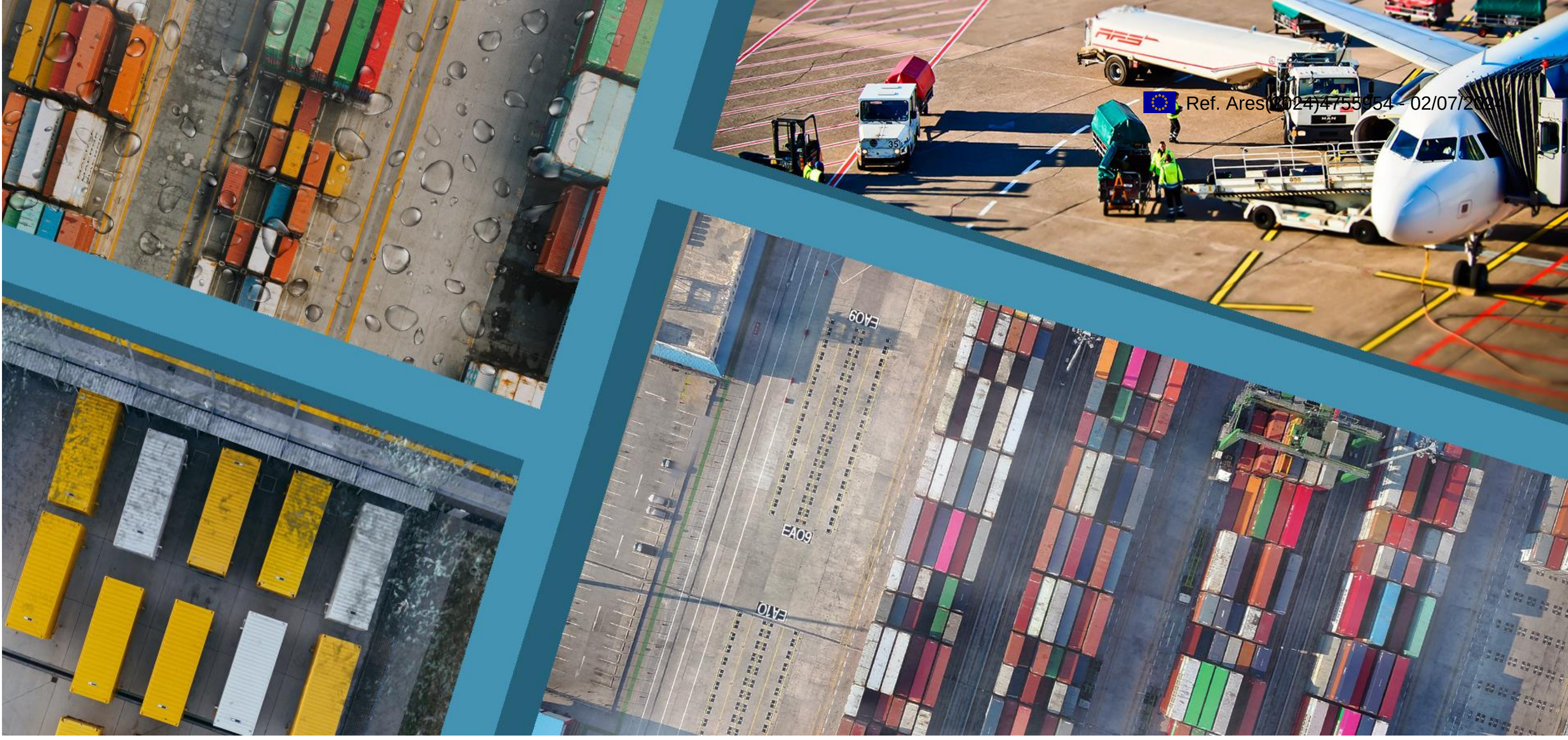

D8.4
Recommendations – regulatory and governance frameworks

—

Lead: CERTX

Due date: June 2024

Actual delivery date: 02/07/2024

Dissemination level: PU

The project has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No 101006817.

Document information

Project	
Project Acronym	AWARD
Project Full Title	All Weather Autonomous Real logistics operations and Demonstrations
Grant Agreement No.	101006817 - H2020-DT-ART-2020
Project Coordinator	EasyMile
Website	www.award-h2020.eu
Starting Date	January 1st, 2021
Duration	42 months

Deliverable	
Deliverable No. – Title	D8.4 – Recommendations – regulatory and governance frameworks
Dissemination Level	Public
Deliverable Type	Report
Work Package No. – Title	WP8 – Economic viability, definition of new business models and regulatory framework
Deliverable Leader	CERTX
Responsible Author(s)	Victoire Couëlle (IRU), Niku Gorji (CertX)
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Quality Peer Review	Magali Cottevieille (EasyMile)
Submission date	02/07/2024

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ACKNOWLEDGMENT OF EU FUNDING

The project has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No 101006817.

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Revision history

Revision Number	Date	Author	Company	Changes
0.1	05/07/2023	Victoire Couëlle, Sylvain Rhême, Ted Zotos	IRU, CERTX	Initial version
0.2	30/02/2023	Jean-Louis Pirat Rebecca Ronke, Dominik Schallauer, Jasmina Turkovic, Sylvain Rhême, Victoire Couëlle, Guillaume Travers	FRACS, Applied Autonomy, AustriaTech, CERTX, IRU, CARA	Input national and international regulation
0.3	17/08/2023	Ann Christin Patzelt, Niku Gorji, Victoire Couëlle, Jean-Louis Pirat, Dominik Schallauer, Jasmina Turkovic	CERTX, IRU, FRACS, AustriaTech	Input on analysis
0.4	7/10/2023	Victoire Couëlle, Holger Loewendorf, Niku Gorji	IRU, CERTX	Review of content
0.5	1/04/2024	Victoire Couëlle, Ann Christin Patzelt, Niku Gorji, Rebecca Ronke Jean-Louis Pirat, Marine Thomasson, Jasmina Turkovic, Dominik Schallauer	IRU, CERTX, Applied Autonomy, FRACS, CARA, Austria Tech	Input on recommendations
0.6	12/05/2024	Victoire Couëlle, Holger Loewendorf, Rebecca Ronke, Jean-Louis Pirat, Niku Gorji, Marine Thomasson	IRU, FRACS, Applied Autonomy, CERTX, CARA	Review of content
0.7	18/06/2024	Sami Koskinen	VTT	Technical peer review
0.8	28/06/2024	Magali Cottevieille	EasyMile	Quality review
1	01/07/2023	Victoire Couëlle, Suzanne Hoadley, Niku Gorji	IRU, CERTX	Final version
1.1	02/07	Magali Cottevieille	EasyMile	Minor modifications

Table of contents

List of figures

List of tables

List of acronyms

ADS	Autonomous Driving System
ADS-DV	Automated Driving System - Driving Vehicle
AGV	Automated Guided Vehicles
AI	Artificial Intelligence
ALKS	Automated Lane Keeping Systems
AltMoC	Alternative Means of Compliance
AltMoCa	Alternative Means of Compliance
AMC	Acceptable Means of Compliance
AMDB	Airport Mapping Data Base
AMS	Apron Management Service
ANS	Air Navigation Services
ARC	Determination of the Air Risk Class
ARTS	Automated Road Transport System
ASPICE	Automotive Software Process Improvement Capability dEtermination
ATM	Air Traffic Management
ATS	Air Traffic Services
AV	Autonomous Vehicle
ConOps	Concept of Operations
CS	Cybersecurity
CSMS	Cyber Security Management System
DDT	Dynamic Driving Task
EASA	European Union Aviation Safety Agency
ESPE	Electro-sensitive protective equipment
FEDRO	Federal Roads Office
FMS	Fleet Management System
FOD	Foreign Object Debris
FuSA	Functional Safety
GRC	Determination of Ground Risk Class
HMI	Human Machine Interface
ICAO	International Civil Aviation Organisation
ISO	International Organization for Standardization
JARUS	Joint Authorities for Rulemaking on Unmanned Systems

KBA	Federal Motor Transport Authority
LiDAR	Light Detection and Ranging
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
OSO	Operational Safety Objectives
PACTE	Plan d'Action pour la Croissance et la Transformation des Entreprises *(Action Plan for Business Growth and Transformation)*
PANS	Procedures for Air Navigation Services
PANS	Procedures for Air Navigation Services
PDRA	Predefined Risk Assessment
RD	Road Directorate
RFFS	Rescue and Fire-Fighting Service
RPAS	Remotely Piloted Aircraft Systems
SAE	Society of Automotive Engineers
SAIL	Specific Assurance Integrity Level
SAM	Safety Assessment Method
SARPS	Standards and Recommended Practices
SBOM	Software bill of materials
SMGCS	Surface Movement Guidance and Control Systems
SMS	Safety Management System
SORA	Safety of Operation Risk Assessment
SOTIF	Safety of the intended functionality
SRP/CS	Safety-Related Parts of Control Systems
StVG	Strassenverkehrsgesetz (*Road Traffic Act*)
TAM	Total Addressable Market
TSVA	Test of Self-driving Vehicles Act
TÜV	Technischer Uberwachungsverein (*Association for Technical Inspection*)
UAS	Unmanned Aircraft Systems
UNECE	United Nations Economic Commission for Europe
VTA	Vehicle Type Approvals
WP	Work Package

1. Executive Summary

The AWARD project has demonstrated connected and automated heavy-duty vehicles in real-life logistics operations and all-weather conditions. The main purpose of this deliverable is the development of policy recommendations as a catalyst for future large-scale testing and deployment of autonomous vehicles in logistics. These recommendations are the product of a comprehensive legislative analysis in conjunction with experiences generated from the four AWARD use cases and desk research.

Following brief explanations of vehicle automation and the project's use cases, this document presents the current regulatory landscape for autonomous vehicles at the international (non-EU), EU, and national levels. Within this jurisdictional taxonomy, further distinctions are made between regulations for road logistics, aerodromes, and ports due to the locations of the AWARD use cases. Whereas logistics operations on regular roads (public and private, including in ports) are relatively straightforward, the aerodrome use case showed that existing regulations for unmanned drones can also serve as a precedent and model when regulating autonomous vehicles (AVs). The subsequent analysis of national regulatory frameworks revealed other opportunities to close legislative gaps, standardise procedures and documentation, and provide for the overall harmonisation of rather disparate policies.

This deliverable generated recommendations in the following issue areas, discussed in detail throughout the text and summarised in a table:

- Operations involved in autonomous driving
- Operating environment monitoring
- Adverse weather conditions
- Safety and liability
- Documentation and permits.

For entities involved in the development of AVs and the related systems, this deliverable highlights several key areas to ensure effective and safe AV operations. Clarifying the types of operation, remote direct intervention and remote intervention/ assistance, and adhering to consistent terminology and categories is necessary to begin with. Furthermore, helping to arrive at a shared understanding of harsh weather conditions safe for AV operation, by clearly defining AV capacities within their designated operational design domain (ODD) and most importantly, explicitly stating the conditions outside the AV's ODD, will help reduce misunderstandings.

Ensuring technological maturity and safety in AV testing and deployment should be a core focus. This includes instilling proper safety management procedures and ensuring that operators are adequately trained on AV systems and emergency procedures. Specific training tailored to the unique aspects of AV logistics should be provided to everyone involved in operations.

Regulators must establish minimum requirements for teleoperator's working environment, to ensure their safety and effective AV performance. This includes managing their workload, providing access to AV cameras before operations, and establishing proper staffing ratios to monitor vehicle fleets. Different regulatory schemes may be required for remote operators and on-board operators, the requirements and differences need to be clearly specified.

For environment monitoring and operations in adverse weather conditions, recommendations to regulators include setting minimum requirements for the collection of data and information from both the ecosystem and vehicles, to ensure that AVs stay within their ODD and can safely operate by adjusting their mode of operation based on environmental conditions.

To establish a clear and reliable framework for hand-over of responsibilities between the different driving entities (autonomous driving system (ADS), safety driver, teleoperator) regulators should adapt national liability laws and develop EU guidelines to harmonize responsibility schemes. Before the start of AV operations, all stakeholders should agree on a handbook outlining their specific tasks and responsibilities, ensuring that teleoperators are accountable only for their assigned duties.

Measures for safe interaction with AVs in mixed environments should also be implemented. Signals indicating AV presence should be clear, simple, and harmonized across the EU, and for aerodrome activities at a global level, i.e. ICAO (UN). AV perception systems and object detection capabilities should meet zoning requirements to protect different categories of individuals, and fleet management systems should include functionalities to safeguard vulnerable users in operating areas.

With regards to documentation and permits for AV operations, three key recommendations are provided. Firstly, a harmonized testing and development permit procedure across the EU is recommended to ensure clarity and a level playing field across EU Member States. Operators should notify relevant authorities of any changes to the AV testing and/or deployment parameters, with new permits required only for changes impacting risk assessment.

Secondly, common guidelines on Safety Assessment Methods (SAM) should be developed to facilitate information sharing among stakeholders involved in AV testing and deployment. This includes creating a common risk assessment methodology and providing sample documents and guidance for standard scenarios to foster clarity and consistency.

Thirdly, recognition of national safety assessment and validation certificates across the world would enable cross-border testing and reduce administrative burdens. Regulators should identify common safety assessment criteria that can be mutually recognized and complemented by national requirements. In the long term, establishing an advisory group with representatives from the industry, operators, and authorities from different countries can help to develop harmonized guidance for obtaining system approval.

As autonomous vehicle technology remains a relatively recent field marked by rapid development, the contributors to this document also identified liability for cargo, maintenance, and options to allow direct remote driving as research needs and potential for future legislation. In short, the work performed in AWARD is highly relevant on its own and can be a building block for future projects.

2. Introduction

2.1. Aim of AWARD

AWARD aims to support the deployment of safe autonomous transportation system in real-life logistics use cases across different scenarios, which include forklift loading/unloading, hub-to-hub open-road shuttle service, automated trailer rearrangement at a port, and airport baggage tractor. An autonomous driving system (ADS) has been developed, which is capable of handling adverse weather conditions such as heavy rain, snowfall, and fog. The ADS solution was based on multiple sensor modalities to allow 24/7 operations. The ADS was integrated into multiple vehicle types operating at low speed, mostly in confined areas. These vehicles were tested and demonstrated in various real-life environments to validate their functionality and to identify limitations to, and opportunities for, further research.

AWARD also sought to optimise logistics operations through a new Fleet Management System (FMS) that acts as a control tower, gathering all information from subsystems (vehicles, road sensors, etc.) to coordinate the operations and to protect vulnerable road users. The project aimed to enable the commercial exploitation of AV technology and to generate policy recommendations for certification processes.

2.2. Scope of T8.4 and relationships with other WPs

This task focuses on regulatory and policy frameworks based on the practical experiences of the AWARD use cases. Following an analysis of existing ADS regulations and the use case experiences in AWARD, a series of recommendations is provided in this deliverable to achieve the safe and efficient testing and deployment of ADS in logistics. These recommendations are an integral part of the public dissemination efforts outlined in WP9.

This is a public report. In addition to its internal use by the AWARD consortium partners (the relationship of this task to other WPs is explained above), external stakeholders including policymakers, researchers, private companies, the public, and many others working on mobility and logistics can use the analysis performed in this report.

2.3. Methodology

This document focuses on key policies and regulations addressing the testing and deployment of autonomous vehicles (AV) in real logistics operations. The main purpose of this deliverable is to generate policy recommendations, which are derived by reconciling existing regulations with the most recent practical experiences gained in the AWARD use cases.

The empirical evidence for this deliverable was produced through a combination of desk research (including gap analyses), experience gathered in use cases to identify opportunities to revise existing regulatory frameworks, and desk research outside of legal texts. The legislative research included extensive analysis of relevant legislation and standards with a focus on their applicability to the AWARD use cases at the following geographic levels:

- International
- European Union

– EU member states/national

Within the legislative research, a gap analysis was the predominant method adopted to identify how existing legislation could be amended, revised, or harmonised to create policy recommendations with EU policymakers as the primary audience. In addition, relevant input from the AWARD use cases has been further developed and analysed to identify regulatory barriers and drivers for optimising AV deployment in logistics. The practical experience from the AWARD use cases was conveyed in reports and interviews. Finally, desk research drawing on publicly available sources, commonly referred to as “grey literature”, complemented the legislative and experiential sources.

Regarding technical terminology and unless indicated otherwise, this deliverable adheres to the taxonomy developed in the EU-funded networking project FAME. Among other objectives, this classification system is meant to enhance the comparability of research and thus corresponds to the goals of AWARD as well.

3. Autonomous vehicles in logistics

Warehouse yards, airports, seaports, and other closed logistics facilities typically allow quicker implementation of self-driving vehicles than public areas, such as open roads, because these private premises are usually subject to less stringent regulations. With an industry-wide labour shortage and focus on safety in operations, logistics organizations are eyeing these closed grounds as entry points for various outdoor autonomous vehicle operations, and there are many tech providers preparing to provide suitable products and services.[1]

3.1. Level of vehicle automation

In this document, reference will be made to the Society of Automotive Engineers (SAE) "Levels of Driving Automation Refined for Clarity and International Audience", describing six levels of automation, ranging from level 0 (no driving automation) to level 5 (full driving automation). Figure 1 below illustrates this gradual shift of vehicle features and operating systems towards full automation by summarising the information and characteristics of each level of automation and outlining the respective role of the driver and the vehicle.

AWARD considers and studies components for automation levels 3, 4 and 5. For present purposes, the term "automated vehicle" used in this document will refer to these vehicles, which are able to drive themselves for a portion of a trip (level 3 and 4).

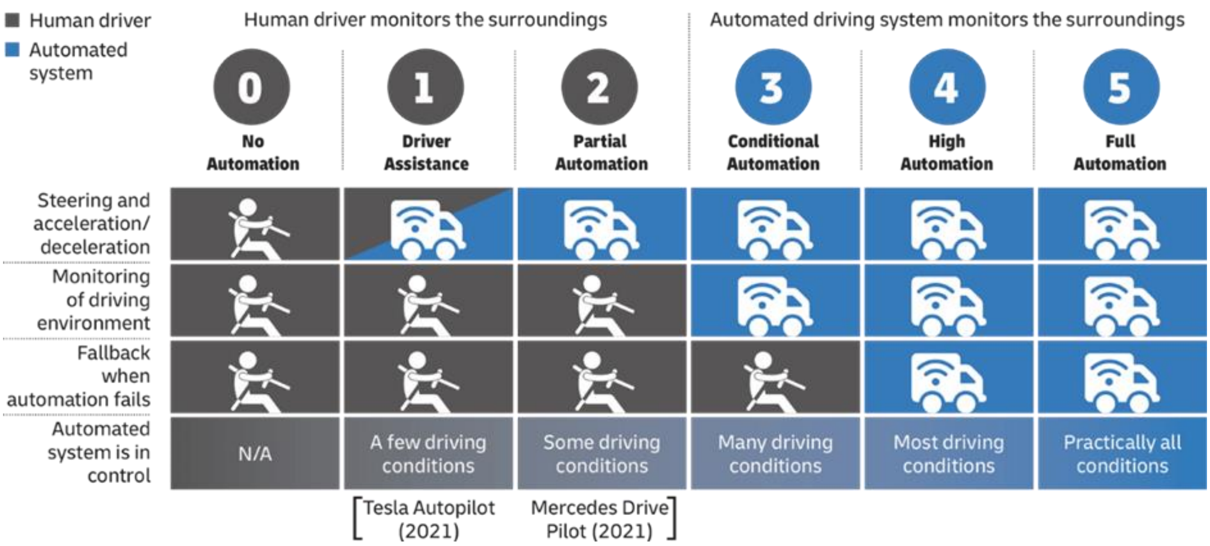

Figure 1: Levels of vehicle automation, with respective functions (source: SAE)

3.2. AWARD Use cases

The following sections provide brief summaries of the four AWARD use cases. A more comprehensive overview can be found in AWARD D2.1.

[1] DHL 2022.

3.2.1. Automated forklift use case

This use case took place in the town of Seibersdorf (Austria) to recreate real-world loading environments in outdoor logistics. Empty racks were moved by an electric automated forklift from a transfer location (point 2) to storage yard stacks (point 3 in Figure 2).

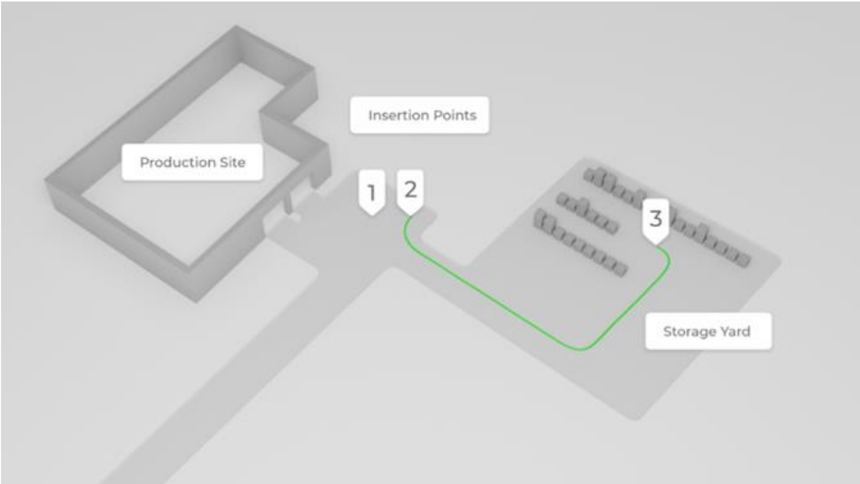

Figure 2: Diagram of the AWARD forklift use case

3.2.2. Hub-to-hub use case

This use case aimed to automate the connection between a production factory and a logistic hub for the transportation of production parts.

An electric automated truck ("swap body transporter") delivered production goods between two adjacent sites (points 1 and 3 in Figure 3) which were separated by a busy public road (point 4). The automated truck first drove boxes from the logistic hub to the production factory, where they were manually (un-)loaded. The boxes were then carried back to the logistics hub, where they were manually (un-)loaded on the vehicle.

Figure 3: Diagram of the AWARD hub-to-hub use case

The truck ran according to a fixed timetable. This shuttle represented a 2-minute drive (600m) and operated every full hour from 6 am to no later than 10 pm, from Monday to Friday. It navigated mixed traffic at the sites and on the public road, including several complex junctions where there were crossing areas with traffic lights and a main road (example: point 2).

3.2.3. Automated ship loading use case

The port demonstration took place at DFDS's Rotterdam (Vlaardingen) terminal in the Netherlands (Figure 4). The tests focused on an automated Terberg Tug that moved trailers in the terminal area.

In addition to rearranging trailers, the planned routes included gate transits to and from public road and also loading and unloading of a ship.

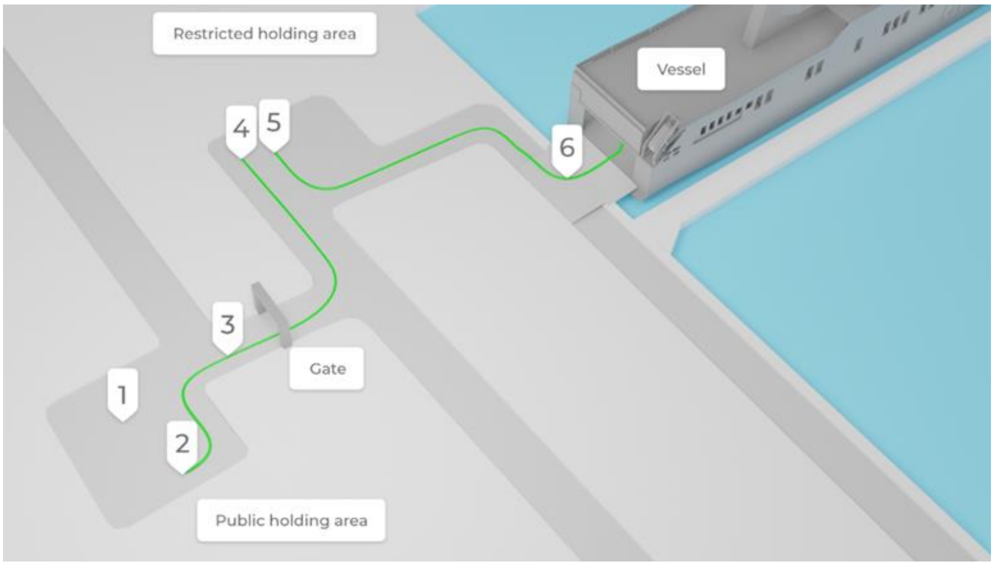

Figure 4: Diagram of the AWARD automated ship loading use case

3.2.4. Aerodrome baggage tractor

This use case carried out at Avinor OSL Gardermoen airport (Norway) demonstrated the ability and limitations of autonomous baggage tractors to transport goods in outdoor and indoor environments.

