading changes to the infrastructure may be required
T	54	As mappers we expect AT manufacturers / users to share data to update maps depending on the coverage AT can give
T	56	For mappers data from AT will mean that high-quality maps can be made available at less expense

T	57	We can operate in mixed traffic, conditional on dedicated lanes / changes to infrastrucutre, enabling hub-to-hub cases
T	61	We need to make different vehicles and technology for highway vs. Operations logistical network roads or terminal yards as technology for motorway driving will not be sufficient
T	62	We need a emission-free charging / fueling infrastructure for in place that can work with AT
T	65	We need coherent, harmonized connectivity across borders for international AT use to be achieved through cooperation of providers from different countries
T	67	We need access to the satellite connectivity for: global coverage to achieve resilient, robust AT or for patchy areas with poor wifi/terrestrial coverage; for weather and traffic information; for global positioning for navigation
T	68	Network slicing: We need to provide AT or AV with an exclusive 5G/6G network to ensure reliability (AT must work all not most of the time)
T	69	We would like regulators to reduce limitations on data use, look at privacy issues
T	69	We can conduct customer journey mapping of each of the use cases to test latency and network stability, check more unusual usages e.g. video feed from vehicle

		As a road owner/operator/authority
R	1	We want data to support that L4 AT with safety driver or remote monitoring+control will (substantially) reduce the number collisions with serious injury outcomes involving trucks in the ODD in which it will be used (cf LL2,3 + driver)
L	57	In countries with lower standard infrastructure the quality upgrade that AT demands will be more difficult
L	94	Port: If AT transport between different terminals and port reception in mixed traffic traffic/infrastructure must be well organized to avoid congestion
L	97	24/7 operations should not be vulnerable to fatigue in remote operators
R	2	We see that sufficient work has been done to understand effects of introducing AT and associated PDI into traffic systems mitigate new and unforeseen risks from automated trucks in traffic, including failures resulting from interacting system components (PDI, V, other road users)
R	3	We see a reduction in transgressions such as speeding, dangerous driving, DUI
R	4	We need to know where AT are in real time (for incidents) and historic analysis for risk areas are for automated trucks so that we can change/maintain infrastructure and improve road safety
R	5	We know that society, human road users and transport company/terminal workers feel safe in traffic with AT because they trust and accept automation technology; they have a simple, correct mental model of how the technology works and its abilities and limitations, the technology is usable, visible, predictable (external HMI) and reliable in practice, and useful (beneficial for society) - this will require transparent systems and openness and honesty from AT suppliers and LA
R	6	We see sufficient work has been done to understand and protect against unforeseen effects of automated trucks on cargo and traffic security
R	7	We need to know what infrastructure changes are needed - we have an open dialogue with *harmonized* AT providers and politicians on steps/roadmap to the future and our role in AT, what physical infrastructural changes we should be planning for in the short (e.g. modified signs, high-quality lines, overhead lights, ensure continuity, dedicated lanes) or long term (e.g. wider roads, stopping areas/transition zones where AT can change mode or be rescued) and have data we need for ROI
R	8	We know that new PDI and roll-out of AT increase not reduce traffic flow and reduce delays for other road users and cargo thus increasing road capacity/efficiency and reliability
R	9	We see that automated technology reduces illegal parking and therefore congestion on city streets, terminal roads etc.