An autonomous baggage tractor moved dolly trains on different routes (points 1-3 in Figure 5) between the baggage handling area, a proximity storage, and an aircraft stand. First, the autonomous tractor picked up bag carts from the aircraft stand and brought them to the arrival terminal (route 1). Then, it picked up the empty bag carts from the intermediate storage and brought them to carts' storage (route 2). Unhooking and hooking carts was done manually throughout the project timeline.

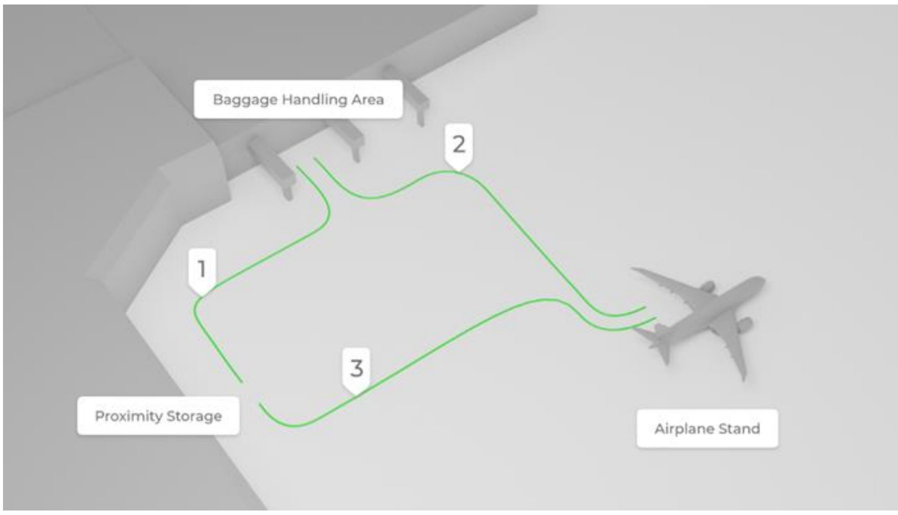

Figure 5: Diagram of the AWARD baggage handler use case

The vehicle only drove on private premises and had a maximum speed of 30 km/h. The autonomous vehicle was slightly wider than a normal tractor, approximately 40 cm, due to sensor instrumentation. The tractor navigated on the open tarmac (and crossed a tunnel) together with other vehicles, such as cars and other tractors, as well as human handlers and other workers.

4. International AV regulatory framework

The following sections provide an overview of general and global frameworks applicable to autonomous vehicles that guide the use of Automated Driving Systems (ADS) in road transport, at airports, and in port logistics.

4.1. Road logistics

Road logistics are covered at the most general and global level by several UN regulations and ISO standards. The EU establishes the regulatory framework for vehicle standards and autonomous vehicle operations within Europe. Documents produced by the UN and ISO organisation are the focal point of Section 4.1., which concludes with a discussion of their relevance for the AWARD project.

4.1.1. UN Vienna Convention

The 1949 Geneva Convention on Road Traffic and the 1968 Vienna Convention on Road Traffic define national traffic laws of countries having signed either of these conventions. While the Geneva Convention focuses on promoting road safety by establishing uniform rules across borders (e.g., driving permits), the Vienna Convention focuses on technical requirements of vehicles. Both Conventions stipulate and refer to a specific definition of "driver", which requires the presence of a human to control the vehicle ('*Every moving vehicle or combination of vehicles shall have a driver*", see Art. 8, paragraph 1) and human control of it ("*Every driver shall at all times be able to control his vehicle or to guide his animals*", see Art. 8, paragraph 5 of the Vienna Convention). Being the foundation of national traffic laws, this definition and interpretation of "driver" as a physical person within and fully in charge of the vehicle was an obstacle to the deployment of automated vehicles on open roads.

On November 3, 2021, an amendment to the Vienna Convention partially addressed this issue and enabled the use of ADS on public roads. This was made possible by inserting a new Article (34bis) which "deem(s)" the driver requirement "to be satisfied" while the vehicle is using an ADS. However, it is important to note that the ADS must comply with international technical regulations and national rules, including domestic legislation on operation, and continues to require human supervision (through teleoperation or technical supervision) with the ability to always take control of the automated system. Therefore, while this provision enables the deployment of lower levels of vehicle automation (SAE level 3 and 4), it does not yet provide a solution for fully automated vehicles (SAE level 5).

4.1.2. UN Regulations

To be approved, the ADS must first comply with international technical regulations. In 2016, the United Nations Economic Commission for Europe (UNECE) World Forum for the

Harmonization of Vehicle Regulations (WP.29) started setting regulatory minimum requirements for type-approved vehicles.[2] As a result, in January 2021, three new UN Regulations on connected and automated driving, meant to ensure the safety of AV systems, entered into force and are now applicable in the 54 contracting parties to the 1958 Agreement.[3]

These new regulations relate to:

- Cybersecurity Management Systems (CSMS, UN Regulation 155)
- Software Update Management System (SUMS, UN Regulation 156)
- Automated Lane Keeping Systems (ALKS, UN Regulation 157).

The following sections provide a brief overview of minimum safety requirements at the UN level set in place to obtain type approval for road vehicles.

4.1.2.1. UN R155 (Cyber Security Management System)

UN Regulation 155 on Cybersecurity and Cybersecurity Management System (UN R155) introduces binding cybersecurity management requirements that Original Equipment Manufacturers (OEM) must submit to competent authorities.

UN R155 establishes a cybersecurity process framework, also called Cyber Security Management System (CSMS) that vehicle manufacturers must demonstrate to obtain a CSMS certificate, a prerequisite to obtain a valid vehicle type approval. During this initial evaluation, manufacturers must identify and assess any cyber threats and provide mitigation measures to address risks and meet requirements. This certificate is not bound to a specific car program and represents the evidence that a manufacturer has the organizational capability to meet UN R155 requirements.

After having successfully obtained the CSMS certificate, vehicle manufacturers may apply for Vehicle Type Approvals (VTA). Carried out by an independent testing institute, this second step evaluates whether the process framework previously “certified” has been effectively applied in the context of a specific car program or vehicle type. During this second phase, manufacturers must present documentation demonstrating vehicle security process implementation (e.g., for risk assessment processes, this includes evidence of complete risk assessment details for a specific vehicle type).[4]

After having obtained type approval, vehicle manufacturers must regularly (at least once a year) report the outcome of their monitoring activities as well as any information related to new cyberattacks and potential incidents which might require adjusting security measures. This reporting enables manufacturer to demonstrate to authorities that cybersecurity protection measures are still effective and adequate against an evolving threat landscape.[5] There-

[2] M. Lance, 2021.

[3] Hogan Lovells, 2021.

[4] Note: for car programs initiated before CSMS certification, deviations from such processes are allowed by June 2024, but require justifications.

[5] If the reporting or response is not sufficient, the approval authority may decide to withdraw the CSMS certificate (and therefore suspend type approval).

fore, to maintain this authorization, regular checks are required to confirm the continuous application of security processes throughout the entire vehicle life cycle. The full process is summarized and illustrated in Figure 6 below.

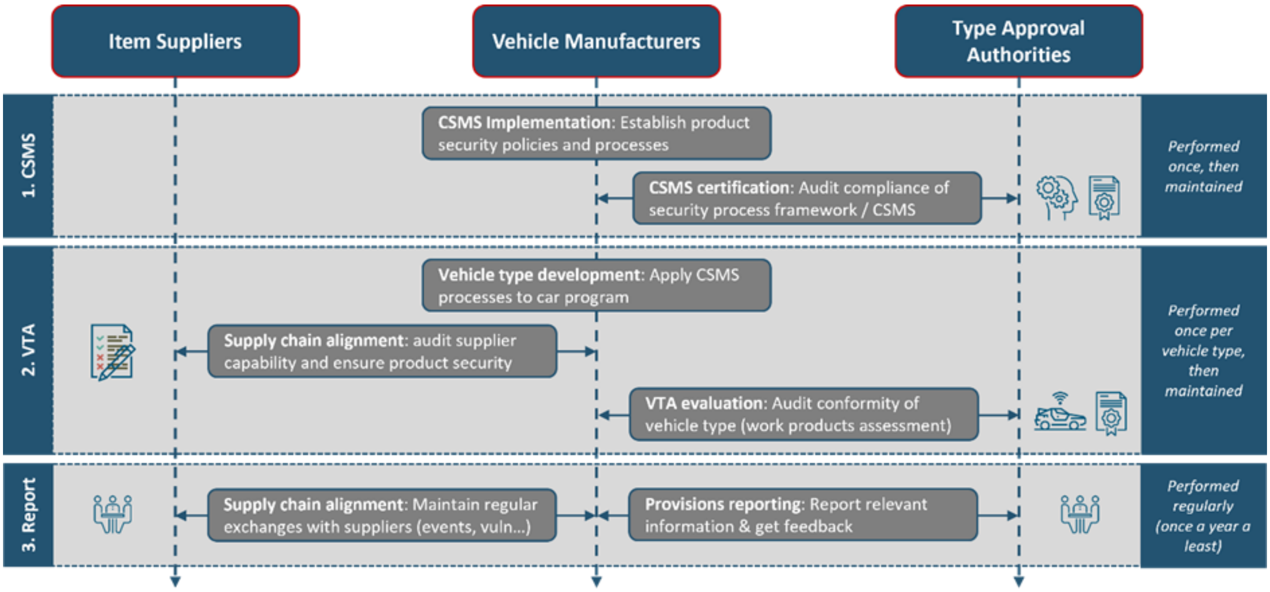

Figure 6: UNR155 process (source: CertX)

4.1.2.2. UN 156 (Software Update and Software Update Management System)

UN Regulation 156 on Software Updates and Software Updates Management Systems (UN R156) requires vehicle manufacturers to demonstrate compliance with new requirements of vehicle software versions, and how to manage them. Similar to UN R155 for cybersecurity, vehicle manufacturers must provide evidence for the traceability of software parts throughout the vehicle's entire lifecycle.

These rules are legally enforced for any new vehicle type approval, impacting suppliers and any other supply chain stakeholders. In fact, any software update deployed in a vehicle by a manufacturer, either developed in-house or provided by suppliers supervised by the manufacturer, requires a specific set of activities depending on their impact on vehicle type approved systems. Non-conformity with UN R156 can lead to a ban on sales throughout UN territory.

In the context of UN R156, a "software update" is defined as "a package used to upgrade software to a new version including a change of the configuration parameters". This broad definition allows to address any software parts that could impact the vehicle type approved systems. For instance, this might include software updates related to the in-vehicle infotainment system that provides a variety of information and entertainment services (e.g., digital radio, reversing camera, button-panel) as well as software updates related to high-level applications such as component-targeted firmware. In addition, the procedure for deploying the software update is also considered in this regulation, either Over the Air (OTA) or wired at a car dealer or a car repair centre.

As an introduction to UN R156 requirements, the flowgraph below (Figure 7) describes high-level procedures that manufacturers are required to follow for the application and continuous compliance with UN R156 requirements.

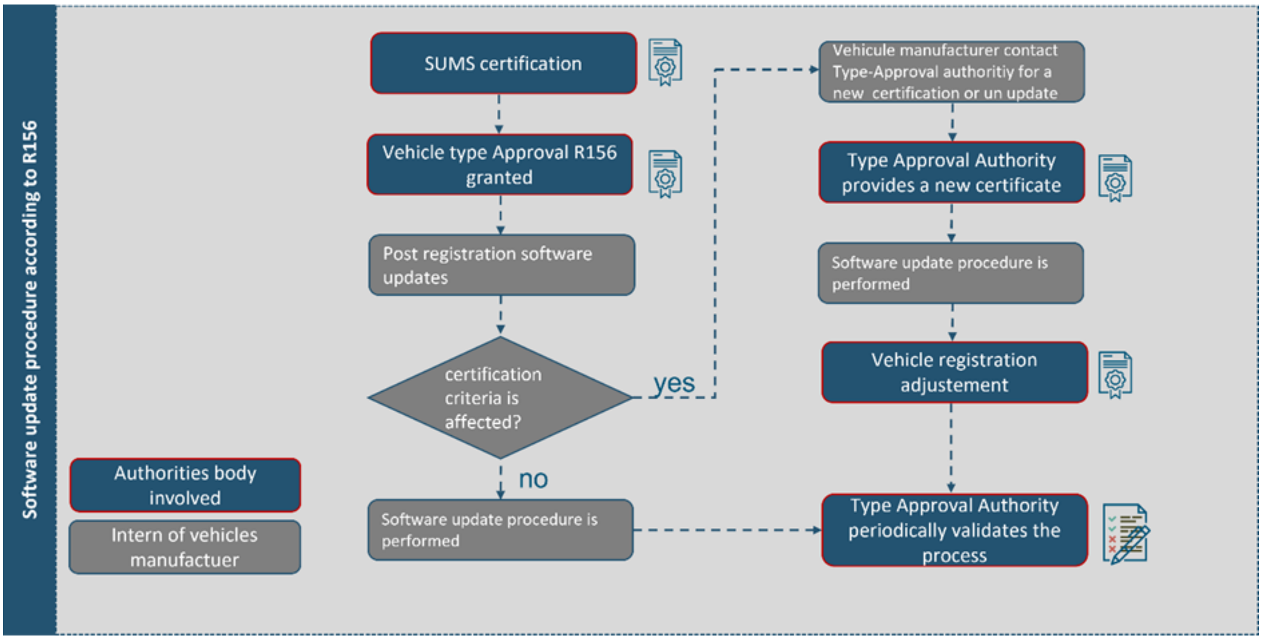

Figure 7: Software update procedure according to UNR 156 (source: CertX)

The key requirements in UN R156 are focused on the full lifecycle of an update, from the security and qualification of the update itself to the reliability of the delivery and deployment procedure.

4.1.2.3. UN 157 (Automated Lane Keeping System)

UN Regulation 157 (UN R157) is the first binding international regulation on automated vehicles for SAE Level 3, adopted in June 2020. It establishes uniform provisions for the approval of vehicles with Automated Lane Keeping Systems (ALKS), which controls the vehicle's movement for extended periods without further driver command. An amendment to the regulation adopted in June 2022 extended the automatic driving systems' maximum speed from 60 km/h up to 130 km/h in certain traffic environments. These systems can only be activated in road environments physically separated from traffic moving from the opposite direction, in which pedestrians and cyclists are prohibited and under the requirement that the systems' control can be overridden at any moment. For automated vehicles replacing the driver on motorways (Level 3 automation), EU legislation aligns with the UN and its latest rules on Level 3 automation.

UN R157 also includes requirements for system safety, failsafe response, and safe handover of driving tasks from the ALKS to the driver, as well as the human-machine Interface to prevent misunderstanding or misuse by the driver.

In addition, UN R157 contains a definition of "reasonable risk" as a unique aspect in its regulatory and standardization framework. UN R157, Annex 4 Clause 2.16 defines "unreasonable risk" as the overall level of risk that is increased for the driver, vehicle occupants, and other road users compared to a manually driven vehicle operated competently and carefully. This definition differs from ISO 26262-1:2018 Clause 3.176, which defines "unacceptable risk" as risk judged to be unacceptable based on valid societal moral concepts.

Compared to the ISO definition, UN R157 sets a threshold for acceptable risk that can be measured and argued to some extent. This enables the approval of vehicles with higher levels of automation, acknowledging the presence of residual risk and providing guidance on how to quantify it. The homologation process in UN R157 demands independent audits of relevant processes and their implementation, unlike the traditional process where real-world test drives at the end of the development process form the basis for homologation.

4.1.3. Relevance of UN regulations and ISO standards for AWARD

Currently, compliance with UN regulations is not a requirement to test AVs in pre-defined and approved EU geographic areas. Within the AWARD project, which solely focused on AV testing, the application of and compliance with national testing regulations are the main requirements to obtain an AV testing permit.

Even if not necessary in the context of AWARD, compliance with UN R155 and UN R156 can be an advantage for future applications to carry out testing or deployment of AVs. Adherence to this framework can accelerate the procedure to obtain a permit to test automated vehicles in another country, as some documents to prove the safety of the AV to be tested will have already been filed and could be accepted by other national competent authorities.

Compliance with these UN regulations becomes increasingly relevant for normal operations, where the autonomous vehicle is set to carry out logistical operations tasks in the "real world". If, for example, an operation is to be conducted in a hub-to-hub context on public roads with type-approved AVs, these vehicles must comply with UN R155 UN R156, as this is a requirement set in Regulation EU 2022/1426 for the type-approval of ADS. The scope of EU 2022/1426 regarding AV is wider than UN R157, Automated Lane Keeping Systems (ALKS). Therefore, EU regulation is a strong baseline for the AWARD use cases.

4.1.4. ISO Standards

The International Organization for Standardization (ISO) is an independent non-governmental organisation composed of 170 national standards bodies. Since 1947, ISO has been issuing over 25,000 standards covering various aspects of technology, management, and manufacturing (ISO). If ISO standards are voluntary, they can become binding when integrated into regulatory frameworks (ISO/IEC 2015).

Safety activities carried out in AWARD followed the ISO 26262:2018 Functional Safety (FuSa) recommendations. Functional safety describes the absence of unreasonable risk that could be caused by malfunctions of any electronic or electrical system. ISO 26262 defines a set of process requirements and provides methods for analysis, development, verification, and testing of items relevant to functional safety of the AV.

ISO 26262 is a standard applicable to road vehicles, but its scope has been extended to all use cases and platforms used in the AWARD project (forklift, hub-to-hub, automated ship loading, and airport use cases). Similarly, ISO 21448:2022 was used to evaluate the Safety of Intended Functionality (SOTIF) of AVs. Dedicated deliverables and tasks in AWARD work packages 3, 4 and 6 are based on FuSa and SOTIF activities (see D2.4, D4.5, D4.7, D6.2, D6.3, D6.4, D6.5). A gap analysis was performed between ISO 26262 and two other relevant standards - ISO 3691-4 and ISO 12100 - to identify any remaining gaps from a safety perspective, which will be covered in the sections below (4.1.5. and 4.1.6.).

Beside safety aspects, cybersecurity together with operational and IT security were some of the most important aspects for the evaluation of AVs. The Fleet Management System

(FMS) is particularly relevant in connection with cybersecurity because it generates a vast amount of highly sensitive user data (related to individual privacy as well as the protection of private business interests) while the vehicles themselves are at risk of being manipulated by bad actors. The FMS was therefore evaluated as part of the activities in AWARD work package 5, following ISO/SAE 21434 and ISO 24089 recommendations.

The above-mentioned standards are among the main references used to define and evaluate the safety and security aspects of AWARD use cases. The next section provides excerpts from and references to the two other ISO standards (ISO 12100 and ISO 3691-4) that were identified early in the AWARD project (D4.1) as relevant for a gap analysis and were therefore reviewed.

ISO 12100 is the basic standard dealing with the safety of machinery, while ISO 3691-4 deals with safety requirements specifically for driverless industrial trucks (often implemented in indoor settings). These two standards are the applied norms for private sites for thousands of Automated Guided Vehicles (AGV) with good track records in terms of safety, allowing AGV to transport goods or materials within a controlled environment without the need for a human operator or driver. While AWARD use cases have implemented some recommendations from these two standards, requirements and evaluations were not based on them. The commentary in the following sections is provided as a form of gap analysis for future development.

4.1.5. ISO 12100: Gaps in use limits, interventions, and training

To be able to define risk prevention and mitigation measures, the limits of machinery must first be determined. To achieve this goal, the ISO 12100 standard requires to identify the machinery "*use limits*", which include the anticipated levels of training, experience or ability of AV users (such as operators and maintenance personnel or technicians). Even if the training, experience and ability of users can affect risk associated with the use of machinery, none of these factors can be used as a substitute for hazard elimination.

The ISO 12100 standard currently requires determining exposure of other persons to the foreseeable hazards associated with machinery. It differentiates between:

- Persons likely to have a good awareness of the specific hazards, such as operators of adjacent machinery.
- Persons with little awareness of the specific hazards but likely to have high awareness of site safety procedures or authorized routes, such as administration staff.
- Persons likely to have very little awareness of the machinery hazards or the site safety procedures, such as visitors or members of the general public, including children.

For these three groups, it is recommended to set specific requirements common to all users (i.e., by considering their background and knowledge). Detailed training on AV warning systems, required reactions, and the definition of intended use and reasonably foreseeable misuse of AVs could be developed. Going further, such trainings could include harmonised modules on basic items, such as checklists for remote handling of AVs, emergency stops design, or maintenance workarounds. Further details on different operating modes, intervention procedures for the user, and interventions required by malfunctions of the equipment could also be provided.

Safety drivers, operators, maintainers of AVs, and relevant stakeholders at the AWARD proving grounds and all test sites were all given a comprehensive set of briefings and written instructions. However, the use limits, level of detail, and the scope of the training material needs to be further evaluated and extended to all persons with potential exposure to AVs as recommended by the standard to ensure the safety of AV operations.

4.1.6. ISO 3691-4: Gaps in safety requirements for zones

To be approved, a project involving ADS must be analysed with respect to safety and risks. Both the environment in which the AV is to operate and the interactions with said environment must be carefully described, and risk and mitigating measures need to be explained. This section of the document clarifies the safety requirements for zones where driverless trucks operate, which must comply with requirements defined in ISO 3691-4 Annex A (normative). This standard provides specifications for the preparations of the operating zone to eliminate associated hazards. Specifications include the speed of trucks in different zones and conditions to enable AV stop and automatic restart functions.

To ensure that autonomous trucks can safely operate within a pre-defined zone, it is necessary to first determine the nature of the zone based on its structural aspects and objects within it, such as racking, columns, block storage, or any other expected objects. Based on these aspects, and the clearance of the vehicle from the structure and objects along its path during operation, an operating zone can be further categorised as an “operating hazard”, “restricted” or “confined” zone.

Specific requirements are provided in ISO 3691-4 for each of these zones. For example, zones with inadequate clearance that cannot be protected by personnel detection means need to be clearly marked by suitable signs and floor/ground markings, and the vehicle needs to emit additional auditory or optical warnings during operation.

It is recommended that zone requirements of ISO 3691-4 be considered in the future for the integration of AVs in industrial sites with mixed (manual and automated) trucks to improve safety.

Furthermore, the FMS can be a useful tool to show the status of AVs across different operating zones, the current position of vehicles in the fleet, and their next intended movements. While not a substitute for hazard elimination, FMS can help personnel or facility users move around the industrial site in a safer manner and avoid potentially dangerous areas. FMS can be helpful to address some of the safety requirements of ISO 3691 in future projects. However, due to the presence of safety drivers in the AWARD use cases and the small scale of the operations tested in this project, the risk across operating zones was very low and did not warrant the large effort of involving other facility users to test the benefits of the FMS for the purpose of reducing potentially hazardous situations.

4.1.7. ISO 3691-4: weather conditions

Autonomous vehicles contain sensors and safety systems which enable them to identify an obstacle (both objects or humans) and stop to avoid collisions. However, object detection across all environmental conditions is a major challenge in AV development. Heavy fog or rain, for instance, impede the sensor’s and system's ability to detect obstacles[6].

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[6] R. Tiusanen, 2020

The ISO 3691-4 standard determines normal climatic conditions for machines operations as follows:

- average ambient temperature for continuous duty: +25°C
- maximum ambient temperature, short term (up to 1 h): +40°C
- lowest ambient temperature for trucks intended for use in normal indoor conditions: +5°C
- lowest ambient temperature for trucks intended for use in normal outdoor conditions: −20°C
- altitude: up to 2 000 m.

Although outdoor ambient temperatures of -20°C are considered normal in this standard, some sensors that are used in AVs (such as Light Detection and Ranging (LiDARs)) may not be fit for operating in temperatures below −10°C.

Furthermore, since the AWARD project focuses on harsh weather rather than normal conditions, these harsh weather conditions must be defined more precisely to be able to carry out safety analysis and identify any challenges to fulfil all safety requirements of the ISO 3691-4 standard. Performance requirements for sensors may include, for instance, operation in fog as well as specification on the type of fog (e.g. density, droplet size and ambient lighting conditions vary depending on the type of fog) which may impact autonomous vehicles' sensors and safety[7].

As autonomous machinery safety systems and sensors might not work effectively under certain weather conditions (e.g., temperature below a certain degree, fog or strong winds combined with dust or sand), it is essential for AV operators and users to be aware and share the same understanding of the limits of AV technology. Unfortunately, these limits are not often clear, and the sensor's capability deteriorates gradually as conditions further deviate from the sensor's ideal working conditions. More information and recommendations on this are further developed in section 7.6.

4.2. Aerodrome logistics

Air regulations in most countries comply with International Civil Aviation Organisation (ICAO) provisions. EU Member States must comply with all EU regulations, including those of the European Union Aviation Safety Agency (EASA).

When looking at airport logistics, or more precisely "aerodromes" following the agreed terminology for the areas dedicated to aircraft movements, ICAO provisions address all types of aerodromes, while EU and EASA regulations cover European certified aerodromes. In most cases national aerodrome regulations only differ on minor items, so the analysis will focus on international aerodrome regulations. Air regulations focus on the safety of aircraft, passengers and transported goods; hence they address only specific requirements relating to vehicles, drivers and systems at airports considering they fall under other regulations.

As autonomous vehicles are not yet widely used at airports, international regulations, including derived provisions and guidance documents, do not address AV deployment and op-

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[7] R. Tiusanen, 2020

eration. However, AV trials and experiments have taken place worldwide. Summary information has been gathered in trials in the United States, Canada, Singapore, Japan, Germany, and France, in addition to the AWARD Oslo use case. From a regulatory perspective, all AV trials have been subject to a "safety assessment before change" according to the applicable aerodrome certification regulation on safety management.

Detailed information on these safety assessments has not been gathered for various reasons, including proprietary rights, language issues, or because actors are no longer in operation. The most detailed documents on AV safety assessment at aerodromes are provided by the Civil Aviation Authority of Singapore which published an Advisory Circular "Guidance on Use of Autonomous Vehicles at the Airside" in 2023.[8]

4.2.1. Drone regulation as a useful precedent for AVs at aerodromes?

Flying drones have been the subject of intense international regulatory activity to allow their operations in non-segregated airspace. ICAO is currently developing provisions to operate flying drones on airport grounds, but their regulation is considered is this section as it could be used as a model for the deployment of AVs at aerodromes.

To introduce unmanned drones, the first issue to resolve was to define the concepts under which regulations could be developed. More specifically, international aviation regulation (under the ICAO Chicago Convention) and subsequent regional and national regulations assume that a human being pilots an aircraft. For unmanned drone operations, the concepts of Remotely Piloted Aircraft Systems (RPAS) and Unmanned Aircraft Systems (UAS) were developed to enable the allocation of obligations and responsibilities to a "remote" pilot and the development of certification and operation requirements for aircraft.

Due to the quantity of regulatory provisions for flying drones, this section focuses on three documents to highlight how the aviation sector dealt with the problem of their introduction.

First, the Manual on Remotely Piloted Aircraft Systems (RPAS), ICAO doc 10019 – 2015, is a comprehensive guide to deal with various issues raised by the introduction of flying drones. Most of its content is also pertinent for the introduction of automated driving systems, notably for the development of a Concept of Operations. If automated driving systems up to SAE Level 4 are comparable with the RPAS cases, fully autonomous vehicles will need more scrutiny as the legal approaches used to deal with entirely automated driving or piloting systems may differ depending on each transport mode.

Second, the Easy Access Rules for Unmanned Aircraft Systems published by EASA in September 2022 contain, inter alia, Implementing Regulation 2019/947 on the rules and procedures for the operation of unmanned aircraft systems and the Delegated Regulation 2019/945. European drone regulations are based on risk assessment and define two categories according to the level of risk: "open" and "specific". These risk levels depend on the intrinsic characteristics of the system considered: mass, size, speed, degree of automation, and the operational context in which it is used. To assess the risks of specific operations, a Safety

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[8] Other international initiatives are Airports Council International (ACI) World's 2019 publication of the "Autonomous Vehicles and Systems at Airports Report" and the March 2024 proposal of the ICAO Aerodrome Design and Operation Panel to develop provisions and guidance on the introduction of autonomous vehicles to airside areas.

of Operation Risk Assessment (SORA) must be carried out, based on standard scenarios Pre-defined Risk Assessment (PDRA) if applicable.

Third, the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) published a set of documents on multiple aspects of SORA.[9] While SORA guidance focuses on the risks of collision in both the air and on the ground, safety assessments for rolling vehicles at aerodromes only address collisions taking place on the ground and include other safety occurrences that should be managed in the context of safety management at aerodromes (e.g., debris from foreign objects, wildlife hazards, runway incursions). Hence, if SORA guidance principles can be used as a model for a common approach, they should be simplified and adapted to meet the needs of safety assessments required to accommodate for AV deployment at aerodromes.

4.2.2. International Civil Aviation Organisation (ICAO) – Annex 14

ICAO provisions are addressed to national authorities that must transpose them within their national legislative framework. ICAO provisions include in hierarchical order:

- 19 Annexes to the ICAO Convention
- Procedures for Air Navigation Services (PANS)
- Circulars that mostly address temporary matters, and
- Manuals that guide the application of ICAO Annexes and PANS provisions.

The central ICAO aerodrome regulation for the purposes of this deliverable is Annex 14 – Aerodromes, which contains provisions directly applicable to ground operations as it covers aerodrome design and operations, which include maintenance and equipment as well as rights and obligations of states and airport operators.

ICAO Annex 14 contains basic standards and recommendations that are globally harmonised to ensure safety, regularity, and efficiency of international aircraft operations. These include specifications of pavement surface conditions, airport emergency planning, airport maintenance practices, and control of obstacles, among others. Over time, additional specifications were added to address aerodrome operations, leading to the introduction of ICAO Procedures for Air Navigation Services (PANS) - Aerodromes (Doc 9981) in 2016, which specifies harmonised aerodrome operations procedures. The document contains safety specifications for both aerodrome and vehicle operations (notably Part II, Chapter 9: "Airside Driver Permit Scheme and Vehicle/Equipment safety requirements").

However, the PANS - Aerodromes document implicitly assumes that all vehicles operating on the grounds of aerodromes are driven by a human. Since AVs are currently not included in international regulations, ICAO provisions should be adapted to include automated systems and vehicles related to the following issues, which would be developed further when use of ADS or automated equipment becomes common practice:

- Vehicle driver and operator skills, training, and authorizations
- Vehicles, notable marking and lighting
- Control and Command link performance
- Airport mapping data

[9] The full set of JARUS documents related to SORA is available at http://jarus-rpas.org/publications/.

- Airport security
- Safety of operations and integration in the aerodrome Safety Management System (SMS)
- Continuity of operations regarding capacity and efficiency
- Compatibility with the aerodrome hardware and software infrastructure.

Current ICAO provisions do not provide specifications for AV operations at aerodromes. ICAO provisions that previously applied to vehicle drivers are transferred either to the AV operator (or safety driver where applicable) or to the AV itself, depending on the split of driving tasks between them which in turn depend on the technology and architecture of the ADS.

ICAO provisions related to vehicles may be easier to address as they mainly refer to the vehicle performance as well as its markings and lighting. The need to require specific colours for marking and lighting of autonomous vehicles is to be assessed against the specific nature, severity, and probability of the risks.

Security aspects mostly concern authorization for airside access. For autonomous vehicles, authorizations must address the operator and the vehicle itself, which should pass a security check (including cybersecurity). This security check should be included in a safety assessment.

Safety requirements include compliance with safety procedures, acceptance of a safety assessment before deployment of the vehicle, and compliance with the Safety Management System where applicable. These three aspects depend on the characteristics of the vehicle, of the airport, and of its area of use and shall be considered before deployment and continuously during operations.

Continuity of operations (including ground handling services) is mostly an airport and aircraft operator issue. There is little, if any, regulatory specification on this subject. Conversely, a lot of guidance is available through the ICAO Doc 10121 “Manual on Ground Handling” and industry documents.

Compatibility with the airport layout and ground infrastructure should be ensured by design. AVs must correctly understand and use the visual and non-visual aids and Surface Movement Guidance and Control Systems (SMGCS) of the airport. If additional means are required to ensure the reliability of autonomous vehicles, there may be the need to develop new Standards and Recommended Practices (SARPS) such as additional guiding devices, specific routes or additional driving rules. Autonomous vehicles must be able to communicate with Air Traffic Services (ATS), Rescue and Fire-Fighting Service (RFFS), and Apron Management Service (AMS) through existing communication systems. Otherwise, the autonomous vehicle manufacturer and operator must provide a suitable alternative solution. Communication with these entities is one of the most challenging aspects to consider as instructions and requests must be followed up on or answered immediately, to ensure the safety of aircraft and other moving objects. Currently, general rules cannot be defined because adapting these provisions to AVs depends on the airport context, the area of AV operation as well as its function and capabilities.

Autonomous vehicle mapping data and systems should be compatible and kept current with (or even be part of) the Airport Mapping Data Base (AMDB) (or an enhanced AMDB to facilitate the ground movement of RPAS and ADS) and the Advanced Surface Movement Guidance and Control Systems where applicable.

In case of AV deployment at aerodromes, regulations have not yet addressed the safety of aircraft operations. This will depend on the type of AV (e.g., baggage trailer on the apron, aircraft towing truck on apron and taxiways, snowplough on runway). A set of minimum conditions to ensure the efficiency of all aerodrome operations may have to be defined to facilitate the acceptability of AVs at aerodromes.

4.2.3. ICAO Procedures for Air Navigation Services (PANS) – Aerodromes

ICAO Procedures for Air Navigation Services (PANS) - Aerodromes aims to harmonise aerodrome management and operations procedures across various aerodromes and countries. ICAO PANS specifies in greater detail than SARPs the operational procedures that aerodrome regulators and operators must apply to ensure operational safety across aerodromes.

ICAO PANS - Aerodromes focuses on:

- Part I: Initial certification of aerodromes, safety assessment and operational procedures at existing aerodromes (aerodrome compatibility)
- Part II: Aerodrome operational management and topics relevant to the provision of uniform and harmonised procedures in aerodrome operations.

While Part I addresses the regulatory procedures needed to approve the introduction of AV operations at aerodromes, Part II focuses on operational management procedures that should be applied or adapted to AV operations. An analysis divided into these two sections and listing the most significant provisions is presented in the subsequent two sections.

4.2.3.1. Aerodrome certification, safety assessments, and aerodrome compatibility

Aerodrome certification applies to all aerodrome components (including the ADS) and has the objective to ensure the safe interaction and operation of all components present in the aerodrome. While there is no need to identify whether any given vehicle is autonomous or not, it is necessary to demonstrate that ADS can safely interact with other aerodrome elements. For this reason, ADS operation can be enabled at aerodromes by documenting the safety of AVs (through a safety assessment) without revising the text of PANS – Aerodromes Part I.

A significant item to consider in this context is the obligation to include ADS management and operation in the aerodrome Safety Management System (SMS). This can be done through a safety assessment before the introduction of ADS operations at the aerodrome, presumably leading to a change in aerodrome safety and operation procedures.

4.2.3.2. Aerodrome Operational Management

Every chapter of PANS Aerodrome Part II can apply to ADS operations depending on functions, features and area(s) of operation. The present review focuses on four chapters which will be analysed for any type and use of ADS.

Chapter 2 – Training

"Aerodrome operators shall be responsible for ensuring that (…) all personnel involved in aerodrome operations at the aerodrome are competent for each task they are required to carry out." This provision applies to ADS operators, dispatchers, remote or fallback drivers, and specific arrangements shall be defined to account for the difference between autonomous and human driving.

Chapter 5 – Foreign Object Debris (FOD) Control

The control of Foreign Object Debris (FOD) needs be addressed from two perspectives. First, as the ADS itself may produce FODs, some maintenance and operation procedures must be in place, as for other vehicles, to prevent the production of FODs. Second, as all personnel should be involved in the prevention and removal of FODs, the impact of task automatization on FOD control measures should be assessed (e.g., reduction of human FOD detection capabilities and conversely automatization of FOD detection, removal, and reporting). This assessment should be done with the safety assessment of change when introducing the ADS and periodically with the aerodrome SMS procedures.

Chapter 7 – Apron Safety

The entire chapter 7 is pertinent to ADS engaged in operations on the apron, the designated area where aircraft are parked, loaded and unloaded, refuelled, and boarded by passengers. In short, this chapter's requirements cover: identification of hazards related to activities, establishment of apron safety procedures for vehicle movements, ensuring that vehicles and wheeled equipment are left properly braked to prevent effects of jet blast and strong winds, airside driving rules (which should include, at a minimum: speed limits, right of way, driving routes), vehicle condition requirements (including marking and lighting of vehicle), use of vehicle lights, low visibility procedures, signs, markings, lights on the apron, procedures for the entry to/exit from the apron areas in which aircraft and vehicle movements are combined. All of these airside driving rules may be adapted to the specificities of ADS when sufficient experience of ADS operations becomes available.

Chapter 9 – Airside Driver Permit Scheme and Vehicle/Equipment Safety Requirements

The airside driver permit scheme should be reviewed entirely to develop a permit scheme adapted to ADS operations, which considers the division of tasks between the ADS vehicle, the ADS remote station, the dispatcher, and the remote or fallback human drivers. However, as this split depends on the ADS level of automation or even on the ADS brand, only a guidance document on the aspects that require closer attention on a case-by-case basis to provide an equivalent level of safety to a human driver permit will be developed. Vehicle requirements contained in paragraph 9.3.15 do not need to change for ADS operations.

The most significant item to highlight is the need to define a counterpart to the human driving permit scheme for ADS SAE Levels 3 and 4. Currently, PANS - Aerodromes (Chapter 2) requires the personnel carrying out various tasks at aerodromes to be trained and have the required competences. However, the training and competence requirements for AV operations should be adapted either to the ADS-DV embedded system, the remote station system (including the fleet management system), the dispatcher, or the remote or fallback drivers.

Currently, traditional permits and certifications requirements are provisionally applied in the absence of ADS ad hoc regulatory provisions. For instance, in the autonomous baggage tractor AWARD use-case, this caused major challenges for recruiting personnel for project implementation at the airport. Initially, it was planned to involve operational personnel at the airport. The handling companies intended to play the role of safety drivers, but this turned out to be impossible due to complicated insurance conditions. Security personnel were then used for a period, but this was also stopped due to challenges related to insurance. As a result, a person from AVINOR was appointed to carry out all tests and communication with the various work packages in the project. As this is not a sustainable solution, it is recommended to develop suitable guidance for safety assessments and for providing a safety assurance equivalent to the airside driving permit for airport drivers. The Singapore Civil Aviation Authority has followed this approach with its "Guidance on Use of Autonomous Vehicles at the Airside".

4.2.4. Safety of Operations Risk Assessment (SORA)

Unmanned Aircraft Systems (UAS) moving on the ground act similarly to an autonomous vehicle as they both operate without direct human intervention. These operational commonalities between UAS and AVs make it relevant to look for commonalities in the safety assessment approach, methodology, and guidance between UAS and AVs at aerodromes.

As seen in section 4.2.1., European drone regulation is based on risk assessment and defines different categories based on the level of risk. The Specific Operations Risk Assessment (SORA) developed by JARUS provides guidance on the requirements needed to obtain a National Aviation Authority authorization required to fly an Unmanned Aircraft System (UAS), whether certified or not, in each operational environment.

The SORA methodology represents an iterative ten-step process in which the risk of complex drone operations is systematically identified. The applicants themselves determine where, when, and how they perform the operation without endangering people and objects in the air or on the ground. At the end of this process, there is a detailed description of the planned operation and the risks associated with it, as well as the measures required to mitigate the risks[6].

The SORA guidance is directed at the competent authority and applicants, and consists of three elements:

1. Approach and methodology
2. Guidance documents (for each step of the methodology)
3. Predefined Risk Assessments (PDRA) for a list of standard scenarios that can be used as models for a specific safety risk assessment or as document templates.

The approach and methodology are summarised below to show the concepts and processes that can be derived for ADS. In the SORA context, "risk" is understood as the combination of the probability of an occurrence and its level of severity, while "safety" is understood as a state where risk is considered as acceptable. The way to reach an acceptable level of risk may differ based on the UAS design integrity and the kind of intended operations, but the safety level (i.e., the probability of potential fatalities on the ground or in the air) remains the same across all categories.

To show that an operator can control the Unmanned Aircraft System (UAS) within the intended "operational volume"[7] and that operations have reached an acceptable level of risk, SORA provides a combination of design and operational mitigation mechanisms for known areas of harm to either people on the ground or in the air.

The ten systematic steps in the SORA methodology are the following:

- Step 1: ConOps Description. The ConOps contains all the relevant technical, operational, and system information needed to assess the risk associated with the intended operation.
- Steps 2 and 3: Determination of Ground Risk Class (GRC)
- Steps 4 and 5: Determination of the Air Risk Class (ARC)
- Step 6: Tactical Mitigation Performance Requirement and Robustness Levels

- Step 7: Specific Assurance Integrity Level (SAIL) determination. A SAIL (scaled from I to VI) is then determined using the proposed ConOps and the consolidation of the final GRC and residual ARC.
- Step 8: Identification of Operational Safety Objectives (OSO). For the assigned SAIL, the operator will be required to show compliance with each of the 24 OSOs, although some may be optional for lower SAILs. Each OSO shall be met with a required level of robustness (high, medium or low), depending on the SAIL. OSOs cover the following areas:
  - UAS technical issue
  - Deterioration of external systems
  - Human error
  - Adverse environmental conditions
- Step 9: Adjacent Area/Airspace Considerations. Compliance with safety requirements associated with technical containment design features required to stay within the operational volume regardless of the SAIL. This addresses the risk posed by an operational loss of control that would possibly infringe on areas adjacent to the operational volume, whether they be on the ground or in the air.
- Step 10: Comprehensive Safety Portfolio. This is the SORA safety case submitted to the competent authority and the Air Navigation Service Provider (ANSP) prior to final authorisation.

Predefined Risk Assessments offer a major tool to facilitate the reuse of previous safety assessments trials. For the baggage tractor use case, they would have allowed to share assessment tasks between the Toulouse and Oslo airports by providing a common document structure and most of the individual risk assessment arguments.

4.2.5. SORA guidelines as an example for AV at aerodrome

To develop AV safety and security, concepts from related disciplines should be examined and potentially transferred. For this reason, existing concepts already in force for unmanned drones can be transferred and implemented in the operation of AVs at aerodromes. SORA-inspired guidance may provide a common framework and facilitate the performance of safety assessments before the deployment of ADS at aerodromes while taking advantage of previous safety demonstrations performed for compliance with ISO standards 26262 and 21448 or for type-certification if the ADS is certified.

ADS may comply with ISO 26262 on Functional Safety and ISO 21448/2022 Safety of the Intended Functionality (SOTIF), but these two standards do not encompass the entire spectrum of safety of operations. For example, the "Annex 1: Identification of potential hazards related to AV operations at airports", which is included at the end of this deliverable, lists the additional hazards (as derived from ICAO Doc 10121: Manual on Ground Handling and ICAO Doc 9981: PANS Aerodromes) that are required by ICAO and EASA to be analysed prior to ADS deployment at aerodromes. Hence, there is a need to supplement them with appropriate guidance to assess their safety in operations at aerodromes. This guidance would cater to cases where compliance with ISO 26262 and 21448 is not verified.

The following items are pertinent for the development of safety assessment guidance for ADS:

- Common concepts for collision avoidance:

- The operational volume consisting of the flight geography (the driving path envelope), the contingency volume, and buffers on one hand, and the two levels of collision prevention on the other (maintaining separation from obstacles and last resource collision avoidance device when separation is infringed).
- The risk assessment approach is classic and applicable to a wide range of systems and situations.
- The 10-step methodology outlined in the previous section (4.2.4). can be tailored and simplified for ADS. Steps 1, 2, 3, 6, and 10 are almost directly applicable; steps 4 and 5 are irrelevant as there is no risk of air collision in AV operation at aerodrome; steps 7, 8, and 9 should be combined and simplified because the complexity and the risk levels in AV operation are much lower than with drones.
- Some documents from the JARUS guidelines on Specific Operations Risk Assessment (SORA) (also known as doc JAR-DEL-WG6-D.04), can serve as models for guidance documents, particularly Annex A on ConOps, Annex E on Operational Safety Objectives, and the Pre-Defined Risk Assessment (PDRA) documentation8 (standard scenarios and risk assessments).
- Developing PDRAs for the most common use of ADS at aerodromes.
- Compatibility of SORA methodology with ISO 26262 and 21448 methodologies, notably on Hazard Analysis and Risk Assessment and on Safety Integrity Levels.

Due to differences between drones and AVs at aerodromes, some distinctions must be highlighted. The adaptation of the JARUS SORA guidance to AV operations at aerodromes should consider three elements:

1. UAS safety assessment pertains to aircraft and air operations regulation, while safety assessment of AV at aerodromes pertains to aerodrome regulation. Their objectives differ as the focus of aerodrome regulation is to prevent and mitigate accidents, while aircraft and air operations regulation (and therefore SORA guidance) is to prevent collisions.
2. ADS guidance should ideally assist ADS manufacturers, ADS operators, and aerodrome operators to perform safety assessments and create documentation.
3. ADS guidance should consider both the entry into service of AVs and the continuous assessment, which is required in the framework of the Safety Management System of the aerodrome.

The ADS guidance first requires the development of a common Safety Assessment Method (SAM) which will be followed, when mature enough, by specific guidance documents and PDRAs for the most common use cases.

The proposed SAM contains five steps:

4. Development of Concept of Operations (ConOps) that includes verifying the compatibility of AV operation with the aerodrome infrastructure and operation.
5. Assessment of the safety risks linked to the AV and of the risks within the ensemble of aerodrome operations.
6. Determination of a Safety Assurance and Integrity Level (SAIL) which sets the required robustness required from the ConOps, the associated mitigations, and the stringency of the verifications.

7. Identification of the relevant Operational Safety Objectives together with their means of verification.
8. Development of a safety portfolio.

These steps are further detailed in 11.2 Annex 2 - Methodology for Automated Driving Systems Safety Assessment Method (SAM) based on SORA page 93.

When operating with AV, some scenarios may arise that can cause a dangerous event. To be able to determine how AV must react, characteristics of this reaction, how the consistency of reactions can be ensured and what technical mitigation mechanisms should exist, these new interaction concepts should be further researched.