R	10	We know that AT do not stop in road when faced with new objects, technical faults, weather or unusual traffic situations such that they cause hazards or congestion to other road users
R	11	We can change existing strict regulations for HGVs without increasing traffic risks
R	12	We can reduce collisions due to human driver limitations e.g. fatigue, DUI, speeding, attention
R	13	We get more efficicent use of /better capacity in the road network, and can link this to less stop-and-go phenomena, closer safe driving distances, fewer trucks in peak times since trucks can operate 24/7 (applies also to port road networks) - effects strong on roads where 30% vehicles are trucks
R	14	We understand how roles, responsibilities, sensor/data possibilities, and needs for information and data integration will change in our traffic centre operations
R	15	We understand how to develop / improve the efficiency and effectiveness of processes for traffic inspections for AT
R	16	We see that call-out/rescue and emergency services, AT operators and other stakeholders have competence and procedures to deal with breakdowns, tunnel fires or other incidents involving truck with no driver - including payment and insurance clarification
R	17	We develop new procedures on how to conduct inspections
R	18	We receive vehicle data from companies to simplify inspection of vehicle maintenance and safety standards - may require legislation - and plan road maintenance, salt use, investments
R	19	We (RAO and port terminals) make only simple minor and gradual changes to infrastructure to accommodate AT due to budget priorities, time it takes to plan larger changes, and from a need to maintain standards for other traffic (which will increase acceptance of AT)
R	20	We see that interactive effects of AT in mixed traffic are understood and accounted for (e.g. wide berth on overtaking, driving to speed limit in roundabouts, unpredictable abrupt stopping, negotiations in traffic, predictable moves, too slow driving for speed limit / conditions)
R	21	Our traffic control centres develop new diversion processes by sending data to AT on stationary/mobile roadworks, lane/roundabout/road diversions
R	22	Our traffic control centres know what to do when an AT cannot be diverted outside of its ODD
R	23	We can help address shortage of qualified or legitimate drivers for national and international goods delivery to society (shortage)
R	24	We have access to data and methods we need to assess business models (who will pay?) / ROI / socoeconomic cost-benefit of PDI investments - this will include accounting for effects on safety, our need to maintain new technology etc. - Cost of infrastructure changes: service infrastructure, mapping out roads, automated charging stations and tele operations, port terminals together pay port for PDI improvements like new gates)

R	25	We know that AT has technology or processes so that it can function given the particular challenges of the road network and weather conditions of our country (e.g. Norway, NL)
R	26	The absence of "driver in" enables us to design lighter, more aerodynamic trucks that give way in collisions with VRU
R	28	We know that new PDI does not reduce safety for human drivers
R	29	We can help improve productivity for our logistics actors to allow them to compete internationally or use our roads as clients
R	30	We see that energy use + emission levels are reduced over the complete life cycle of AT and required PDI developments
R	31	Our traffic control centres or other call-out centres are warned of problems and know who to contact about AT
R	32	We as regulators develop / apply internationally standard regulations on who is legally and liably responsible for the behaviour, state and content of the vehicle and cargo along the logistics journey and in different operational modes and situations in the ODD in which the AT will be used (teleoperator, AV operator or public authortiy etc., Who is liable for collisions? "The entire legal path is important" - human operator in control room or terminal? This concerns also new players eg IT manager, OEM)
R	33	We help develop regulation needed to support potentially positive effects of AT on daytime traffic volumes, emissions
R	34	We can consider minor changes to the physical infrastructure but prefer intelligent vehicles over intelligent roads - dedicated lanes or specialised junctions are not possible where capacity or geography limits - so more accepting of changes to road authority's digital infrastructure - to adjust digital maps and provide infor needed about dynamic road conditions
R	35	We support orcehstration (e.g. V2V connectivity) of automated trucks that helps traffic control centres manage traffic flows and incidents
R	36	Public highway and port RAOs have open dialogue with harmonized manufacturers on data we can reliably and vontinuously provide for AT onboard client or FMS to improve road safety and flows by supplying data on planned changes, roads are clear of snow, state of road network, hazardous incidents, weather, route planning, road characteristics, friction, speed limits (variable), advisory speed limit, queues, adverse weather, lane closure, roadworks, obstables
R	37	We are assured of secure V2V, V2I and V2TCC connectivity
R	38	We can use C-ITS (e.g. warning of light changes) rather than expensive physical changes to infrastructure to reduce congestion
R	39	We need manufacturers to share data and work with us and other regulators at EU level to develop type approval and on their *collective* needs for road infrastructure developments that we can consider alongside other needs
R	40	Will not be legally responsible for data provided to vehicles
R	41	We work with OEMs/LA on procedures that allow us to determine whether the load is secure
R	42	Out traffic central is warned immediately that an AT has stopped due to engine/tyre/brake/cargo trouble - may require legislation
R	43	We see that road networks at freight villages or port terminals are a good testbed for AT before testing on public roads
R	44	We see that AT can handle normal complex "social" traffic situations involving interactions with human road users such as braking for (real) obstacles, pedestrian crossings, roundabouts
R	45	We will see evidence that AT are involved in less near miss or hazardous situations than trucks with human drivers
R	46	Port road operators expect to be able to direct vehicle successfully
R	47	Customs may need to interface with, control and access the AT
R	48	We can control road accessibility and flexibly set maximum speed limit for AT
R	49	Road signage is packaged digitally and sent to and processed by the AVs which behaves accordingly
R	50	We can support use areas that improve road safety e.g. operating routine AT transport in dedicated lane overnight - could be converted bus/taxi lane
R	50	We can locate, communicate with and direct the AT, are given the digital information and physical access we need inspect the AT and cargo at borders or control stations
R	51	Toll road operators can generate increased income by dedicating lane for overnight use by AT, due to backfilling during day
R	52	We should consider how to keep other traffic from using lanes dedicated for AT
R	52	We maintain or improve security (contraband, stowaways, trafficking, theft, vandalism) despite removing the driver
R	52	Many different private and public road operators within and across countries and sectors (port) work to standardize PDI needed to enable crossing regions and borders to accommodate AT (signs, lane markings etc.)