4.3. Port logistics

Since ports serve international maritime transportation and are embedded in global trade and supply chains, there are several international organisations involved in regulating port logistics.[10] For the purposes of this deliverable, "port logistics" can be broadly described as the "logistics and distribution services based at the port where goods arrive." Port logistics encompasses a wide range of operations, such as cargo handling, loading and unloading, custom paperwork, surveillance, etc.[11]

As autonomous technology is introduced throughout the entire logistics chain in land-, air- and waterborne transport, ports are challenged to prepare themselves for the arrival of such vehicles and vessels.[12] A 2021 study co-authored by the European Sea Ports Organisation describes the maritime and logistics portscape during the preceding decade. In other words, ports are increasingly open to adopting innovations and understand that both their activities and their governance (i.e., port authorities) will be disrupted by them.[13]

However, similar to aerodrome logistics, there is a time lag between the initial use of autonomous technology and its regulation. International (non-EU) organisations have not yet addressed the deployment and operation of AVs in ports in a systematic manner. To the extent that automation and its regulation are discussed in detail, the focus of the maritime industry thus far is on Maritime Autonomous Surface Ships.[14] Unlike aerodrome logistics, where grounded drones could serve as a regulatory model for other forms of autonomous driving systems, it is not necessary to draw analogies between autonomous ships as seaborne vessels and land-based vehicles involved in port logistics. Both for the sake of regulatory parsimony - which the EU articulates in terms of burden reduction and simplification[15] - and because portside traffic takes place on (public or private) roads, quays, and terminals, this deliverable applies the regulatory framework for "road logistics" as discussed in section 4.1 above to ports.

Ports have been described as providing the kinds of closed and structured environments that provide ideal conditions for the deployment of AVs. Routes and driving tasks can be pre-

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[10] Dr. A. Pallis et al.
[11] B. Dey Sarkar, et al, 2021.
[12] R. Fiedler, et al, 2019.
[13] Deloitte, 2021.
[14] International Maritime Organisation.
[15] European Commission.

planned and standardised, and the entire area of AV deployment can be mapped, geofenced, and controlled by a smart terminal operating system. Private port operators will encounter fewer obstacles to AV deployment than officials responsible for public roads.[16]

At the same time, the physical infrastructure of ports and the range of technologies used within their premises present unique challenges for the deployment of AVs, as outlined below:

- Infrastructure:
  - Complex layouts with bridges connecting yards and berths without dedicated areas for automation
  - Single truck lanes with potential impediments through container stacking areas
  - Communication signal obstructions from containers, quay cranes, and vessels.
- Vehicle technology, including vehicle-to-vehicle and vehicle-to-everything communication.
  - Mixed operations with AVs and non-AVs
  - Frequent interactions with remote-controlled dock cranes, manually operated vehicles, and workers.[17]

The need to regulate AVs in port logistics arises from the same requirements to enhance efficiency and safety that the other AWARD use cases present. These considerations include cybersecurity and data protection requirements.

[16] Konecranes.
[17] Chcnav, 2024.

5. EU Governance and Regulative Framework

5.1. EU Artificial Intelligence Regulation

The EU Artificial Intelligence (AI) Act published in March 2024 is a pioneering piece of legislation that adopts a risk-based approach to the regulation of artificial intelligence. It classifies AI systems according to the level of risk they pose, from minimal risk to unacceptable risk, and prescribes regulatory requirements accordingly. This framework is intended to be broad and inclusive, making the AI Act a horizontal piece of legislation that applies across various sectors and industries.

The AI Act's horizontal nature allows it to be used alongside specific EU regulatory frameworks applicable to individual sectors, such as the automotive industry. In this context, the AI Act provides a general framework to ensure AI safety and compliance, while sector-specific directives address unique risks and requirements pertinent to specific applications of AI, such as in autonomous vehicles or advanced driver-assistance systems.

Complementing this regulatory framework, there are also international standards currently being developed to address various dimensions of AI safety and responsibility. Over forty documents have either been published or are under development, each focusing on specific aspects of AI such as robustness and reliability, transparency and explainability, and security and data privacy. For instance, ISO standards on Functional Safety and AI system standards play a crucial role in defining technical requirements and benchmarks for the design and implementation of AI systems. These include SO/IEC TR 5469:2024 – Artificial intelligence – Functional safety and AI systems, and ISO/IEC AWI TS 22440 – Artificial intelligence – Functional safety and AI systems – Requirements.

These standards are envisioned to serve as sets of technical requirements or potential means of compliance for the EU AI Act. They provide detailed guidance and methodologies that can help AV developers and manufacturers demonstrate their adherence to the requirements set forth by the AI Act.

Beyond the EU, other global initiatives are also focusing on AI trustworthiness. For instance, the U.S. National Institute of Standards and Technology has developed a risk management framework specifically for AI, providing a structured approach to identify, assess, and manage risks associated with AI technologies. Similarly, the European Union Aviation Safety Agency (EASA) has published a concept paper and a roadmap for AI systems classified as level 1 and 2, which include actionable requirements and anticipated means of compliance. EASA also introduces an innovative, iterative W-shape model for AI software development, which is an alternative to the traditional, linear V-shape model, potentially offering better integration of safety and compliance considerations throughout the development process. More information and recommendations on this specific element can be found in section 7.13.2 of this document.

5.2. EU Automated Driving Systems (ADS) Framework

The European Union developed a regulatory framework to ensure uniform safety standards for AV testing and ADS type approval. Entered into force in September 2022, the Implementing Regulation (EU) 2022/1426 (also known as ADS Act) contains procedures and technical specifications for the type approval of motor vehicles equipped with ADS. In February 2024, the European Commission's Joint Research Centre published a first interpretation of several innovative features in the Regulation with the overall goal to support the operationalisation of different aspects of the legislation.

As the first EU regulation focusing on AVs, it no longer requires the mandatory use of safety drivers for fully automated vehicles. In addition, the text provides guidance for all stakeholders involved in the development and deployment of driverless vehicles by informing manufacturers of the performance requirements and technical specifications that vehicles must meet, as well as specifying the modalities and competent authorities needed to obtain a compliance certificate.

It should also be mentioned that the regulation remains quite open regarding the Operational Design Domain (ODD) that the manufacturer must specify. Additionally, it establishes aggregate safety metrics that will be used to benchmark performance and ultimately as a measurement for allowing AV real-world deployment. This Regulation currently specifies:

- Information required by the ADS manufacturer to support their request for EU type approval
- Performance requirements and technical specifications applicable to ADSs, under a variety of scenarios and operating conditions (ODD) that the vehicle finds itself in
- Review process to be used by the relevant approval authorities in their assessment of ADS compliance with the applicable technical specifications
- Review of documentation, tests to be conducted and guidance for approval authorities, when reviewing applications.

The scope of the ADS Act is limited to specific "use cases" of fully automated vehicles or dual mode vehicles operating on a pre-defined route or area, which may include urban, suburban, motorway or predefined parking facilities environments. The use case approach becomes particularly relevant due to manufacturers obligation to demonstrate that their ADS is free from unreasonable safety risks when measured against "comparable transport services and situations within the operational domain". The manufacturer is responsible for the identification and selection of similar services the vehicle could be employed for as well as for the evaluation of current levels of risk of those services. Acceptability criteria and related metrics must be defined by the manufacturer to allow a comparison with those similar services based on the available data. For an example applicable to the AWARD project, the hub-to-hub use case employing an ADS would be compared to trucks (and their data) as a reference human-driven service.[18]

This regulatory framework will be crucial in shaping the future of AVs across the EU by gradually opening the door to permit the European type approval of fully automated vehicles. The ADS regulation is part of a broader maturation in Europe's AV regulatory and commercial

[18] Ciuffo et al. 2024.

environment, which provides a harmonised approach while granting adequate flexibility to enable the development and deployment of AVs.[19]

While the ADS Act specifies the framework for the type approval of vehicles at the EU level, national authorities are granted a level of flexibility to guarantee alternative national requirements and permit exceptions for AV test operations and deployment. Different countries have introduced regulatory measures to support the testing of autonomous vehicles on their roads: while some countries grant authorisation on a case-by-case basis, others focus on modifying national laws to facilitate vehicle testing across their territory.[20]

5.2.1. Teleoperation in EU Regulatory Frameworks

Teleoperation is used as an umbrella term for different concepts to remotely support the operation of automated vehicles. This may include different levels of remote functions such as remote driving, remote assistance, or remote monitoring.[21] Various teleoperation concepts and functions have undergone testing in Europe, including their incorporation into the AWARD project.

However, Implementing Regulation 2022/1426 introduced a clear definition of the remote functions that may be used in type-approved ADS. The regulation foresees a so-called remote intervention operator, able to remotely achieve tasks such as confirming a manoeuvre proposed by the ADS when the vehicle is at standstill or assist passengers of fully automated vehicles. The regulation states, that "the remote intervention operator shall not drive the fully automated vehicle and the ADS shall continue to perform the Dynamic Driving Task".[22] Therefore, it can be concluded that other modes of teleoperation, such as remote direct driving - involving the direct remote control of the vehicle's movements - are not eligible parts of a type-approved ADS.

5.3. EU Implementing rules at aerodromes

From a regulatory perspective, European regulations must comply with ICAO provisions but can also be more stringent, notably regarding certification and oversight of aerodrome operators by the competent national or regional authority.

For instance, although compliance with and "Essential Requirements" of the Basic Regulation (EU) 2018/1139 is the ultimate regulatory safety criterion for aerodromes, the acceptance and management procedures of Alternative Means of Compliance (AltMoC) or specifications specified by EASA are more detailed and stringent than those provided by ICAO. The acceptance and management procedures of EASA provide additional tasks for the aerodrome operator and the competent authority, both for full ADS operation and possibly for some ADS tests at the aerodrome.

Regulatory challenges to certification and oversight may arise when the ADS (notably when its type is certified according to EU regulation 2022/1426), the ADS operator, and the aerodrome operator are certified and overseen by different competent authorities in different

[19] European Commission, 2018.
[20] Traton, 2022.
[21] D. Majstorovic, et al, 2022.
[22] European Commission, 2022.

Member States. For instance, if compliance with UN Regulation 157 (Automated Lane Keeping System) or with ISO 12100 is considered as a valid means of compliance and overseen by the certifying authority of the ADS in one Member State, it may not be accepted in the Member State where the ADS operates.

5.3.1. Lack of definitions for AV operations

Regulation 139/2014 and the Basic Regulation (EU) 2018/1139 do not include definitions related to autonomous vehicles. Moreover, they do not include definitions for “vehicle” and “driver”. Definitions may be derived instead from the aforementioned November 2021 amendment to the UN Vienna Convention (Article 34bis), which “deems the driver requirements to be satisfied while the vehicle is using an ADS”. However, this amendment has not yet been ratified by all countries.

In addition, there are no definitions of “vehicle”, “driver”, and “Automated Driving System” in ICAO Annex 14 and ICAO PANS – Aerodromes, which may have been inherited by EU regulations. ADS up to SAE Level 4 falls within the scope of the definition of “mobile object: a movable device moving under the control of an operator, driver or pilot” in PANS - Aerodromes, but this definition is not mentioned, even implicitly, in the Implementing Rules of Regulation 139/2014 and creates an ambiguity for the role of “operator”.

There is also a need to define regulatory terminology for various parts of an ADS, such as the vehicle itself (Automated Driving System - Driving Vehicle (ADS-DV)), the driver (whether “remote” or “safety”), or the Fleet Management System, if any. These definitions are required, to clarify which parts are implicated by which provision. The terminology in “SAE J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles” could be used as a basis, with caution needed to avoid possible confusion with aviation acronyms (such as ADS, ATM, FMS) and applicability.

Although EU regulations 2019/2144 (type-approval) and 2022/1426 (implementation of type-approval) contain set definitions for ADS that can be applied to vehicles at airports and ports, these definitions may not cover the whole spectrum of autonomous vehicles and systems at airports (e.g., grass mowers or runway inspections devices).

As long as the introduction of ADS at aerodromes can be managed solely through safety assessments, the lack of regulatory definitions for ADS can be circumvented. The AWARD airport use-case carried out at the AVINOR aerodrome required a full safety assessment including verification of the vehicle in compliance with Norwegian road regulations, a safety assessment report of the intended operation, and a documented compliant safety case by AVINOR.

However, this lack of regulation may create issues, if the accommodation of ADS requires an Alternative Means of Compliance (AltMoCa) or change in the certification basis, or a change in the Aerodrome Manual, as this would require amending the certificate of the aerodrome which may take a long time.

5.3.2. Management of changes

Whether for tests or for operation, the introduction of AVs at aerodromes is a change that must be notified to the competent authority, either for prior approval if the change significantly affects the aerodrome management system, or for information within the oversight process.[23] Both cases require documentation containing the description of the change led by the introduction of AVs at aerodromes and a safety assessment. The description of the change must include the Concept of Operations (ConOps). In broad terms, for both cases but with different levels of scrutiny, the competent authority must verify the conformity of the safety assessment performed by the operator for the change. This includes the compliance of the change with the certification specifications and the Alternative Means of Compliance (AltMoC) developed by EASA or AltMoCs agreed by the competent authority, or other requirements (i.e., the certification basis and the terms of the aerodrome certificate). This may eventually result in a notification of Special Conditions or other requirements, notably AltMoC, leading to a change of the certification basis and/or the terms of the certificate.

5.3.3. Aerodrome manual

The aerodrome operator shall amend, where necessary, the Aerodrome Manual items affected by the change brought by AV operation at aerodromes, whether for testing or operations. The introduction of AVs at aerodromes for either testing or operations is a change that must be assessed by the aerodrome operator. More specifically, EASA 139/2014 Annex III - ADR.OR.E. provides a comprehensive checklist of the items which should be verified, and about one third of them may be impacted by the introduction of AV. However, discretion is advised for their application according to the function, area of operation, technology, and operational procedures. For instance, if the intended operation is in a remote area where no aircraft is present, the risks of collisions with aircraft will not be considered. For that reason, guidance should be developed to perform the change assessment and the safety assessment. Such a document can simplify the tasks of the competent authority, of the aerodrome operator, and of the other parties involved while facilitating the introduction of autonomous vehicles.

5.3.4. Management of aeronautical data and information

Management of aeronautical data and information is crucial for the safety and security of aerodrome operations. Aeronautical data means a representation of aeronautical facts, concepts, or instructions in a formalised manner suitable for communication, interpretation, or processing. EASA 139/2014 Annex III – ADR.OR.D007 (Management of aeronautical data and aeronautical information) applies to tests and operation of autonomous vehicles at various levels depending on the technology and procedures used for the autonomous vehicle navigation data and driving performance (e.g., use of aerodrome visual aids, physical characteristics, information on works or other operational temporary constraints).

Notably, "the aerodrome operator shall, as part of its management system, establish a security management system to ensure the security of operational data it receives, or produces, or otherwise employs, so that access to that operational data is restricted only to those

[23] See Easy Access Rules for Aerodromes (Regulation (EU) No 139/2014), Annex III — Part-, ADR.OR.B.040 Changes: https://www.easa.europa.eu/en/document-library/easy-access-rules/online-publications/easy-access-rules-aerodromes-regulation-eu?page=12#_DxCrossRefBm647789172.

authorised."[24] In the ADS case, the fulfilment of this requirement is shared between the aerodrome operator, the organization operating the ADS, and the ADS manufacturer. However, there are at least two unresolved issues which require regulatory clarification. First, it is not yet established whether a manufacturer's compliance with UN Regulation 155 (Cybersecurity Management Systems) is an acceptable means to meet this obligation. Second, future revisions of the regulation should address how to manage the oversight of this requirement pertaining to various regulatory realms and possibly to different States. To fulfil this requirement in the short-medium term it is recommended to develop guidance on how to comply with the applicable security management provisions and oversight.

5.3.5. Authorisations of vehicles and drivers

Requirement EASA 139/2014 Annex IV - ADR.OPS.B.026 (Authorisation of vehicle) describes the conditions to obtain authorisation of the vehicle to operate at the aerodrome. In the absence of suitable communication or surveillance means (points (a).3 or (a).4), condition (e) allows a vehicle to be used if it is escorted by another vehicle equipped for communication and surveillance where required. Since it is currently unclear whether condition (e) applies to automated vehicles, the text of this requirement should be amended accordingly.

Requirement EASA 139/2014 Annex IV - (Marking and lighting of vehicles and other mobile objects) describes specific markings and lighting for vehicles other than aircraft but may exempt servicing equipment and other vehicles used exclusively on aprons. ADS may not be exempted if operational tests show that they are hazards to persons, vehicles, or aircraft.

Requirement EASA 139/2014 Annex IV - (Authorisation of vehicle drivers) describes the skills to be acquired during training, particularly in terms of communication and radiotelephony. The application of this requirement to autonomous vehicles shall be tailored to the split of tasks between the autonomous vehicle embedded system, the remote station, and the remote or safety driver. Overall, the training program needs to be reviewed in the context of an autonomous vehicle, as does ongoing training (e.g., in the event of changes in regulations or modifications to the traffic pattern).

5.3.6. Communication means and procedures

Requirement ADR.OR.E.005 Aerodrome manual Part E (Handover of activities - provision of operational information) states that in low visibility conditions, special procedures must apply. They should be tailored to the situation and affect the presence of a safety driver, a remote operator, and the fleet management system. It must be ensured that information about various thresholds of visibility conditions and corresponding procedures as well as the return to normal are instantly received and applied by autonomous vehicle.

[24] European Aviation Safety Authority, 2023.

6. National EU road-testing frameworks

While the European Union has adopted type approval procedures at the EU level, Member States differ in their national testing and deployment regulations for automated vehicles (SAE levels 3 to 5). While national authorities continue to require the presence of an on-board safety driver for the testing of some AV use cases, some countries such as France and Switzerland enable the testing of automated vehicles without a safety driver under the supervision of a person in charge of remote intervention.

Legal characteristics for the testing of automated vehicles across several European countries have been collected and consolidated in Table 1. This section will look at the legal framework for AV testing (and deployment if applicable) for Germany, France, Austria, Norway, and Switzerland. These countries were chosen following their developments in AV regulation (e.g., Germany, France) and the geographic scope where AWARD pilots took place (e.g., Norway for the airport use case, Austria for Hub-to-Hub and forklift).

Table 1: EU Member States testing regulation overview

	Regulation	SAE level	Authority	Duration	Conditions for testing	Use cases
Germany	Verordnung zum autonomen Fahren" ("Ordinance on Automated Driving") -	4-5	Kraftfahrtbundesamt (KBA)		• Pre-defined areas • Human monitoring (outside of the vehicle, able to take control at any time)	Amended in 2020 to include more complex scenarios and "conditional automation".
France	Loi LTECV Loi PACTE	3-4-5	Ministère chargé de la transition écologique	Duration 2 years, renewable once	• Pre-defined area • Human supervision (outside the vehicle able to take control at any time)	All use-cases
Austria	AutomatFahrV	3-4	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)	Test period as requested by the applicant	• Pre-defined areas • Safety driver (in vehicle able to take control at any time	Eight use cases: automated minibuses, automated valet parking, automated vehicle for transport of passenger, automated vehicle for the transport of goods, automated working machine, autonomous military vehicle, motorway pilot with automated lane change, motorway pilot with automated driving on ramps and exits
Norway	Lov om utprøving av selvkjørende kjøretøy (exemption approval for AV)	3-5	Road Directorate of the Norwegian Public Roads Authority	Test period as requested by the applicant	• Pre-defined areas • Human supervision (outside the vehicle, field operator or remote operator able to take control within minutes)	Case-by-case
Switzerland	Exceptional approval of Art. 106 para. 5 Road	3-4	Federal Roads Office (FEDRO)	Test period as requested – needs renewal	• Pre-defined areas (can include highways, urban and non-urban areas)	Case-by-case

	Traffic Act (SVG)			as test conditions change	• Human supervision (outside the vehicle able to take control at any time, pre-defined area)	

6.1. France

The French regulatory framework enables automated driving on public roads through two main regimes: the testing framework and the permanent regime (Table 2). These regimes do not differentiate based on the type of use cases (e.g., public transport, automotive, logistics) but rather on the level of vehicle automation which results in three major categories.[25]

Table 2: Overview of Trance AV Regulation

	European level	National level	
Framework	Type approval	Experimental regime	Deployment regime
Regulation	ADS	Loi LTECV Loi PACTE	LOM (only passenger for now)
Content	• Safety requirements for manoeuvres performed by an automated system • Safety demonstration based on driving scenarios • Mandatory minimum list • Principle of coverage of the field of use • Consideration of off-board functions (connectivity, supervision) • Cyber security requirements • Requirements on data loggers	• Authorization on a case-by-case basis: Minister responsible for transport after opinion including road manager and Adaptive Operation Mode if necessary) • All possible use cases • Duration 2 years renewable once • No obligation to approve the vehicle. • Criminal liability of the holder of the experiment authorization	• Definitions and allocation of roles and responsibilities (system / driver) • High level safety requirements • Vehicle certification • Possibility of services based on driverless vehicles without drivers on board subject to demonstration of demonstration on pre-defined routes safety demonstration rules

In France, the circulation of a vehicle without a fully engaged driver, for testing and experimental purposes, requires a testing permit. These testing may involve different use cases: technical testing and development, performance evaluations in the situation for which the vehicle is intended to be driven, and public demonstrations and events. Testing of automated

[25] (1) Partially automated (the system must issue a take-over request to respond to some traffic hazards or failures during a manoeuvre); (2) Highly automated (the system ensures safe manoeuvres in response to any traffic hazard or failure within its Operating Design Domain, without doing a take-over request during a manoeuvre); (3) Fully automated (the system ensures safe manoeuvres within its ODD and is subject to remote control).

vehicles that does not require a driver's partial intervention must be registered under a specific certificate called "WW DPTC".[26]

To ensure safety, the testing approval may require specific conditions, for instance: the approval of the geographic areas in which the vehicle is allowed to drive in delegated driving mode and the delegated driving functions that can be activated within these areas.

The French legal and regulatory framework on AV is evolving. Article 125 of the Plan d'Action pour la Croissance et la Transformation des Entreprises (PACTE) Law extends the possibility to carry out self-driving testing to all use cases where the driver is neither required to be present in the vehicle nor responsible for all driving tasks. The PACTE law stipulates conditions to authorise testing when the driver is not present in the vehicle: the driver must supervise the vehicle and the driving environment throughout the experiment, and they should be able to neutralise or deactivate the AV at any time. [27] The PACTE law provides a framework that covers experimentation for the highest levels of automation with an adapted liability regime.

An Automated Road Transport System (ARTS) is a set of highly or fully automated vehicles and technical devices, allowing remote intervention or safety, deployed on predefined routes or zones, and complemented by operating and maintenance rules, for the purpose of providing passenger road transport service.[28] In June 2021, the Decree No. 2021-873 set the conditions for the deployment of automated vehicles and road transport systems across French roads. It covers automated vehicles and driving systems up to "fully automated" systems (i.e., without a driver on board), provided they are under the supervision of a person in charge of remote intervention and that they are deployed on predefined routes or zones.[29]

The Decree also includes definitions and general safety provisions for automated systems and specific requirements for the driver or person in charge of remote intervention (Table 3). In addition, the Decree sets conditions under which fully automated systems (including vehicles, roadside or remote equipment and operational procedures) may be put into service, following a specific safety demonstration process.[30]

Finally, this regulation also specifies procedures for approved qualified bodies and the content of their reports on system safety. Several reference documents are intended to support stakeholders (system designers, operators, service organisers, and approved bodies) in the implementation of AV safety demonstrations. For instance, conditions to authorize remote operators, particularly in terms of training, are also listed.

When the automated driving system is active, the driver (in the vehicle) is no longer required to be in a state and condition to carry out all manoeuvres traditionally incumbent on them. However, approved bodies in charge of the automated systems homologation still need to be approved by French ministry of transport. Once they will be approved, they will be able

[26] See also https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5e93ce7e9&appId=PPGMS. The certificate used for the temporary tests of partially or fully automated vehicles is named "WW DPTC". "WW" is used in French vehicle plates as an identification for a temporary vehicle registration, and DPTC stands for "Delegation Partialle ou Totale de Conduite", meaning "full or partial automated driving".

[27] Norton Rose Fullbright, 2019

[28] The regulatory framework for freight and logistics services will be set at a later stage.

[29] Ministère Chargé des Transports,2019.

[30] Ministère Chargé des Transports, 2019.

to homologate the automated systems in deployment regime. Then, the LOM law, that provides the deployment regime framework, will be enforced. Until then, the safety driver must always remain on-board fit and able to respond to recovery requests, to be able to comply with summonses and instructions from law enforcement, such as facilitate the passage and give way to priority to general interest vehicles (e.g., ambulances), as stipulated in the PACTE experimentation regime. The LOM law is expected to be enforced in early 2025.

Table 3: Overview of provisions depending on use cases (source: UNECE 2019)

Overview of provisions depending on use cases		
Use case	*Case A: On-board driver*	*Case B: Remote intervention*
Partially automated vehicle	To be able to respond to any request for handover. To be able to respond to law enforcement orders and facilitate the passage of priority vehicles.	Not allowed
Highly automated vehicle	To be able to respond to any request to take over (NB: by design = out of scope). Be able to respond to law enforcement orders and facilitate the passage of priority vehicles.	Only within an automated road transport system (ARTS) System validated by decision of the service organiser, after safety demonstration and opinion of an approved qualified body. Remote operator able to intervene according to the system's conditions of use.
Fully automated vehicle	*Not applicable*	

6.2. Germany

Germany has been leading on AV regulation internationally by creating a legal basis to place autonomous systems on the market (through type approval) and operate them (in compliance with traffic regulations) in specific operating areas, including public roads.

As a first step, the Road Traffic Act was amended in 2017 to enable drivers to relinquish control of a vehicle under specific requirements. The new framework applied to vehicles up to SAE Level 3 by specifying that they must comply with traffic regulations, recognize when the driver needs to resume control of the vehicle, and inform them with sufficient lead time to allow for a safe manual override or deactivation of the automated driving mode. In July 2021, Germany created the first legal basis for fully automated driving by amending the "Straßenverkehrsgesetz" ("German Autonomous Driving Act"), allowing vehicles with automated capacities to operate within defined operating areas, after having obtained the approval from the relevant public authority.

The German Federal Motor Transport Authority (Kraftfahrtbundesamt or KBA) is the national type-approval authority for autonomous vehicles and driving functions.[31]

German law regulates some of the following matters for motor vehicles with autonomous driving functions:

[31] Kraftfahrt-Bundesamt.

- Technical requirements for the construction, condition and equipment
- Examination and procedure for the granting of an operating licence (by the KBA)
- Regulations relating to the obligations of persons involved in the operation
- Regulations relating to data processing during the operation
- Enabling the (subsequent) activation of automated and autonomous driving functions of already type-approved motor vehicles ("dormant functions") [32]
- Adapting and creating uniform regulations to enable the testing of automated and autonomous motor vehicles.

Germany created a legal framework for the use of automated vehicles within pre-defined operational areas, which include the following scenarios:

- Shuttle transport from A to B
- People movers (buses travelling on a fixed route)
- Hub-2-hub transport (e.g., between two distribution centres)
- Demand-responsive services at off-peak times
- Transport of passengers and/or goods on the first or last mile
- "Dual Mode Vehicles" such as in Automated Valet Parking.

Most use cases are variations of fixed-route AV operation, where first- and last-mile passenger and goods transport were included due to their considerable commercial potential. For flexible-route AV operation, "demand-response service at off-peak times" was included, which could potentially be expanded to off-peak and full robotaxi services. Personal AVs are not currently included in the regulation.

To enable the regular operation of autonomous vehicles in public road traffic within defined operating areas, singular technical exemptions of the respective federal state are no longer required. An amendment of the Road Traffic Act Strassenverkehrsgesetz (StVG) specifies a generally applicable three-stage procedure, which is now regulated in detail in the newly adopted legal ordinance as follows:

1. Operating permit: Apply for an operating permit for motor vehicles with autonomous driving functions from the Federal Motor Transport Authority (KBA).
2. Defined operating range: Apply for approval of one or more vehicles of the same type for a defined operating range from the authority responsible in the respective federal state. For this purpose, the operating area must be described (i.e., the roads on which the vehicle will operate). Approval is granted in agreement with the local authority.
3. Road registration of the motor vehicle with autonomous driving function takes place by assigning an official license plate and issuing the vehicle documents.

In addition, Regulation states that vehicle owners must regularly check the safety of driving functions and carry out a departure check before every journey. Among other things, the braking, steering, and lighting systems must be checked, as well as the chassis and electronically

[32] Type approval of all vehicles sold in Europe is required. If AV functions are added to existing vehicles, a new type approval is required. The regulation of such AV additions is called "dormant functions".

controlled vehicle systems. Every 90 days, the owner must have “suitable persons,” i.e., mechanics or engineers, perform an overall inspection according to the specifications in the owner’s manual. Owners must also demonstrate that autonomous driving functions can be disabled as required in the Regulation.

The Regulation that enables autonomous vehicle testing across Germany is called "Verordnung zum autonomen Fahren" ("Ordinance on Automated Driving"). Introduced in May 2017 and in effect since June 2019, this regulation allows companies to conduct tests with highly and fully automated vehicles on public roads across Germany under certain conditions. Tests must be approved by the KBA and must comply with specific safety requirements. Testing on public roads must be done in accordance with a specific testing plan, which must be submitted to the KBA for approval. The plan must include a detailed description of the testing scenarios, the location of the tests, and the measures taken to ensure the safety of other road users.

Among safety requirements, the automated vehicles must be equipped with a data recording device, must have a safety driver on board who is trained to take control of the vehicle if necessary, and must comply with specific technical and safety standards.

In May 2020, the German government published an updated version of the “Verordnung zum autonomen Fahren” regulation, expanding the scope of permitted AV testing to include more complex scenarios (e.g., overtaking manoeuvres and driving in emergency situations). The updated regulation also introduced a new level of automation called "conditional automation," which allows vehicles to drive themselves in certain situations while requiring a human driver to be ready to take control. The basis for inter-municipal serial vehicle regulations in Germany is defined by the KBA guidelines for implementing the UN-R157 on Automated Lane Keeping Systems. According to the Bundesanstalt für Strassenwesen (Federal Highway Research Institute), this regulation defining a traffic queue pilot for highways will be successively extended to higher speeds and additional operating design domains across other regulations currently being developed.

For more highly automated vehicles, the publication 86/22 of the German Ministry “Bundesministerium für Digitales und Verkehr” is defining the framework for vehicle approval. Single municipalities, which are already allowing highly automated traffic in limited areas (e.g., “Tempus” Munich), may have stricter regulations for their areas of responsibility.

6.3. Austria

A dedicated legal framework to enable testing automated vehicles on open roads was first established in 2016 (AutomatFahrV). Back then, Austria took the approach of defining specific use cases, which included automated minibuses, motorway pilots with automated lane change and automated military vehicles. In April 2022, a major amendment added five new use cases, including the use case “Automated vehicle for the transport of goods” which enables the testing of the Hub-to-Hub use case in the H2020 EU-funded Project AWARD.

This new use case was introduced to allow testing of automated freight transport on public roads. It is primarily suitable for short distances, since the speed is limited to 30 km/h for testing automated vehicles without prior type approval, and to 50 km/h for automated vehicles where the base vehicle has been type-approved before. In any case, the actual approved operating speed must be based on the results of a detailed route analysis and risk assessment.

This route analysis and risk assessment is one of the new requirements introduced by the amendment in 2022. Applicants must analyse every segment of the route based on a provided checklist. If risks are found, appropriate mitigation measures must be defined. Additionally, the training of the safety operator must include the specific characteristics of the route and use case-specific manoeuvres. Table 2 contains an overview of the information to be provided by the applicant to obtain a test permit.

Testing on public roads is possible for vehicle manufacturers, research institutions, system developers and transport companies.

Table 2: Summary of requirements and necessary information to obtain a test permit in Austria

Filled in application form	Safety relevant information

– Contact person
– Description of the use case
– Purpose of the test/research questions
– Name of operators
– Licence plate number
– Confirmation of third-party liability motor insurer
– Duration of tests
– Planned route or area
– Evidence of having informed the state governor and the road administration
– Approval from the driver/operator to perform data recording
– Accident data recorder
– Description of necessary infrastructure adaptations
– And a few other brief questions
	Analysis and risk assessment of the planned route following a given template (including corresponding documentation of risk mitigation measures)
	– Confirmation of operator training:
	  ▪ Test driver certificate (or similar) – focussing on driver skills
	  ▪ Training/introduction covering the vehicle specifics, route specifics, use case specific manoeuvres, etc.
	– Description how the necessary manoeuvres have been tested beforehand on a proving ground and in simulation
	– Description of manual override of the system
	– Description of manual deactivation of the system
	– Description if a risk analysis for the whole test has been carried out and if mitigation measures have been taken, including description of method used

The regulation does not impose additional restrictions on the time of the operation, weather conditions, or similar issues. The safety validation is based on an assessment by the applicant. The applicant must describe the results of the safety validation for the overall test case and specifically for the intended route, which also includes documenting the corresponding risk mitigation measures.

As specified in § 1 Abs 6 of AutomatFahrV, test reports must be submitted at the end of the approved test period. If the trial period is longer than six months, interim testing reports must be submitted every six months in addition to the final report[33]. These reports are publicly available on the website of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology.[34] Critical situations and/or accidents that occurred during the test drives must be reported immediately.

[33] AustriaTech and Federal Ministry Republic of Austria, 2022.
[34] Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology.

Currently, testing permits can only be issued if they are covered by one of the pre-defined use cases. The different needs of possible extensions of pre-defined use cases are collected on a regular basis by an AustriaTech contact point for automated mobility through the application process.

Further developments of the Austrian legal framework are stimulated by a clear need for and interest in enabling new use cases. Therefore, amendments of the ordinance might take place on behalf of different requests, but first the demand must be validated within a separate process. Nevertheless, an amendment of the ordinance requires time and might not be adjusted one-on-one to the original request(s).

6.4. Norway

Across Norway, self-driving vehicle test applications are governed by the "Lov om utprøving av selvkjørende kjøretøy" (Test of Self-driving Vehicles Act, TSVA), which came into effect in January 2018.

TSVA aims to encourage and formalise the testing of self-driving vehicles by setting a framework centred around traffic safety and privacy. AV tests are to be performed in line with the maturity of technology at hand and should be designed to establish the implications of using self-driving vehicles with respect to mobility and traffic development, the environment, and traffic safety. Considered as self-driving are any vehicles comprised of an electronic system capable of automatically controlling the vehicle and the driving of the vehicle, which operates either without a responsible driver or with a responsible driver which is located outside of the traditional driver's seat. This also includes any vehicles that allow the electronic driving system to hand over control to a driver.

To test self-driving vehicles in Norway, an application for a test permit must be filed with the Road Directorate of the Norwegian Public Roads Authority. The applicant must be a natural or legal person, and the permit is issued for a fixed time period that can be extended if the circumstances justify it. Permission to test self-driving vehicle is given based on (1) a specific vehicle and its functionalities, (2) a risk analysis of the proposed project, and (3) the presence of one or more designated responsible drivers or operators. Should any of these parameters change, for example because the vehicle software is updated, the test environment changes, or a new operator is given the permission to operate the self-driving vehicle, the Road Directorate must be at least notified. If safety-relevant aspects of the project are affected, an application for a new permit might be required. Permits may be suspended or revoked if the conditions for the permit are no longer met.

The three parts of an application for tests under the TSVA are detailed as follows.

1. Description of the vehicle and of the automatic system

To be included in the tests, the vehicle should comply with relevant regulatory requirements (depending on whether it is a car, vehicle, motorcycle, tractor, etc.), unless an exemption has been agreed. In practice, many self-driving vehicles need an exemption as they lack features considered essential to comply with standard regulations, such as a steering wheel.

The regulation includes standard provisions for vehicles operating in the public domain, such as adequate brakes and compliance with EU regulations on Electromagnetic Compatibility emissions. The vehicle should also be registered in accordance with the Road Traffic Act (Lov om vegtrafikk), although this requirement can be waived (such as cases involving very limited testing under strictly controlled circumstances). All vehicles must be insured, and proof of insurance must be provided with the application.

The vehicle's automatic driving system, meaning the system that allows the vehicle to be self-driving, is subject to particular scrutiny. Documentation must be provided that details a functional description of the automatic system, its capability to safely drive the vehicle (together with proof that these functions have been adequately tested by a third party), in addition to documentation that details the system's security (including provisions protecting the system from cyberattacks). This latter aspect is also relevant for General Data Protection Regulation considerations, with which the automatic system must comply.

2. Risk analysis of the proposed project

The proposed project must be analysed with respect to safety and risks. Both the environment in which the AV is set to operate and the interactions with the environment must be carefully described, and risk and mitigating measures explained. The assessment of the project must be complete and illustrative enough for the Road Directorate to be able to evaluate whether the proposed project fulfils the TSVA safety requirements. Normally, this means that an applicant will provide a full safety analysis of every feature along a proposed track for the self-driving vehicle including pictures of the route, explanations of the interactions between the vehicle and other traffic participants, as well as a risk matrix evaluating potential risks by severity and frequency.

The Road Directorate can ask for a risk analysis to be verified by a third party. Risk-mitigating measures should be proposed where appropriate. If the Road Directorate issues a permit based on the application, these proposed measures must be put in place, documented, and an updated risk analysis must be sent to the Road Directorate for their records. If the Road Directorate decides to inspect a project, the environment must match the environment proposed in the application (including risk-mitigating measures). Otherwise, the permit will be suspended or revoked.

3. Responsible driver or operator

A distinction must be made between the safety responsible for the project and the responsible drivers or operators. The former assumes legal safety for the pilot and must ensure that the pilot is executed under the circumstances for which the permit is given. On the other hand, a responsible driver is an operator of the self-driving vehicle whose responsibility it is to monitor the vehicle (either within the vehicle or remotely). All operators must be named and identified in the application, and documentation for the qualifications of the operator to assume responsibility for the vehicle must be provided. These qualifications usually include at least a driving license for the vehicle category that the self-driving vehicle falls under (e.g., car, truck, minibus, bus) and a certificate for having been trained on the use of the automatic system.

The relationship between the responsible driver and the self-driving vehicle must be made clear in the documentation supporting the application. For example, routines should be described that remedy emergency situations, such as means for an operator to remove the vehicle from the flow of traffic if the automated system becomes unresponsive. It should be clear how much involvement the operator has during normal operations, and under which circumstances they are expected to intervene and take action. How much is expected of the operator depends on the vehicle's abilities.

All permits are given on condition that not only the Road Directorate be kept up to date with any significant events during the project (especially any incidents), but that information from the project is shared. The Road Directorate can, and often does, requires applicants to keep a data log with vehicle data that the Road Directorate can access if required and in case of incidents. It is commonly stipulated that data from the end of the set-up period it to be submitted in a way that the Road Directorate can verify that operations with the self-driving vehicle are running as expected. Furthermore, all tests are required to have a test report submitted at the latest 6 months after the end of the project, together with a version of the report that can be made public.

6.5. Switzerland

A test permit from the Federal Council is required to test self-driving vehicles from level 3 (conditionally automated) to level 5 (fully automated). The legal basis is the exceptional approval of Art. 106 para. 5 Road Traffic Act (SVG). Authorisations are issued for pilot trials with a safety driver who is present. The lead agency is the Federal Roads Office (FEDRO), which has published a corresponding fact sheet.).

In November 2021, the Federal Council approved the dispatch on an amendment of the Road Traffic Act, to enable automated driving. The Federal Council can determine the extent to which drivers are relieved of their traditional duties and to what extent driverless vehicles with an automation system can be permitted, provided they operate within defined individual routes and remain monitored.

The framework conditions were clearly defined in the amendment of the SVG, which entered into force in March 2023. FEDRO was granted the possibility to approve and financially support pilot trials with automated vehicles.

A FEDRO factsheet for conducting pilot tests in Switzerland provides entities interested in conducting AV pilot tests with information about the legal basis, authorisation procedure, responsibilities, required A successfully conducted trial can be a relevant element for granting an exceptional authorization for a registration under the normal procedure.

FEDRO has the power to authorize ADS of driverless vehicles which are not type-approved. Applicants must prove on a case-by-case basis that a certain safety level is guaranteed, and a detailed ODD description is present. The safety level must be equal to the one guaranteed by a type-approval procedure. With exceptional authorization for the ADS, the vehicle may finally be registered under the normal procedure and may be used commercially.[35]

Cantonal authority is responsible for issuing the vehicle's licence plate to be used during tests, but not for issuing the authorisation to conduct the test. Relevant cantonal agency (e.g., road traffic office) is involved in inspecting the vehicle technology.

Furthermore, the respective road owners (e.g., federal government, canton, municipality/city, or private individuals where required) must be involved in determining which stretches of road may be used to conduct tests. Due to their comprehensive knowledge of the local area, their role as enforcement bodies and the interests of good relations, cantonal and local authorities and the police should be involved in the test.

[35] A. Jost, 2024.

Currently, new regulations are under discussion that are intended to cover the following types of vehicles equipped with an ADS, which include fully automated vehicles (vehicle with takeover requests, driverless vehicles, and vehicles with an automated parking system). The regulations are expected to enter into force in early 2025.

6.6. National Regulation across the EU

The presence of different national rules for automated vehicles can lead to fragmentation across the EU market and may have a significant impact on AV development and implementation in European countries.

It can be challenging for manufacturers to design vehicles that comply with multiple sets of rules, potentially increasing the cost and complexity of development. Some companies may be hesitant to invest in AV technologies if they are uncertain about the regulatory environment. This could slow down innovation, especially for smaller companies and startups. This could lead to companies from outside the European union to penetrate the EU market and increase competitiveness.

For AVs to operate seamlessly across borders, consistent regulatory frameworks are necessary. Differences in national rules can impede the ability of AVs to travel between countries, limiting the potential for international travel and logistics. This is particularly relevant in regions like the European Union, where cross-border travel is common.

To address these challenges, the Automated Driving Systems (ADS) Act aims to harmonise the rules within the EU for autonomous vehicles, focusing on creating a common regulatory framework for all Member States regarding the homologation of vehicles. This harmonization is essential to facilitate the introduction and adoption of autonomous vehicles on European roads.

7. Lessons from the use cases and recommendations

7.1. Understanding and defining teleoperation

Teleoperation refers to driving or controlling vehicles remotely, which is already being used in off-road environments such as mines, farms, or warehouses.[36] These closed logistics facilities typically allow quicker implementation of self-driving vehicles than public areas such as open roads, because these private premises are usually subject to different regulations. However, with the ongoing improvement of telecommunication and automation, the broader use of teleoperation, including on public roads, is gaining traction.

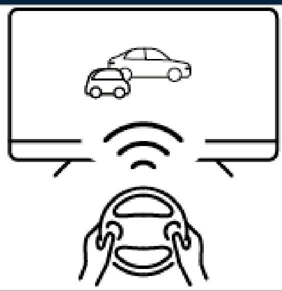
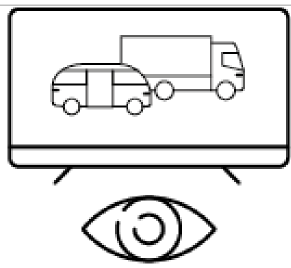
It is important to note that teleoperation has a wide spectrum of possible applications. In Germany, companies such as Vay[37] and Fernride[38] are conducting tests with remotely driven cars.[39] In these cases, teleoperation is mostly used independently from automated driving (directly controlling the vehicle's movement). By contrast, within the EU ADS type approval, teleoperation can only be used as an adjunct to automated driving (e.g., by approving manoeuvres suggested by the ADS). In these cases, the ADS must perform the driving task, and directly controlling the vehicle's movement through teleoperation is not foreseen (for more details in section 5.2 and 5.2.1 of the deliverable).

Given the diverse array of teleoperation concepts and functions, it is important to distinguish between them. This distinction can help better understand the various teleoperation characteristics and requirements. For instance, signal transmission latency is crucial for teleoperation that directly controls the vehicle (remote direct driving). On the other hand, the ADS capability to suggest viable trajectories is crucial for teleoperation that is used as an adjunct to automated driving (remote intervention and approval of manoeuvres/paths).

An initial classification of the different types of teleoperation is proposed in Table 3, following the logic presented by Majstorović et al. (2022).[40] It distinguishes between three different types of teleoperations.

[36] Law Commission, 2023.
[37] Vay, 2022.
[38] Port of Hamburg, 2023.
[39] T. Hoffmann, et al, 2023.
[40] D. Majstorović et al., 2022.

Table 3: Characteristics of different types of teleoperation (Illustrations: AustriaTech)

Type of teleoperation	Characteristics of teleoperation	Illustration of teleoperation
Remote direct driving	Remote/direct driving implies drivers located in a remote-control centre (outside of the vehicle) and performing driving tasks such as steering (lateral control), braking, releasing, or accelerating (longitudinal control). In addition, these drivers also monitor the vehicle or driving environment to be able to carry out immediate and safety-critical interventions.	
Remote intervention/assistance (approval of manoeuvres/paths with ADS)	Remote intervention, also referred to as remote assistance, is commonly used as a complementary feature to fully automated driving systems. In this mode, the remote intervention operator does not take direct control of the vehicle's movement but rather executes manoeuvres, by activating or deactivating the automated driving system, or provides assistance to passengers in particular situations.	
Supervision or monitoring	Supervision and monitoring refer only to monitoring the vehicle or driving environment. However, the operator cannot perform lateral or longitudinal control of the vehicle.[41]	

7.1.1. Experience from AWARD

In the AWARD project, the Ottopia teleoperation platform provided real-time communication between the ADS and remote operators to ensure safe human intervention and vehicle takeover. The teleoperation platform is composed of in-vehicle components such as Artificial Intelligence-based networking, video encoders, a computer platform, and interfaces with other ADS sub-systems, to ensure reliable data transmission to the teleoperator.

The AWARD project focused on two types of teleoperations. While the AWARD port, aerodrome, and forklift use case focused on remote intervention and approval of manoeuvres/paths with automated driving systems (ADS), the hub-to-hub use focused on remote direct driving. Research on all kinds of teleoperation is crucial to better understand the different teleoperation tasks, requirements, and potential critical areas to be further investigated.

In the AWARD hub-to-hub case, remote direct driving was implemented and limited to proving grounds, with no provision for operation on public roads. In this research setting, the following procedures were put in place:

[41] Law Commission, 2023.

- Manual Takeover: In the event the ADS requires assistance, an on-board safety operator activated the manual takeover process by pressing a button to request help. This action prompted the fleet management system to notify the teleoperator. Then, the teleoperator could take direct control of the vehicle's movements.
- Logging Teleoperating Status: The fleet management system always receives and records the teleoperating status. This logging mechanism provides an overview of all teleoperation activities and take-overs from the different controlling entities.

Differentiating and defining the various types of teleoperations (i.e. remote direct driving, remote intervention, and approval of manoeuvres/paths with ADS, or supervision/monitoring of AV) will be important to develop clear terminology shared by all stakeholders involved in AV logistics research and deployment.

Different teleoperation concepts and functionalities are likely to coexist in the future, to suit the specific requirements of the different logistics use cases. To foster clarity, liability, and transparency on the technology being researched and potentially deployed, clear definitions on the various types of teleoperations should be further developed and shared by all stakeholders, across the EU.