R	53	At inspection stations we can talk to a person who is responsible for and has situational awareness of the vehicle and contents as and when we need to
R	53	Other road users should know it is AT and have situational awareness of AT
R	54	We receive data from AT companies and leverage visibility that digitalisation of AT movements will bring to learn about and improve environmental performances

R	55	We understand the functions of the border crossing and inspection stations and develop with stakeholders a reliable processes for information exchange (e.g. between customs, the customs broker, importer and exporter) and physical checking
R	56	We receive digestible data from vehicles we need that helps us improve road safety and investigate collisions and incidents
R	58	We (RAO and customs) can interrogate AT remotely to get digestible information / dahboard on situation awareness on e.g. company safety record, vehicle inspection history, type of cargo, cargo owner/cupplier/customer, mode, technical status, origin, destination, disengagements, hard braking, speed
R	59	We see necessary regulations on cybersecurity affecting AT are developed, implemented and controllable
R	61	We see that sufficient work has been done to understand the effects of automated trucks on traffic volumes and traffic flow e.g. sudden braking/swerving of traffic around, and "wide berth" and "politeness problem" are considered
R	62	We consider the effects that AT will have on traffic at charging areas along roads that are already congested today
R	63	Infrastructure modifications, dedicated lanes, approval for trials e.g. at night may require political decisions; modifications will need to work for different types of AT and possibly AV so there may be a need for standards
R	63	We help test in different situations (night/day, lot of light/not so much light, sunny/rainy or snowy, no traffic/lot of traffic) to learn on effects on safety, congestion on traffic behind
R	64	We expect that trials of one or two AT consider the ramifications of having many more AT operating
R	65	It has to be possible to stop the truck in order to check it
R	66	We need to know if cargo is hazardous in the event of stops or incidents
R	67	To ensure safety, if the truck is controlled remotely after an incident, we know that the remote control has full situation awareness of site events (e.g. oil spill) and does not interfere with operations on site
R	68	We are clear about the legal requirements for AT, expect manufacturers/operators to follow them and can check them
R	70	We see reduction in NOx and CO2 emissions from trucks on the road
R	74	If road not drivable we can withdraw digital permission for vehicle to drive
R	75	We (some) are positive to dedicating one lane of a specific multi-lane highway for testing where we can see clear potential benefits to users of that road and where political will and regulations allow
R	77	Super-control of all automated trucks using the road or of different remote ops might be needed and will require open data sharing from manufacturers and truck operators, probably regulation for this too
R	78	Automated trucks reduce noise
R	80	Port road operators need process for port access and situation awareness (with live tracking) on ingoing / outgoing trucks and their container number and cargo
R	82	We know that AT reduces and does not increase congestion on port roads and in terminals
R	83	We process trucks effectively and continuously at borders so they are not released in pulses causing congestion upstream
R	87	We develop legislation so that EC ultimately will be able to demand changes to highway codes to accommodate automated trucks
R	88	We receive info from trucks on queues (e.g. 20 trucks slow down in same area), CAM messages, braking/steering patterns implying need for road maintenance
R	89	Need to think through how traffic management by road authorities might change e.g. visualize and respond to vehicle movements in real time
R	90	Port needs traffic management system for AT using its roads that coordinates movements for optimal flows
R	91	AT must always be monitored
R	99	We are interested in short-term roll-out limited to simple physical infrastructure settings at night
R	100	Pictures, movies and data should be able to be deleted
R	101	Permits to operate AT must be in place accounting for cargo (hazardous) including certification for remote operators
R	105	Assess effects of AT on land and energy use through need for more parking areas or more hubs or load transfers for last mile deliveries