Recommendation:

- *Due to different teleoperation characteristics, limitations and functionalities, the various teleoperation types should be differentiated and categorised. An initial teleoperation categorisation differentiates between AV remote driving operator, remote intervention/assistance, and supervision.*
- *Further develop and foster standardised terminology on the various types of teleoperations, to foster clarity, liability, and transparency on the teleoperating technology being researched and potentially deployed.*

7.2. Future research on remote direct driving

Through the Automated Driving Systems (ADS) Act, the EU aims to harmonise autonomous vehicles rules for across the EU, by creating a common regulatory framework for all EU Member States on vehicle homologation. Consistent regulatory frameworks are necessary, particularly for manufacturers designing vehicles that must comply with multiple sets of rules and for AVs to safely operate across borders.

While the ADS Act regulates the type-approval of some types of teleoperations (i.e., remote intervention and approval of manoeuvres/paths with ADS), it however excludes others (i.e. remote direct driving). Some EU countries have been developing national regulatory provisions to introduce the possibility of testing teleoperation features currently excluded from EU ADS such as remote direct driving, including on public roads.

For instance, although remote direct driving is not included in the EU ADS type approval, member states such as Germany permit its testing on public roads, provided that certain requirements and standards are met. Several companies in Germany are currently conducting tests with remotely-driven cars. To test and deploy remote driving in Germany, local traffic authorities must issue exemptions to operate on public roads, after having successfully received a certificate from a technical service such as Technischer Uberwachungsverein (TÜV). Technical services verify that the vehicle and functional safety is in accordance with ISO

26262, that cybersecurity is in accordance with ISO/SAE 21434 and other standards based on individual vehicle approval. The verification of remote direct driving ensures that the communication path between the vehicle and its telestation (i.e., the communication and connected systems) is protected against cyberattacks and any hazards that may result from a potential connection failure and/or a respective risk-manoeuvre or fail-operation mode.

As EU regulation does not currently indicate that remote direct driving technology is sufficiently mature for market introduction, it remains an area of interest for further research. In real-life automated operations, if an AV loses connection, it must be able to safely delegate control of the vehicle to the teleoperator. For this reason, the interlink between the ADS and the regulatory framework must be clear to avoid any future obstacles. Further investigation of remote direct driving on proving grounds, as in AWARD, can facilitate the understanding of the capabilities and limitations of remote direct driving, which was one of the focal points of the teleoperation tests in the AWARD hub-to-hub use case.

7.2.1. Experience from AWARD

In October 2023, specific teleoperation tests were performed in AWARD at Digitrans proving ground of St. Valentin, Austria. The primary research objective in this AWARD use-case was to identify scenarios that required intervention from the on-board safety operator and assess the feasibility of effectively handling those situations through teleoperation (direct remote driving).

Figure 6 shows a scenario where a remote teleoperator tries to circumnavigate an obstacle on the proving ground. It is important to highlight that because the teleoperation feature tested in the AWARD hub-to-hub research is focused on remote driving, it cannot be eligible to be included in an EU type-approved ADS.

Figure 6: AWARD demonstration carried out by Digitrans of driving around a parked vehicle using teleoperation, November 2023 (Pictures: AustriaTech)

During the testing phase on the AWARD proving ground, the teleoperation (remote direct driving) technology has proven to be successful in various scenarios, such as avoiding obstacles, recognising objects and other road users, and driving in heavy rain.

However, limitations also existed, such as in scenarios that required precise awareness of the vehicle's dimensions or distance to other objects. These limitations are partly attributed to the teleoperation solution itself, which includes the position of cameras and viewing angles. Addressing these issues through proper adjustments of camera positioning will require further research.

During the AWARD testing phase, specific success criteria were identified. Some of these criteria for successful use of teleoperation solutions were technical maturity of hardware, transmission rates, network coverage, and encryption. Other success criteria identified were the teleoperator's experience, training, education and familiarity with the vehicle and setup. If training, experience and ability of users can affect risk associated with the use of machinery, these factors cannot be used as a substitute for hazard elimination.

Providing teleoperators with more information and communication options, such as additional cameras, sensor data (e.g. infrared vision in darkness), intercom systems, etc., was also identified as crucial for safe AV operation.

For future research, possible teleoperation (remote direct driving) critical areas and scenarios should be further investigated. More specifically, critical and relevant teleoperation scenarios should be identified and examined to determine the reactions of remote operator and technical mitigation mechanisms.

In the long-term, it is important to consider the differences in teleoperation regulation between countries. If national regulation on the topic remains in its infancy, it is important to avoid regulatory gaps and obstacles for instances that involve teleoperation in more than one country.

Recommendation:

- *As remote direct driving is currently excluded from EU type-approval, future research on it and ADS integration with AV is crucial to better understand technological capabilities and limitations.*
- *Technological maturity, safety of the system and good practices should be at the core of the development of teleoperation testing and deployment frameworks.*
- *In the long-term, consider the differences in national teleoperating frameworks to avoid regulatory gaps and obstacles for instances that involve operation in more than one country.*

7.3. Teleoperator working environment

With the growing deployment of automated vehicles in logistics activities, new specialised professions will be necessary. The remote management, monitoring, and control of automated logistics vehicles involves both driving and non-driving related tasks, when vehicles are driving autonomously.

Currently, select teleoperation elements are addressed in regulation, while other elements such as teleoperating working conditions have not yet been addressed, due to the early stage of development. For instance, the French national framework defines teleoperation as an intervention solely on the vehicle's ADS, for the purpose of acting on it but without substituting the system's action on the dynamic driving task (remote intervention). The teleoperator can activate or deactivate the system, provide instructions to perform, modify, interrupt a manoeuvre, or acknowledge manoeuvres proposed by the system, and provide instructions to the navigation system to select or modify route planning. Any remote action can only be performed by an authorized person holding a valid driving license in line with the vehicle category in question.

In addition, the user interface concepts, tasks, and associated practices remain scattered and have largely not been adapted for the specific properties of AV operation. To date, there are several teleoperation taxonomies, proposed by different service operators or developers of connected supervision platforms, for the operation of AV fleets based on the SAE levels of automation model.

7.3.1. Experience from AWARD

In the AWARD hub-to-hub use-case, the teleoperator sees the relevant information via the FMS. The teleoperator had two screens, one with FMS information and one with the Ottopia teleoperation system (Figure 7). At the control centre, the teleoperator was provided with the controls needed to remotely take control of the vehicle.

In AWARD, five fleet management systems (KION/DEMATIC, Applied Autonomy, EasyMile, KAMAG, and TLD) were analysed to gain concrete understanding of possible user interactions. The fleet management human machine interface (HMI) was developed to best support logistics personnel to supervise and manage transport jobs, vehicles, and routes. The teleoperator in AWARD was also provided with information on pending issues. This allowed to provide the supervisor the understanding needed to take control of the vehicle, to prepare for the remote control or teleoperation. More detailed information on the HMI design for fleet management and control services can be found in D5.3.

Teleoperator's distraction and workload must be considered when designing a teleoperating platform that allows to swiftly and safely take control of the vehicle when requested. The interface should enable teleoperators to monitor the ADS and perform the needed tasks. For this, teleoperators must have the information needed to perform the tasks and take over requests, without negatively impacting their workload. Adding new information flows and visual indicators would run the risk of overloading teleoperators who, especially when driving in traffic contexts, already need to pay attention to a wide variety of visual cues and indicators. For this reason, during take-over requests, the teleoperating platform and the information shared with teleoperators should only focus on what is strictly necessary, without additional initial indicators or modalities. It is important to define common information elements that the teleoperator should receive to ensure effective vehicle takeover within a short period of time.

Figure 7: Photo of the teleoperation center from Ottopia, used for assisting the AV via remote control

The Ottopia teleoperation platform used in AWARD also allowed the AV supervisor to check vehicle cameras and to remotely control a few functionalities that do not require teleoperation. Checking the cameras can serve as preparation before teleoperation, so that the supervisor can get familiar with the operating area, situation, and AV's surroundings, before taking over full control of AVs.

Regarding the teleoperator's working environment more broadly, an overarching principle for the proposed HMI design is the achievement of a "unified experience", providing a seamless transition between fleet overview and detailed teleoperation tasks. The notion of telepresence, meaning a strong sense of physical presence at the remote site, should be ensured at the worksite.

In addition, an effective teleoperator's staffing ratio should be implemented, to ensure an adequate number of operators are available to monitor the vehicle fleet. This ratio must guarantee that in the event an operator needs to take over the driver role for an individual vehicle, no vehicle is left unattended. On the other hand, to ensure fair and safe teleoperator working conditions, an optimal workload balance should be established, to prevent both mental underload and overload. In line with current professional drivers working hours and rest time periods, currently regulated at the EU level (e.g., Regulation (EC) No 561/2006), teleoperators working hours should be regulated to ensure safe AV operations and monitoring. Teleoperator's duty periods, duty times, and adapted rest periods, should be effectively managed through a rostering system, to prevent fatigue.

Recommendation:

- *The Fleet Management System (FMS) Human Machine Interface (HMI) should best support logistics personnel to supervise and manage transport jobs, vehicles, and routes.*
- *During ADS take-over requests, the teleoperating platform and take-over requests should only include relevant information necessary to perform the teleoperating tasks, without additional indicators or modalities that may distract.*
- *Effectively regulate and manage teleoperators working conditions, including workload, duty work and rest periods, to ensure safe AV operations and working conditions.*
- *Provide teleoperators the access to vehicle's cameras before the start of AV operation, to monitor AV's surroundings and environment before the start of any operation.*
- *Foster teleoperators' telepresence (sense of physical presence at the remote site) and implement an effective staffing ratio, to ensure an adequate number of operators can monitor the vehicle fleet, without leaving any vehicles unattended at any time.*

7.4. Training and skills requirements for AV operators

To ensure safe AV testing and deployment, it is crucial to ensure the proper training of in-vehicle safety drivers and remote teleoperators. It is also necessary to make sure they have the capacity and competences required to monitor and take over the vehicle at any moment.

In Germany, regulations set requirements that teleoperators must meet to be able to carry out teleoperation. Indeed, the German Autonomous Driving Regulation in Section 14[42] sets additional requirements for the persons in charge of AV technical supervision. These include (amongst other aspects):

- A master's or bachelor's degree or as state-certified technician in mechanical engineering, automotive engineering, electrical engineering, aerospace engineering or aircraft technology.
- The successful completion of appropriate training in relation to the vehicle with the automated driving systems from the manufacturer (who is obliged to offer respective appropriate training).
- Holding a valid driving licence for the same category as that of the automated vehicle.

France has also taken proactive measures on remote intervention operators training, by implementing specific regulations to ensure their competence and qualifications, including detailed specifications on their education and medical certificates.[43] More specifically, the French Decree No. 2021-873 of 29 June 2021 requires teleoperators to possess a driver's license in the same vehicle category as the automated vehicle they operate. Furthermore, evidence of competences is required when working as a teleoperator. The mandatory teleoperator training in France covers a wide range of topics, including understanding remote intervention functionalities, technical knowledge, vehicle capabilities, resource performance, monitoring skills, operational procedures, emergency response, cognitive load management, field deployment safety, human interactions, and procedure enforcement. Additionally, training addresses system-specific resources, characteristics and risks of the specific routes and areas used by the vehicles and communication with relevant parties.

Overall, each European country has its own set of requirements and legal basis to ensure the competence and qualifications of safety drivers and teleoperators. If training and requirements commonalities can be identified between European countries, it is important to develop a common basis for unified safety drivers and teleoperation requirements and conditions, providing the opportunity to harmonise legal requirements across Europe. It is also important to keep in mind the difference in tasks and therefore trainings requirements that the different personnel involved in AV operation should have, namely between safety drivers and teleoperators.

7.4.1. Experience from AWARD

In the AWARD hub-to-hub and port use-cases, safety drivers were trained by EasyMile's test engineer. At the end of the training, a signed version of a document proving the training of safety drivers was issued. The training’s focus was to explain how EasyMile's vehicles and technology works, how to start missions, to switch into manual and auto modes.

It is important to note that environments, vehicle characteristics, and onsite rules differ across the different AWARD use-cases (port, aerodrome, hub-to-hub and forklift), which re-

[42] Bundesministerium der Justiz.
[43] République Française, 2022.

quires trainings to be adapted to the unique specificities of the different vehicles and environments. Each AWARD use case environments were analysed in detail by the verious stakeholders involved in the use cases.

Following the AWARD tests on proving grounds, it was found that the teleoperator's experience, training, and familiarity with the specific proving ground was an essential criterion for successful AV testing operation.

Specific requirements for teleoperators' comprehensive education and training are already being identified by some European national regulation (e.g., France and Germany). For instance, to ensure operators have previous experience with operating a vehicle of the same category on public roads and in real-world conditions, the permission for safety drivers and teleoperators to operate AV should be issued as an addition to the regular driver's license. The driver licence required should align with the category of the AV being monitored. This requirement is already in force in different national regulations across Europe, such as France and Germany.

In addition, knowledge of the AV operational area would be beneficial. Obtaining inputs from operators regularly working across different operational areas would provide a valuable input for AV trainings and setup. Experts with dedicated background in AV technology must become familiar with the operating area and on-site environment.

For logistical operations at aerodromes, operators must meet the skills and training requirements stipulated in EASA 139/2014 Annex IV - ADR.OPS.B.024 "Authorisation of vehicle drivers" particularly in terms of communication and radiotelephony. To be adapted to AV, the application of these requirements should be tailored to the split of tasks between the AV embedded system, the remote station, and the remote or safety driver. Overall, the training program and ongoing training (e.g., in the event of changes in regulations or modifications to the traffic zone) should be reviewed in the context of AV. In addition, communication can be a bottleneck in the event of a radio problem, as the fallback procedures for non-AV rely on visual or hand signals, which may not be understood by AVs.

As seen in section 4.1.5, the ISO 12100 standard defines different categories of people that could encounter AVs, from operators of adjacent machinery, administration staff. Across the AWARD proving grounds and test sites, relevant stakeholders exposed to AVs were given a comprehensive set of briefings and written instructions. However, the AV use limits, level of detail, and the scope of the training material needs to be further evaluated, particularly to individuals with extensive exposure to AVs, as recommended by the ISO1200 standard.

It is recommended to provide specific common guidance to stakeholders with extensive exposure to AVs, such as operators of adjacent machinery. More specifically, detailed training on AV warning systems, required reactions, the definition of intended use, and reasonably foreseeable AV misuse could be developed. In addition, a harmonised training on basic items could be developed (e.g., checklists for remote handling of AVs, emergency stop design or maintenance workarounds). Further details on different AV operating modes, intervention procedures, and interventions required by malfunctions of the equipment could also be provided.

For the general public, the development of specific guidance common to all stakeholders with potential exposure to AVs (i.e., by considering their background and knowledge) could be developed as a way to promote safe interaction with Avs and foster trust and public acceptance.

Recommendation:

For safety driver & teleoperator:

- *Require an obligatory driver's license category aligned with the autonomous vehicle category being monitored.*
- *Set specific common training requirements, which include: (1) detailed training on AV warning systems and required reactions, (2) definition of intended use of the AV and (3) reasonably foreseeable misuse of the AV.*
- *Tailor training requirements to consider the specificities of AV operation, particularly regarding the split of tasks and communication.*
- *Provide further details on different machine operating modes, intervention procedures for the user and interventions required by malfunctions of the AV.*
- *Develop harmonised training on basic items (e.g., checklists for remote handling of AVs, emergency stop design or maintenance workarounds).*

All stakeholders:

- *Set specific guidance common to all stakeholders with potential exposure to AVs (i.e., by considering their background and knowledge).*

7.5. Dealing with hazardous conditions and sensing solutions

One of the main goals of the Fleet Management System (FMS) is to ensure safe operations. This entails keeping the autonomous vehicle within operating conditions deemed safe, also known as Operating Design Domain (ODD).

To maintain the autonomous vehicle within its ODD, the FMS gathers information from different sources available in the ecosystem to keep track of the environment in which the AV operates. These data sources may include weather stations and road sensors to help determine the environmental conditions (e.g., how windy is it? Is the road icy? How heavy is the rainfall?). Data sources may also include traffic information such as accident reports or locally reported incident information to determine traffic conditions (e.g., road obstructions or hazards, such as an oil spill at a certain location).

7.5.1. Experience from AWARD

In AWARD, the teleoperation platform by Ottopia enables an autonomous vehicle experiencing an issue to notify the FMS of its need for assistance (see Scenario 1 below). Alternatively, the FMS also acts as an additional safety layer as it can detect a problem (see Scenario 2 below). Regardless of which entity detected an issue (the AV or the FMS), the FMS will ping the teleoperating system to find a suitable teleoperator to then connect the vehicle requiring assistance with a human teleoperator.

The FMS is an additional safety layer to monitor the vehicle's ideal operating environment and detect any issues. Depending on the nature and magnitude of the change of the vehicle's ODD, the FMS has different options for taking safety-ensuring actions. Some concrete examples of the scenarios and actions implemented in AWARD are described in Table 4.

Table 4: FMS follow-up actions for different operating issues

Scenario	Issue	Follow-up action
Scenario 1: Vehicle requires assistance	An issue has already taken place which cannot be solved by the autonomous vehicle alone but requires the intervention of a human operator (e.g., engaging in high-risk manoeuvres such as driving around an obstacle when visibility is poor).	The FMS connects the autonomous vehicle to the teleoperator when the vehicle requires human intervention. The human teleoperator is then able to take control of the vehicle and carry out tasks. Once these tasks are completed, the teleoperator hands back the control of the vehicle and the FMS will disconnect the teleoperator from the AV. The ADS can then take back the control of the AV.
Scenario 2: Obstacle is reported	An obstacle is reported (e.g., road is closed due to an accident).	The FMS will try to reroute the vehicle*. If no alternative route can be found, the autonomous vehicle will not be dispatched. If the vehicle is already on its way when the only possible road is suddenly closed, the FMS must ask a teleoperator to help turn the vehicle around (Scenario 1). **In AWARD, we have only been able to show this on test grounds and in the simulator as none of the actual use cases offer an alternative route to the only programmed path.*
Scenario 3: ODD conditions not satisfied	The weather suddenly changes and conditions are beyond the vehicle's ODD.	The FMS will refuse to dispatch the AV.
Scenario 4: ODD conditions are met, but do not enable the automated vehicle to operate within ideal operating conditions	The weather conditions are not ideal but still enable the autonomous vehicle to operate within its ODD. These instances only temporarily or gradually affect the AV's ODD. For instance, when it is raining but not enough to overwhelm the sensors. For instance, if it has been reported that one stretch of the road is currently icy, but the rest of the route is fine.	In these instances, the AV should operate in degenerate rather than normal mode. In degenerate mode, the safety margins are increased to accommodate slightly more challenging situations. More information in the paragraph below.

The behaviour of the automated vehicle is controlled by the vehicle's Automated Driving System (ADS), over which the FMS has no influence. The vehicle provider defines different vehicle behaviours and the threshold for environmental parameters that trigger these different behaviours. The FMS uses data received from the environment to check these parameters and dispatches the AV in a way that ensures it operates within its ODD. The design of mechanisms that will trigger and lead to an alteration of the autonomous vehicle behaviour will depend on the mechanisms developed by the vehicle provider and the interfaces available to the FMS. For example, a simple design could for the vehicle provider to define multiple routes, which cover the same locations but with different speed profiles depending on the weather conditions. In that case, if the threshold for light rain has been crossed, the FMS will dispatch the automated vehicle on route "slow mode 1", which the ADS will then translate into the according vehicle behaviour (e.g. "drive at 80% of the highest programmed speed").

This is particularly crucial for situations that may gradually or temporarily affect the AV operating conditions (e.g., light rain). For instance, when the FMS detects that visibility is bad for humans and can lead to an increase in risk of accidents, the FMS will take action to protect both the autonomous vehicle and vulnerable users. To ensure safe AV operation during these instances, the AV should operate in a degenerate mode where the safety margins are increased to accommodate for more challenging situations. In practical terms, this means reducing the AV speed (either globally or for selected parts of the route) and/or increasing the safety zone around the AV. In these instances, the AV can operate in a more conservative mode by increasing the safety zone around the AV: when objects/persons enter this zone, they are detected as obstacles instead of being ignored, and therefore the vehicle avoids collision with them entirely. This will ultimately allow the AV to stop earlier in case people enter the proximity of the AV.

In the AWARD project, dispatching autonomous vehicles in degenerate mode was not an available function. Nonetheless, the FMS at the hub-to-hub site during these instances was configured to either disallow dispatch entirely (e.g., in case of fire alarm) or on part of the route (e.g., in case of a closed section of road). In addition, when road conditions were detected to be potentially dangerous, the planned driving time was increased. In the hub-to-hub use case, a Vaisala road sensor detected road friction, ice level, snow level and water level as conditions that might lead to a deviation being identified. During the testing of these functions, a rain tunnel was used to create low road friction conditions which crossed the set threshold of 0.6. When the rain tunnel was turned off and the road friction returned to levels above the threshold, the deviation was removed from the FMS and the planned vehicle driving time was returned to its default value. These tests allowed to effectively showcase the automatic identification of situations outside the AV's ODD, leading to the FMS's related refusal to dispatch the vehicle.

Recommendation:

- *To ensure proper detection, implement minimum requirements on data and information a FMS should gather from the ecosystem and the vehicle itself (e.g., weather sensor, information on road closures) to ensure the safe AV deployment and ensure it stays within its designated ODD.*
- *If conditions that may temporarily or gradually negatively affect the autonomous vehicle's ODD (e.g., light rain) are identified, the AV should operate in degenerate mode*

which alters the vehicle's behaviour (e.g., by lowering the driving speed) to ensure there is no increase in driving-related risks.

7.6. Understanding and defining harsh weather conditions

Weather conditions may impact sensors capacities and therefore impact the overall autonomous machinery safety system (e.g., temperature below or above a certain value, fog, heavy rain, snow). It is therefore essential for AV operators and users to be clearly aware of the limitations of autonomous vehicle technology. Unfortunately, these limits are not often clear because AV sensors' capabilities gradually deteriorate as the conditions deviate further from the sensors' ideal operating working conditions.

With AV being gradually tested and deployed across various regions of the world with different weather conditions (e.g., Norway or California) and across logistics centres with different operational needs (e.g., usage predominantly at night or during the day), it becomes crucial to clearly delimitate and communicate the conditions under which it is not safe to operate an autonomous vehicle. Likewise, the conditions in which it is safe to operate an AV should be clearly stated and communicated between the vehicle provider and the stakeholders that will deploy the vehicle.

As mentioned in section 4.1.7, some ISO standards already determine normal climatic conditions. However, provided an automated vehicle meets the safety requirements and can prove to the competent national authorities that it can safely operate under certain conditions (also known as the vehicle's ODD), an AV can obtain a permit to be tested and potentially deployed under conditions established and monitored by national competent authorities.

7.6.1. Experience from AWARD

The AWARD project focuses on autonomous logistical operations under real-life conditions, including harsh weather conditions which affect the autonomous vehicle's sensor capacity and machinery safety of AVs.

As the vehicles' ODDs are defined by the vehicle providers, they should define thresholds for different degrees of harsh weather conditions and clearly define how the vehicle behaviour should be altered when certain thresholds are met. The FMS collects data from sensors in the ecosystem to which it has access and compares the recorded values to the thresholds defined by the vehicle provider. That means that in mixed fleets (with different vehicles and/or vehicles from different providers), the same amount of rain might qualify as "heavy rain" for one vehicle, but not for another.

It is also important to note that caution is needed to avoid the creation of overlapping and conflicting standards. Indeed, different automated technologies have different capabilities, and the rapid changes taking place in the field may lead to additional standards (e.g., how to define harsh weather conditions) with limited added value in ensuring AV safety.

It is important to highlight that ODDs cannot be exhaustive. An automated vehicle may have a list of 'n' attributes used for its ODD definition (e.g., operation is safe between –2°C and + 20°C), but there will always exist a 'n + 1' attribute which has not been specified (e.g., operation between -2°C and +3°C when there is fog). This specificity of ODDs leaves the door open for miscommunication, misunderstanding, and potential risk. A way to avoid this would be for vehicle providers to explicitly state the conditions which are outside the AV's ODD. This would facilitate the customer operating AVs to have a clear understanding of the conditions in which the AV cannot safely operate. This approach may be more holistic, efficient, and safe than requiring the vehicle provider to set a minimum amount of data to be included in an AV's ODD description.

Clearly defining the "limitations" of when an AV can no longer operate safely and ensuring that the operational boundary is clearly understood and shared by both the manufacturer (or the system designer) and the end-user is essential to ensure safe AV deployment in logistics.

Recommendation:

- *Manufacturer (or the system designer) and the end-user should share the same understanding of the AV's operational conditions.*
- *To mitigate any misunderstanding and potential risk, the conditions which are outside the AV's ODD should be clearly stated, to ensure the AV does not operate if the ODD conditions are not met.*

7.7. Clear task delegation and the role of Fleet Management System (FMS)

In AWARD, only one single entity could have control over the vehicle at any time. No splitting of control and/or overriding between the various controlling entities was possible. To ensure this, the FMS prevented any situation where more than one entity could control the vehicle. In addition, the FMS provided complete teleoperation log records and documentation of the entity in control over the vehicle at any moment.

7.7.1. Experience from AWARD

This clear differentiation is crucial for situations that may require to later identify which entity had control, and therefore legal responsibility, over the vehicle. For instance, during one of the hub-to-hub testing operations, a vehicle was damaged while reversing. Both the vehicle and the driver were insured, but the insurance wanted proof that it was the driver, and not the automatic system, that was in charge of driving the vehicle. Due to the FMS complete log, this information could be shared with insurance company. The FMS provides a tool to help establish the exact cause of an accident, whether it is due to a defect with the automated vehicle or a lack of action by the remote safety operator/teleoperator.

It is important to highlight that the FMS is a dispatching tool that has no legal responsibility over the automated vehicle itself. For this reason, if the FMS loses connection during teleoperation, the automated vehicle should stop. In a normal state, the FMS always monitors the vehicle, regardless of who has control over it.

To ensure safety of AV operation, the entity overseeing the overall operation should bear the responsibility for guaranteeing effective hand-over procedures.

Recommendation:

- *Ensure clear hand-over of responsibilities between drivers (ADS, safety driver, and teleoperator).*

- Eliminate grey areas of shared driving responsibilities. Clearly define the division of driving tasks, ensuring that either the ADS or teleoperator takes complete responsibility. *The entity overseeing the overall operation should bear the responsibility for guaranteeing effective hand-over procedures.*
- *Maintain a detailed log of the teleoperating status recording all teleoperation activities and take-overs, which is crucial to identify legal responsibility over the vehicle at any time.*

7.8. AV liability regime

Currently, there is no harmonised EU framework on liability for damages caused by accidents involving motor vehicles (and automated driving vehicles). Most national liability regimes across the EU use the concept of causality to determine and allocate liability for an accident.

The introduction of automated vehicles in traffic might interfere with the objective of liability regimes to apportion of risks. Therefore, an adaptation of national liability law to new technologies and the development of new liability regimes for owners and/or drivers of automated vehicles could be necessary. [44]

7.8.1. Experience from AWARD

To adapt national liability law to the introduction of new AV technologies and harmonise these liability regimes across Europe, an EU responsibility scheme could be developed. Such a scheme should consider the different causes that might result in an automated system not performing as expected. If, for example, the loading environment that an automated vehicle interfaces with is changed, and the vehicle causes damage to the environment's infrastructure as a result, it must be clear if the automatic system was expected to be able to handle such change (as would be expected of a human driver), or whether another entity was expected to report the changes to the responsible of the automatic system, to adapt the AV to the change.

To ensure a clear differentiation between responsibilities, stakeholders involved in autonomous vehicles operation must agree on the tasks and responsibilities incumbent on each stakeholder before the operation of AV. This clear operation handbook should then be valid throughout the AV operation, as is currently the case for other procedures (e.g., fire evacuation). Any changes that affect the operation and have consequences on the liability, will need to be revised.

Individual teleoperators should only be accountable for the task's incumbent on them, from the moment the control the vehicle's movements or decisions on driving paths is handed over to the teleoperator, to the moment the control is transferred back, or manoeuvres/trajectories are approved. In conventional traffic, the driver has many responsibilities that go beyond the driving task. These includes inspecting tire conditions as well as placing the warning triangle. These specific duties are not feasible for a teleoperator to perform.

Recommendation:

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[44] European Parliamentary Research Services, 2016.

- *Develop an EU responsibility scheme to harmonise national liability regimes associated with the introduction of AV technology.*
- *Before the start of any AV operations, all stakeholders involved should agree on an operation handbook which clearly states the tasks and responsibility incumbent to of each stakeholder throughout the AV operation.*
- *Individual teleoperators should only be accountable for the vehicle's movements or decisions on driving paths if control is transferred or manoeuvres/trajectories are approved.*

7.9. Interacting with automated vehicles in mixed areas

Automated vehicles in logistics will have different sizes to be adapted to their logistics needs, but also have different looks and characteristics (e.g., maximum velocity or braking behaviour) depending on the Original Equipment Manufacturer (OEM) and their degree of automation.[45] Therefore, a holistic approach should be taken for the different automated agents circulating, when analysing interactions between these various automated vehicles and other road users.

The principles of safety and risk minimization may require for other road, port, or aerodrome users to have clear indications to understand when an automated vehicle is on or off (status indicator) and additional information on the autonomous vehicle's planned actions (e.g., turn indicators, braking light). Automation of logistics operation will continue to require human intervention due to the complexity of the logistics process. For this reason, it is important to develop automation and guidance in a way that takes into account the interaction between autonomous vehicles and the human personnel required.

7.9.1. Experience from AWARD

In the AWARD use cases, the boundaries of automation were identified when the pilots operated in their respective environments for the first time. More specifically, these tests revealed where and when human interactions with automated vehicles were still necessary (e.g., to load or unload vehicles, or manually clear dirt from the sensors), and consequently identify the ways to inform stakeholders who would come into contact with automated vehicles (Figure 8).

[45] A. Miring, 2023.

a)  b) 

Figure 8: a) Sign marking the presence of AV demonstrations at the Rotterdam port terminal. b) Close-up of the sign

It was found that the more fast-paced the environment, the more aggressive the driving of the manual drivers on site was, which therefore required a higher need for communication. This was particularly visible at the port and at airport use-cases, where operations are under time pressure as they must often compensate for delays elsewhere in the transport chain.

The port use-case represented a specific case as operations at port terminals are carried out by a mix of drivers from AWARD's project partner and external drivers. Manual drivers from external companies delivering trailers were often not familiar with the site and any special provisions on it, such as the presence of an automated vehicle. To mitigate this, the presence of the AV was marked in the specific terminal in the port of Rotterdam where the AV testing took place (see Figure 8). Due to the international nature of operations, there is also a linguistic challenge to consider when communicating with drivers. This underlines the need to develop simple, clear, and easy to understand signalling marking the presence of autonomous vehicles within certain areas, which should be harmonised across the EU.

In AWARD use cases, the clearance between the AV, the structures, and objects along the AV's path (including personnel) was continuously monitored through the AV's perception system and object detection capabilities. However, to ensure an appropriate level of protection for different categories of persons, the zoning requirements as set in ISO 3691-4 should be integrated in AVs in industrial sites with mixed (manual and automated) trucks to improve safety.

Furthermore, the FMS can be a useful tool to show Avs status across different operating zones, their current position of vehicles in the fleet, and their next intended movements. While not a substitute for hazard elimination, the FMS can help personnel or facility users move around the industrial sites in a safer manner and avoid potentially dangerous areas. Due to the presence of safety drivers in AWARD use-cases, and the small scale of the operations tested in this project, the risk across operating zones was not considered high enough to warrant the large effort of involving facility users in benefitting from the FMS.

When the FMS is made available as a tool to personnel or facility users, it can provide to the users of an operational area a limited overview on the vehicles, so that they can have the information mentioned above without having access to sensitive information or functions.

Additionally, dynamic geofencing could be used to automatically send alerts to operating area users when an autonomous vehicle is getting close to them. This would enable users to be more aware of autonomous vehicles close by, even when they are not in line of sight. This is especially valuable in noisy environments, where approaching vehicles cannot be heard, and to aid users with visual or hearing impairments.

Recommendation:

- *Signals to indicate the presence of AVs in areas with external personnel should be clear, simple, easy for all to understand, and harmonised across the EU.*
- *AV perception systems and object detection capabilities should consider zoning requirements, such as those set in ISO 3691-4, to ensure an appropriate level of protection for different categories of persons.*
- *Fleet Management Systems and/or other safety systems should provide functionalities to protect vulnerable users of the operating area.*

7.10. Definition for accident avoidance in different scenarios

The development of safety validation criteria for ADS is an evolving field. While the EU type approval and Automated Lane Keeping Systems (ALKS) regulations have made contributions by establishing initial values and outlining minimum safety and performance requirements, they only represent the beginning of this essential work. To achieve a comprehensive and mathematically precise definition of accident avoidance, further efforts are needed.

7.10.1. Experience from AWARD

The AWARD project has suggested scenario-based success criteria in D4.7.

Recommendation:

- Mathematical models must describe what constitutes safe driving under various conditions.
- Scientifically grounded safety margins must be developed to ensure ADS can handle a wide range of real-world scenarios.
- Create specific, measurable safety goals for ADS to achieve, ensuring consistent and reliable performance across different driving situations.

7.11. Obtaining a national AV testing permit

To be able to conduct tests with automated vehicles on public roads, it is mandatory to obtain a testing permit from the national competent authority. This permit is typically issued after the submission and validation of the required documentation, as outlined in the national testing regulations (further details are available in section 6 of the deliverable), along with the completion of safety assessments to ensure the safety of AV testing.

7.11.1. Experience from AWARD

As the AWARD hub-to-hub use case took place in Austria, the applicant needed to provide to the Austrian authority specific documents to obtain a test permit. The applicant of the AV testing permit indicated that the biggest challenge was the preparatory work, including a detailed risk analysis for the pre-defined testing route.

In Austria, there is a periodical process which allows to submit the documents needed to obtain a new permit four times a year. Once a testing permit is granted, no modifications to the test setup, whether technical or administrative, are permitted without requiring obtaining a new permit. This includes minor changes, such as adding a safety operator. However, if a safety operator needs to be added, the applicant can use the same documents (assuming no other changes), update the list of operators, and resubmit the documents.

In other European countries such as Norway, the national competent authority must be notified of any changes of the AV testing parameters (e.g., vehicle software is updated, the test environment changes, or a new operator is given the permission to operate the self-driving vehicle). However, only changes that affect safety-relevant aspects of the project require a new permit application. Operators are required to promptly notify the competent national authority of any changes. If this not done and conditions for the initial permit are no longer met, the AV testing permits may be suspended or revoked.

In the AWARD hub-to-hub case, the permit was issued by the Austrian competent authority (Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology) on time and the test phase started as scheduled. In general, the challenges mentioned above did not lead to any delays and the process was supported by the Austrian Contact Point for Automated Mobility.

The applicant of the AWARD port use case did not mention any challenges in the permitting process, since the permit for public roads was only required for a short period of time. AV demonstrations at the Rotterdam terminal took place during assigned time slots (8:30-11:30h and 15:30-18:30h) to prevent the slow-moving test vehicle from interfering with faster traffic during ship arrival and departure times. For public road driving, the port use case obtained an event-based exemption from the municipality of Vlaardingen, based on a safety case presented by AWARD. This exemption included requirements to limit public road use to off-peak hours (20:00-22:00h) while stopping all other traffic and mandated the presence of traffic marshals.

The EU-funded project FAME is currently developing a comprehensive analysis of 30 national legal, administrative, ethical and technical requirements for AV testing on public roads. Findings will look at similarities, special features and differences in the country-specific framework conditions for testing automated vehicles and systems. Recommendations for a Europe-wide harmonisation of the framework conditions for (cross-border) tests of automated vehicles on public roads will be made available to the public in June 2025.

Recommendation:

- *Operators should have the possibility and be required to notify competent authorities of any changes to the AV testing and deployment parameters stipulated in the permit.*
- *The competent authority should be notified of changes that do not have consequences for the risk assessment, while changes that impact the AV's risk assessment should require a new permit to test or operate.*

7.12. Guidance and common safety assessment method

In aviation, aerodrome operators and any stakeholder involved in automated logistics must assess the safety of introducing and operating a new device, technology, or process at the airside. This requirement stems from existing regulations, notably the requirement for Safety Management Systems (SMS).

Safety assessments are used to measure the performance of automated vehicles both before introduction and throughout the operation to trigger improvements of aerodrome procedures and SMS, ultimately contributing to improve regulations and industry standards.

Safety assessments, which are necessary for any AV testing or deployment, can be quite cumbersome tasks in which each stakeholder, manufacturer, and ADS operator is directly or indirectly involved. While regulatory provisions and standards on these safety assessments are compatible, they however remain too generic to be able to use already existing Safety Assessment Method (SAM) and documentation as a basis to obtain a new SAM for a new AV testing or deployment permit. To facilitate this, the development of a common Safety Assessment Method (SAM) is recommended, to facilitate the transfer and consistency of results at each step of the permitting process, as well as the seamless exchange of information between all parties involved. This harmonisation would provide considerable value to all stakeholders involved.

Ideally, a common Safety Assessment Method (SAM) should be shared between the manufacturer, the ADS operator, the aerodrome operator, and the competent authority. Each stakeholder involved should ensure the safety of AV's operation and their own level. More specifically, the ADS manufacturer should ensure and provide evidence that the design and build of ADS vehicles is fit and safe for use, as well as specify maintenance and operation procedures. The ADS operator should ensure and show that ADS operation and maintenance procedures comply with the end user's and operator's operational requirements. Lastly, the aerodrome/port operator should ensure and provide evidence of the safety and compatibility of ADS operations with aerodrome or port operations.

However, the development of a common safety assessment method requires the development of guidelines to provide a common risk assessment methodology and documentation structure. These guidelines should provide clarity on the documents and information needed to assess the safety of ADS in operating areas (i.e. ADS safety and the safety of ADS's interactions with other vehicles and obstacles). The risk assessment methodology should include an agreed mode of risk evaluation, an agreed process, and an agreed list of hazards to be assessed as well as supporting guidance for each hazard. In addition, common documentation should provide sample documents required at each step of the assessment process, guidance to adapt and fill out the sample documents, and ultimately pre-filled samples for standard scenarios.

Such a methodology and documentation has already been developed in aviation by JARUS with the Specific Operations Risk Assessment (SORA) for aerial drones (UAS or RPAS). To meet similar international and national objectives, and to ensure a common approach with UAS and RPAS vehicles that may be moving on aerodromes ground, an example of SAM has been developed and proposed to assess the safety of introducing ADS operations at aerodromes Section 4.2.5 summarizes the SORA applicable to RPAS and outlines the proposed SAM. Further details are provided in 11.2 Annex 2 - Methodology for Automated Driving Systems Safety Assessment Method (SAM) based on SORA page 93.

This proposed SAM could be used as a basis to assess the safety of ADS operations at aerodromes (including their introduction) within the Safety Management System (SMS) framework of aerodromes. In addition, the safety assessments performed to measure the safety and operation requirements can contribute to feed the work of international bodies to improve industry standards and regulations.

7.12.1. Experience from AWARD

Common guidelines on safety assessments would facilitate the sharing of information between stakeholders. Currently, traditional permit and certification requirements for AVs are provisionally applied in the absence of adapted ADS ad hoc regulatory provisions.

In the autonomous baggage handler AWARD use-case, recruiting personnel for project implementation at the airport was a major challenge due to the difficulties faced with insurance. Initially, it was planned to involve operational personnel at the airport and have handling companies carry out the role of safety drivers. However, this turned out to be impossible due to challenging insurance conditions. Security personnel were then used for a period, but this was also stopped due to insurance challenges. As a result, one person from a partner project was appointed to carry out all tests and ensure communication with the various AWARD work package. As this is not a sustainable solution, it is recommended to develop suitable guidance for safety assessments and to provide a safety assurance equivalent to the airside driving permit for airport drivers. The Civil Aviation Authority of Singapore has followed this approach with its ''Guidance on Use of Autonomous Vehicles at the Airside".

The development of common SAM and guidelines to provide a common risk assessment methodology and documentation structure will not only be a benefit for stakeholders involved in obtaining an AV permit, but also to facilitate the sharing of relevant information with external stakeholders such as insurance companies.

Recommendation:

- *Develop a common Safety Assessment Method (SAM) between stakeholders involved in AV testing and deployment to facilitate the transfer, exchange and consistency of information between all parties.*
- *A common risk assessment methodology and documentation structure should be developed as a prerequisite for a common SAM.*
- *The process of providing common documentation should be supported by sample documents, guidance to adapt and fill out the sample documents, and pre-filled samples for standard scenarios.*

7.13. Recognition of national safety assessment and validation certificates

AV safety assessments and validation require extensive (supporting or ad hoc produced) documentation, but also several submission and acceptance exchanges between vehicle providers or operators and approval authorities, making the process quite cumbersome.

AV safety assessments are performed at two different moments: initially before the AV certification, commissioning, or deployment, and then across the vehicle's lifetime to allow the operator or manufacturer to prove its operational safety and functioning of the Safety

Management System (SMS). The initial safety assessment is usually part of a full validation plan that may include the following verification criteria:

- Fit for use: the system complies with technical requirements of the manufacturer and of the end user
- Compliance with applicable regulation and standards
- Fit for operation: the system, its operation and maintenance procedures comply with operational requirements in the expected context
- Safe for operations: The system is considered acceptably safe according to the safety threshold (or a series of safety criteria) used.

In most situations, the information required for validation, notably the supporting evidence documentation, remains the property of the vehicle provider or the operator and is not disclosed to third parties unless explicitly requested by a regulatory or judicial authority. In addition, the safety assessments carried out during the AV's lifetime belongs to the vehicle provider or operator. The safety information may be shared with authorities when the SMS is being audited or at the initiative of the manufacturer or operator towards clients/users, partners or authorities when deemed useful or necessary.

As vehicle providers and their subcontractors are private entities which may be in competition or in restricted cooperation (by contract or specific agreement), there may be constraints on the information about their product that can be shared. Similarly, operators are entities that may be in competition or cooperation, that bear the primary responsibility for the service provided, and for the safety of their clients and users. Their knowledge is generally closely linked to a local (operating) environment and societal context which cannot be transposed directly to another location.

Authorities are usually public entities that certify and approve automated systems and/or the conditions of their operation. By doing so, they discharge the vehicle provider or operator of responsibility, provided the latter complies with requirements and statements included in the approval documentation. Approval authorities may be at the local, national, EU, or international level, as designed by law. For instance, in the aviation sector, the type certification of aircraft is the competence of the European Aviation Safety Agency, while the certification of aerodromes is a national competence in France and federal competence (Länder) in Germany. The level of the authority's competence and its ability to share information depends on each state, according to its own regulatory regime. Each stakeholder involved in autonomous vehicle design and deployment therefore bears full responsibility for the validation and required supporting evidence.

Divergent testing approaches across European countries create challenges to recognize national safety assessments and certificates when testing AVs, particularly on public roads. Furthermore, regulatory challenges on the certification and oversight may arise when the ADS (notably when its type is certified according to EU regulation 2022/1426), the ADS operator, and the aerodrome operator are certified and overseen by different competent authorities in different Member States. For instance, if compliance with UNR157 (Automated Lane Keeping System) or with ISO 12100 is considered a valid means of compliance by the ADS certifying authority in one Member State, it may not be accepted in the Member State where the ADS operates. Therefore, the current regulatory regime requires that national safety assessments and validations must be obtained for each country.

One of the ways to reduce the burden of obtaining validation is to decrease the number of cases that need to be submitted to various operators and authorities, i.e., the amount of documentation delivered and the number of validation tasks. To achieve this burden reduction, a first option would be for an operator/authority to use a validation case performed by a previous operator/authority, as proposed in the 1990s for the validation of Air Traffic Control Systems and Procedures. Although generally perceived as an efficient way to streamline validation processes due to the commonality of operations in various states, this was not fully implemented as it requires an agreement discharging the responsibility of the provider and transferring ownership of part of the validation case to the receiver. Another example is the Sohjoa-Baltic Project where the Latvian project partner needed to buy insurance from a Belgian insurance company, as the Latvian insurance was not willing to provide insurance for a car that did not have a Latvian plate number. Such a transfer suggests, inter alia, a loss of integrity of the previous validation case.

Nevertheless, some international bodies have created website repositories where safety information could be posted and shared: the European Civil Aviation Conference NLA Forum website in 2006 dedicated to the accommodation of New Larger Aircraft at existing aerodromes, the Eurocontrol Skybrary initiated in 2008, and lastly the EASA repository created with the Commission Implementing Regulation (EU) 2023/2117.

A second approach would be to allow two authorities (or operators) to mutually recognize the validation certification agreed by the other authority (or operator). This was already implemented, by an agreement between the United States Federal Aviation Administration and France for aircraft type certification, later subsumed in a similar agreement between the United States Federal Aviation Administration and the European Aviation Safety Agency (EASA).

Mutual recognition of national validation certifications and/or safety assessments would enable operators having already obtained a safety assessment or validation certification from a national authority to make it count towards obtaining a test and/or deployment approval in other countries with similar standards. For instance, an operator having obtained the approval by the TÜV to test its autonomous vehicle in Germany would not have to completely restart the process to obtain safety approval to carry out testing from French or Norwegian authorities, provided these countries recognize the German authority's approval. Implementing mutual recognition of validation certification through bilateral agreements requires confidence in the technical and legal competences between two parties as well as a legal negotiation which may take a long time.

The third approach would be the creation of an advisory group gathering manufacturers, operators, and authorities to develop a uniform, informal agreement on common elements required to obtain approval. This was the case with the A380 Airport Compatibility Group, which developed an agreement document adopted by the participating authorities and further used by other states. More recently, JARUS, a worldwide international body gathering industry, operators and authorities, developed the SORA Safety of Operation Risk Assessment guidance to assess the safety of operations of Unmanned Aircraft Systems (UAS). Though not formal, this guidance document is used worldwide by operators and as a basis for validation by authorities. An ambitious solution would be the creation of an EU structure in charge of systems and operations certification, analogous to EASA for the aviation sector. However, the creation of such an organisation will be a long-term effort.

In conclusion, the most promising solution at this stage would be to enable the mutual recognition of national safety assessment and validation to reduce the administrative and cost burdens faced by operators and manufacturers when testing autonomous vehicles across multiple EU Member States. This could be supported by the creation of an advisory group gathering industry, operators, and national authorities to develop harmonised guidance on what should be performed and documented to obtain a system type certification or an approval for AV operation and to handle a repository website where relevant safety information could be posted and retrieved.

7.13.1. Experience from AWARD

The recognition of national safety assessment and validation certificates was not fully applicable in AWARD due to the diversity of use cases. However, all use cases have relied on EasyMile's demonstration of compliance of its software with Functional Safety (FuSa), Safety of the intended Functionality (SOTIF), and Cybersecurity (CS).

Predefined Risk Assessments offer a potential tool to facilitate to use previous safety assessments trials as a basis for new trails. In case of the baggage tractor AWARD use case, it would have allowed to share the task between the Toulouse and Oslo airports by providing a common document structure and most of the individual risk assessment arguments. International airports are aware of this issue and are already cooperating to resolve it in various organisations (e.g., ICAO, International Air Transport Association, EASA).