R	108	Traffic police: the differentiated and targeted addressing and controlling of automated vehicles and human drivers
R	109	Evaluating which concrete support measures of the infrastructure have made a difference in the end in terms of effectiveness & efficiency and applying learnings by adapting infrastructure
R	125	We can requirements for use of AT by our services through tenders
R	126	Citizens should be informed of what is happening before AT is implemented in their society to develop trust
R	127	AT systems need successful interplay between infrastructure and vehicle and, where relevant, a control center or control tower
R	128	No increased risks due to automated cargo handling or securement in absence of qualified/experienced driver

R	140	Munipalities need to know which data should be shared between them and customs or port
R	142	Measure operator response time to incidents involving AT - how long before blockage removed?
S	5	As regulators we work internationally and with harmonized manufacturers to overhaul and standardize road, vehicle, cargo-handling and connectivtiy standards, rules and regulations in a case-independent way (homologation) , to account for mixed traffic, border crossing, standard PDI. vehicle technology modifications and maintenance (e.g. sensors, LIDAR)
S	27	We (and researchers) can collect technical requirements from demonstrations order to standardize
S	37	As road authorities, port authorities and customs we will need information about the automated transport system and competence to assess it
S	40	Contingency plans are developed describing roles and responsibilities for AT and other actors in the event of natural or man-made disasters, demonstrations or roadblocks
S	41	We know that automated trucks will not decrease traffic flows and acceptance by other road users by operating at lower speed in mixed traffic
S	42	We know that trucks stop safely and in safe locations if in difficulty and transition between manual and automatic operation safely and in safe locations
S	45	We consider segregating AT from other road users for optimal safety
S	49	We know that when safety in the operational geofence is not guaranteed the truck should stop safely or safely transfer control to an alert human driver
S	53	We see that AT can detect and respond appropriately to approaching or stopped emergency vehicles
S	54	We can still enforce the responsible party to make necessary physical adjustments to the cargo or vehicle as and when needed
S	59	We can consider digital speed limits that match optimum energy use by engine
S	61	We do not have to depend on anything outside the vehicle to validate the safety of the truck
S	63	Remote centre receives detailed real-time data it needs to ensure the robustness and functioning of the truck
S	71	AT helps address lack of parking facilities and reduce land use, curb space taken by trucks
T	31	We have analysed system scenarios and mitigated risks e.g. need to open dedicated lane when crash in non-trucking lane, decide criteria when AT can attempt to evacuate from tunnel fire
T	55	We can use digestible data gathered from autonomus trucks to upgrade physical and digital infrastructure and learn about missing signs from differences between HD maps and perceived objects
T	58	We understand the commonality of the data between the government and automotive sector
T	59	We know how long the changes we make will last and how they can be kept up-to-date for developing technology
T	63	The transport system depends on interoperability - so we - and EU projects - need collaborate and specify data/interface standards, infrastructure, customs, tolls, charging, parking (haulier can come from Norway to Sicily with automated truck), and vehicles and platforms (so big companies must not develop exclusive platforms and ecosystems around automated transport as this may lead to poor interoperability and suboptimal AT systems in traffic)
T	68	We understand and can mitigate the risks (probability and consequences) of data and connectivity systems needed for AT and other AVs dropping out or being sabotaged - may require 24/ operational centers and system redesign to account for evolving technology
T	70	We need to collaborate on granting site permission to develop the background and competence we need to assess L4
T	93	We account for information needs between the connected vehicles and the non-connected vehicles (external HMI)
W	9	We reduce not increase opportunities for or consequences of terrorist attacks or increase risks to harm from cyber attacks or GPS spoofing in society