Recommendation:

- *To ensure cross-border testing and reduce the administrative and cost burdens faced by operators and manufacturers, set common EU-wide requirements for safety assessments before AV testing, which may be complemented by national requirements.*
- *Enable a national or international authority to mutually recognize the validation certification agreed by another national or international authority.*
- *In the long term, develop an advisory group consisting of representatives from the industry, operators, and authorities of willing EU Member States. This group should work on harmonized guidance outlining the necessary procedures and documentation required to obtain approval for a system type or operation.*

7.14. Other recommendations

7.14.1. Cargo liability

Automation of logistics implies changes in transportation as we currently know it. By transforming the role of the driver from manually driving the vehicles to remotely overseeing them, it also affects other elements of transportation, namely cargo liability.

Currently, the transport service organizer assumes responsibility in case of direct loss or material damages occurring during transport, unless it can prove that the damages resulted from a non-apparent defect in loading - at the shipper's liability - for shipments of three tonnes or more. With automation of logistics and the driver's role outside the vehicle, it is less evident which entity is responsible for the safety of the cargo.

To meet this gap, France was the first European country to develop regulation on cargo safety in the case of automated transportation. If any issues arise regarding the vehicle and damage the cargo, the manufacturer holds primary responsibility. If the manufacturer believes the problem is not caused by their system but rather how it was handled by the transport service organizer, an investigation may be initiated. In any other case, the transport service organizer assumes responsibility in case of direct loss or material damages as if it was a non-automated service.

Automated road transport of certain substances or weight categories may be prohibited by order of the minister in charge of transport in the national territory. In the case of the transportation of living beings, animals must be fed and hydrated at appropriate intervals with rest periods suited to their species and age, which does not match the prerequisites of autonomous driving. Transportation of goods that may present a risk to the environment and would require instant human intervention in case of incident can be forbidden.

Loading and unloading procedures for cargo remain unchanged with autonomous vehicles: for shipments weighing less than three tonnes, the transport service organizer assumes responsibility for loading and unloading operations. For shipments of three tonnes or more, the shipper is responsible for loading and the consignee for unloading. However, this regulation could be subject to alteration if loading and unloading processes also transition to automation. This case remains still uncovered by the French regulation and should be discussed at national level.

Regulation regarding fully automated passenger transport services beyond an experimental phase came into effect in September 2022. French authorities then decided to adapt this regulation for automated freight transportation. This regulation is under validation by French authorities and will most probably enter into force during the second half of 2024.

Recommendation:

- *For automated transport of cargo, a contract may be established between the transport service organizer and the manufacturer to outline scenarios of cargo damage, to allocate responsibility accordingly.*

7.14.2. Managing the interplay of FuSA, CS, SOTIF, and AI standards

While extensive project management methodologies may not have been deemed necessary for research and development purposes of the AWARD project, going forward, there is a critical need to define protocols for handling the Safety of the Intended Functionality (SOTIF) and Artificial Intelligence complementary to existing provisions about handling Functional Safety (FuSa) and Cybersecurity (CS).

Various requirements of multiple standards must be aligned with different phases of the development lifecycle, but automotive process owners may find it challenging to define a viable methodology that covers existing requirements and new process requirements as the standards evolve.

Especially in industrial companies with larger teams, where communication and coordination between developers and testers may become challenging, methodologies such as the V-model or W-model can be used for the development process, as each stage of the development process and its respective requirement can be clearly defined.

The V-model, also known as Verification and Validation model, describes the relationship between each phase of the system or software development life cycle and its corresponding testing phase. The V-model can ensure that all team members are working toward a shared understanding of the project's ultimate goals and objectives. It allows them to check with their internal process model which stage requires which inputs and outputs, and which documents must be produced. With the help of checklists, team members are also able to review whether the work products achieve the required level of maturity. An example of the standard V-model can be found in Figure 9.

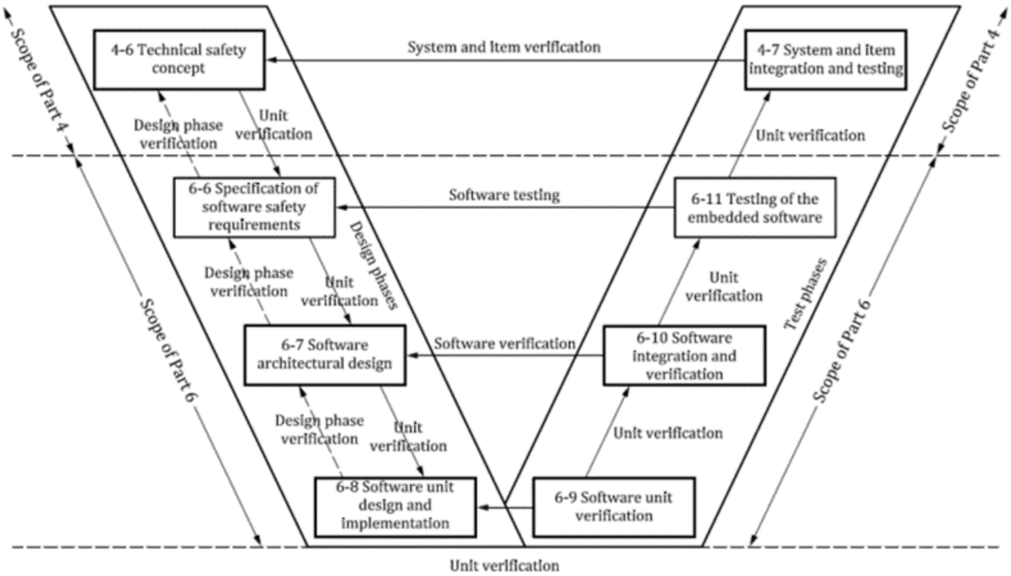

Figure 9: An example from CertX training material for the V-Model Applying ISO 26262 (source: Standard ISO 2626)

The W-model modifies the traditional V-model to better accommodate the iterative and complex demands of AI and Machine Learning projects. Unlike the linear sequence of the V-model, the W-model recognizes the need for iterative experimentation in AI projects. In particular, the W-model integrates iterative loops at various stages, enabling continuous refinement of models based on testing feedback. This approach allows for adjustments to algorithms, datasets, and requirements in response to project evolution, crucial for managing the unpredictable outcomes of AI projects. In addition, the W-model advocates for simultaneous validation and verification during the development process. As AI models are being built, their adherence to user needs and specifications is assessed concurrently, facilitating early issue detection, and embedding quality assurance throughout the project lifecycle.

Regardless of the model, it is important to compare the requirements of the standards for each phase and use the potential to combine them to reduce the workload. The main target of the process must be kept in mind, which is a dependable and, in terms of AI, trustworthy end product. To be able to describe and tailor the properties of a development process, the model used should provide flexibility while complying with the five following aspects/standards listed below.

1. Complexity of the management process

The approach to add new parallel processes or sub-processes to manage all aspects of autonomous driving development process can likely miss its aim, as it may result in a development process unsuitable for a distributed development approach. The aim must be a viable process that unites the standard requirements in a single run wherever possible.

2. Configuration control

Configuration control is recently mainly associated with the Software Bill of Materials, particularly due to the requirement for implementation in the US, enforced on May 12, 2021, in the US executive order on improving the nation's cybersecurity. However, the problem goes beyond cybersecurity, as configurability has to be considered as an interface discipline between all areas of dependability, possibly affecting the function of interconnected systems in unexpected ways.

3. Update management

The possibility to update single systems inside a vehicle, be it over the air or in the workshop, creates new challenges for system dependability. New regulations like UNECE R156 have been issued to define minimal requirements for a Software Update Management System (SUMS) and require its interlinking with CS and FuSa. These regulations help make AV safer, more reliable and help track software changes.

4. Verification and Validation Management

For verification and validation some outlines can already be drawn, e.g., based on UNECE R157 or ISO 21448, which can be seen as a starting point for future autonomous driving regulations, defining the interplay of verification, simulation and necessary field validation. These can be applied (and are to some extent with EU Regulations 2019/2144 and 2022/1426) to initial type-certification and further updates.

5. Field monitoring and management of system ageing

CS and AI, but also SOTIF, are disciplines that require a much closer monitoring and management of possible impacts on the end-product - may it be due to emerging vulnerabilities, the rapidly moving state of the art or due to new regulations. Regulation 1426 necessitates that a safety management system is in place especially for ADS manufacturers.

The relevant standards for safety, security and SOTIF are extensive – sufficient effort has to be spent on creating a joint process, that on the one hand considers all relevant aspects of standardization, but on the other hand does not add process steps without added value for the goal of AV safety and security.

Due to the overlap of some of the aspects/standards listed above, complying with them requires a step-by-step integration of these standards into the company's process should be developed. The creation of parallel processes that enables the timely execution of the relevant steps in an overall development plan requires ongoing synchronization between the sub-processes. Particularly for the management and supporting processes, some synergies can be leveraged, as all three standards rely on vertical, horizontal and temporal traceability of all activities.

The following steps describe an efficient approach to integrate FuSa, SOTIF, CS and AI into the company's processes.

- Integration Step 1: ASPICE and FUSA: The integration of FuSa into existing process maturity models like Automotive Software Process Improvement Capability dEtermination (ASPICE) is a common approach. As ASPICE has been developed prior to all other disciplines, it is recommended to integrate FUSA into an ASPICE-based development process.
- Integration Step 2: FuSa and CS: Following the timeline of the publishing of standards, CS is the next discipline that is integrated in the process. ISO 26262:2018 and ISO 21434:2021 should combine each other in a joint process.
- Integration Step 3: FuSa/CS and SOTIF: With the publication of ISO 21448:2022, another standard is added to the list of processes that must be considered in automotive dependability development. As with ISO 21434:2018, SOTIF can be based on the existing process by adding new means of analysis and validation.
- Integration Step 4: FuSa/CS/SOTIF and AI: A process landscape following the above-mentioned standard relies on deterministic processes for the design of autonomous systems and is describing the vehicle and system level activities down to conventional hardware and software design, whereas artificial intelligence, a core technology for computer vision and hence indispensable for autonomous driving, is more or less treated as a black box. Several international (e.g., ISO PAS 8800), European (e.g., CENELEC JTC21) and national (e.g., VDE-AR-E 2842-61) committees are working on the standardization of artificial intelligence for automotive.

The synchronization of future standardized AI development processes and frameworks has to be analysed for adequate solutions.

Recommendation:

- *An appropriate project management methodology and method is needed to compare and combine relevant standards requirements at each phase of the AV software development process, to reduce the workload and to maintain compliance with current and future regulations and standards.*

8. Recommendations overview

This section gathers the recommendations (Table 5) based on topics:

- Operators involved in ADS
- Operating environment monitoring and adverse weather conditions
- Safety and liability
- Documentation and permits
- Items for further research.

Table 5: Overview of AWARD 8.4 recommendations

Topic	Regulatory and AWARD experience	Recommendations	Level of action
Operators involved in ADS			
8.1 Understanding and defining teleoperation	While some types of teleoperations are regulated by EU ADS act (i.e. remote intervention/assistance) some are excluded, but national regulation is being developed (i.e. remote direct driving). Further teleoperation terminology and research on characteristics and limitations in real-life logistical environments is needed.	– Differentiate and categorise the various types of teleoperation. An initial categorisation could differentiate between AV remote driving operator, remote intervention/assistance, and supervision. – Further develop clear terminology on the various teleoperation types, to foster clarity, liability, and transparency on the technology being researched and potentially deployed.	EU harmonisation
8.2 Further research on remote direct driving	Remote direct driving is currently excluded from EU ADS Regulation, but national regulation is currently being developed (e.g. Germany). A consistent regulatory framework for all EU Member States will be needed, particularly for manufacturers designing AV and ADS that will have to comply with multiple sets of rules to safely test and operate across borders.	– Future research on remote direct driving is crucial to better understand the technological capabilities and limitations. – Technological maturity, safety of the system, and good practices should be at the core of teleoperation testing and deployment frameworks. – In the long run, consider differences in national teleoperating frameworks to avoid regulatory gaps and obstacles for operation across more than one country.	EU harmonisation
8.3 Teleoperator working environment	Currently, regulations on teleoperators' working conditions have not been developed. To ensure safety of personnel involved in AV operation, a framework to ensure safe working conditions and AV operation should be developed.	– During ADS take-over requests, only provide relevant information necessary to perform the task, without additional distracting indicators or modalities. – Provide teleoperators with access to AV's cameras before starting operation, to monitor AV's surroundings and environment. – Effectively regulate and manage teleoperators working conditions (e.g.	EU harmonisation

Topic	Regulatory and AWARD experience	Recommendations	Level of action
		workload, duty work and rest periods) to ensure safe working conditions. – Foster teleoperators' sense of physical presence at remote sites. – Implement an effective staffing ratio that ensures the monitoring of whole vehicle fleet at any time.	
8.4 Training and skills requirements for AV operators	Develop common EU training requirements, to ensure unified and consistent AV operator training across the EU. Adapt legal framework to ensure minimum requirements of training for safety drivers and teleoperators.	***For safety driver & teleoperator:*** – Require an obligatory driver's license in line with the AV category being monitored. – Set specific common training requirements, which include: (1) detailed training on AV warning systems and required reactions, (2) definition of AV intended use and (3) reasonably foreseeable AV misuse. – Develop harmonised training on basic items (e.g., checklists for remote handling of AVs, emergency stop design or maintenance workarounds). – Tailor training requirements to consider the specificities of AV operation, particularly regarding the division of tasks and communication. – Provide further detail on different machine-operating modes, intervention procedures for the user, and interventions required following AV and equipment malfunctions. ***All stakeholders***: – Develop guidance material common to all stakeholders potentially expose to AVs, taking account of their background and knowledge.	EU harmonisation
Operating environment and adverse weather conditions			
7.5 Dealing with hazardous conditions and sensing conditions	Certain measures should be implemented to accurately identify the characteristics and any changes to the operating environment (e.g., weather, obstacles) to ensure safe operation of the AV within the boundaries of its Operational Design Domain (ODD).	– To detect and ensure the AV stays within its designated ODD, implement minimum requirements on data and information the FMS should gather from the ecosystem and the vehicle itself (e.g., weather sensor, information on road closures) to ensure safe AV deployment – If conditions are identified that may temporarily or gradually negatively affect the AV's ODD (e.g., light rain), the AV should operate in degenerate mode (e.g. lower speed) to ensure no increase in driving-related risks.	EU harmonisation

Topic	Regulatory and AWARD experience	Recommendations	Level of action
7.6 Understanding and defining harsh weather conditions	AV's capacities to safely operate across different weather conditions are defined in the AV's ODD. Harmonised and good practices should be implemented to ensure all stakeholders share the same understanding of the AV's safe operating conditions.	– Manufacturer (or the system designer) and the end-user should share the same understanding of the AV's operating conditions. – To mitigate any misunderstanding, the conditions outside the AV's ODD should be clearly stated rather than stating the conditions within the ODD.	EU harmonisation (through guidelines)
Safety & liability			
7.7 Clear task delegation and the role of Fleet Management System (FMS)	A clear framework to design and monitor the different AV controlling entities should be established, to ensure safe AV operation.	– Ensure clear hand-over of responsibilities and tasks between drivers (ADS, safety driver, and teleoperator). – Eliminate grey areas of shared driving responsibilities. Clearly define the division of driving tasks, ensuring that either the ADS or teleoperator takes complete responsibility The entity overseeing the overall operation should bear the responsibility for guaranteeing effective hand-over procedures. – Maintain a detailed log of the teleoperating status by recording all activities and take-overs, to help identify legal responsibility over the vehicle at any time.	EU harmonisation
7.8 AV liability regime	The introduction of new AV technologies might interfere with EU and national regimes on risk allocation. National liability laws should be adapted to AV introduction, with the development of EU guidelines on a responsibility scheme.	– Develop an EU responsibility scheme to harmonise national liability regimes linked to the introduction of AV technology. – Before the start of AV operation, all stakeholders involved should agree on an operations handbook that clearly states the tasks and responsibility incumbent on each stakeholder throughout the AV's operation. – Individual teleoperators should only be accountable for the tasks assigned to them.	EU guidelines and adaptation of national regulation
7.9 Interacting with automated vehicles in mixed areas	Due to the diversity of AV operating environments, additional measures should be taken for instances and in areas where AV interacts with external personnel and individuals.	– Signals indicating the presence of AVs should be clear, simple, easy for all to understand, and harmonised across the EU, particularly in areas with external personnel. – AV perception systems and object detection capabilities should consider zoning requirements, such as those set in ISO 3691-4, to ensure the appropriate level of protection for different categories of individuals.	EU harmonisation

Topic	Regulatory and AWARD experience	Recommendations	Level of action
		– Fleet Management Systems and/or other safety systems should provide functionalities to protect vulnerable users of operating areas.	
7.10 Definitions of accident avoidance across different scenarios	While some initial values and minimum safety and performance requirements are outlined at UN and EU level (UNR157 and EU type-approval), there is the need for more accurate and mathematical definitions of ADS accident avoidance.	– Mathematical models must describe what constitutes safe driving under various conditions. – Develop scientifically-grounded safety margins to ensure that ADS can handle a wide range of real-world scenarios. – Create specific and measurable safety goals the ADS must achieve, to ensure consistent and reliable ADS performance across different driving situations.	UN and EU level
Documentation			
7.11 Obtaining an AV testing permit at national	AV testing and deployment permits and permitting processes are stipulated at national or local level. Harmonisation is needed to provide clarity and ensure a level-playing field.	– Operators should notify competent authorities of any changes to the AV testing and deployment parameters stipulated in the permit. – Competent authorities should be notified of changes that do not impact AV's risk assessment, whilst changes that impact the AV's risk assessment should require a new permit to test or operate.	EU harmonisation
7.12 Guidance and common safety methodology	The development of common guidelines on Safety Assessments Methods (SAM) would facilitate the sharing of information with both internal and external stakeholders.	– Develop a common Safety Assessment Method (SAM) to facilitate the transfer, exchange and consistency of information between stakeholders involved in AV testing and deployment. – Develop a common risk assessment methodology and documentation structure to foster clarity – Sample documents, guidance to adapt and fill out the sample documents, and pre-filled samples for standard scenarios, should be provided to stakeholders.	UN and EU level
7.13 Recognition of national safety assessment and validation certificates	To ensure cross-border testing and reduce the administrative and cost burdens faced by operators and manufacturers, national common safety assessment criteria and certification should be identified to enable mutual recognition and/or common EU requirements.	– Identify common national safety assessment criteria that should be recognised across the EU, that may be complemented by national requirements. – Enable a national or international authority to mutually recognise the validation certification agreed by another national or international authority.	EU general framework or bilateral agreements

Topic	Regulatory and AWARD experience	Recommendations	Level of action
		– In the long term, develop an advisory group (consisting of representatives from the industry, operators, and authorities of willing EU Member States) to develop harmonised guidance outlining the required procedures and documentation to obtain approval for a system type or operation.	
Further research			
7.14.1 Cargo liability	Responsibilities traditionally incumbent on the driver (e.g. safety of cargo) need to be addressed in regulation with the development of AV logistics (e.g., France).	– To allocate responsibility in case of damaged cargo transported by AV, a contract may be established between the transport service organiser and the manufacturer.	EU and national level
7.14.2 Managing the interplay of FuSA, CS, SOTIF, and AI standards	To ensure safe AV market access and deployment, current and future AV legal frameworks should be intrinsically included in the project management and methodologies of AV development.	– AV software development should include a defined project management protocol and methodology that compares and combines relevant standards requirements at each phase of development process, to facilitate workload and maintain compliance with current and future AV regulations and standards.	Manufacturer level

9. Conclusion

AWARD's final goal is the realisation of a safe and effective autonomous logistics chain using connected and automated heavy-duty vehicles in real logistics operations, regardless of weather conditions. The project developed, tested, and operated autonomous driving systems (ADS) and fleet management systems (FMS) across four use cases: forklift operations in a warehouse, a hub-to-hub open-road shuttle service, automated trailer arrangement at a port and ship loading, and an airport baggage tractor. Within the broader project vision of enhancing innovation, safety, competitiveness, and replicability, this deliverable focused on the last item by generating a series of policy recommendations that will serve to facilitate a shift from proof of concept to large-scale testing and deployment of autonomous vehicles in logistics.

The project partners and contributors to D8.4 based their recommendations on a combination of desk research, policy analysis, and empirical evidence gathered from AWARD use cases. An extensive review of global (e.g., UN, ISO, ICAO), EU-level, and national regulations and standards was performed to identify opportunities for revisions and standardization. Topics covered by the recommendations listed in this document include operators involved in ADS, operating environment monitoring, adverse weather conditions, safety and liability, and documentation and permits. In addition to addressing regulatory gaps with amendments and revisions, the scope of the recommendations extends to harmonization and standardization to promote regulatory parsimony and avoid redundant procedures for national and subnational competent authorities. This process is aligned with the principles espoused by the EU Commission in its "Better Regulation agenda" and is meant to facilitate the establishment of a regulatory "floor" that enables AV testing and deployment across all EU member states.

As this deliverable has shown, there are numerous governmental and private entities at work to address autonomous technology from the global to the regional level. However, the overall regulatory regime is lacking specificity. Experiential data from the AWARD use cases revealed limitations of the legal status quo as well, but also identified opportunities for further research with an eye towards future legislation. For instance, assigning liability for cargo and maintenance as well as options to allow direct remote driving could be addressed in more detail in other projects.

Autonomous vehicles in general and autonomous logistics operations in particular are rapidly evolving fields with a complex dynamic involving technological and regulatory innovations. If technology outpaces policy, it can reduce the safety of users and other stakeholders, which would negatively affect the public acceptance of autonomous vehicles. Conversely, regulations can inadvertently discourage the development and deployment of new technologies to the detriment of a competitive business. It is important to maintain a balance between these two elements, and the partners in the AWARD project make a meaningful contribution to an ongoing debate with this deliverable.

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11. Annex

11.1. Annex 1 – Identification of potential hazards related to AV operations at airports

To perform a safety risk assessment for the introduction of a new equipment, it is necessary to list the relevant hazards and the corresponding safety occurrences which should be subject to a risk assessment.

The hazards considered in this study are listed below:

- Collision with a moving aircraft
- Collision with a parked aircraft
- Collision with other mobile
- Collision with passenger or other personnel
- Other injuries to passenger or other personnel
- Collision with field equipment or infrastructure
- Damage caused by Foreign Object Debris (FOD) or jet blast
- Fire of the equipment (ADV) or caused by the equipment
- Jeopardy of airport operations.

The causes or contributing factors to these hazards, as well as their potential consequences depends on the characteristics of the equipment, its function, the area(s) where it is operated and its operation procedures, hence the safety occurrences which need be considered.

This study addresses generic scenarios to cover typical ranges of equipment characteristics (notably size, weight, and speed) and the two areas of the movement area: the apron and the manoeuvring area (runways and taxiways). The manoeuvring area will be addressed in two logical parts: the runway(s) and the network of taxiways and service roads linking the apron to the runway(s).

For the apron, the risk assessment takes account of the guidance provided in the ICAO Manual on Ground Handling (ICAO doc 10121), Appendix E as many ADV prospects are targeted at ground handling operations. This guidance includes a list of safety occurrences categorized by severity in its table E-3. The safety occurrences relevant to ADV operations are listed in Table 6.

Table 6: List of occurrences to be assessed for safety derived from ICAO doc 10121 Ground Handling Manual

Severity	Ground handling occurrences that should be subject to a risk assessment
Catastrophic	– Ground support staff falling from or being hit by ADV resulting in death – Personnel falling from unprotected aircraft door after stair removal resulting in death – Fire causing aircraft destruction or death

Hazardous	– Staff falling from equipment resulting in serious injuries – Staff being crushed between equipment – ADV puncturing aircraft skin – Aircraft damage that would require major repair and flight cancellation, for example wingtip or fuselage collision while being marshalled or towed – Misuse of the equipment restraint area resulting in aircraft damage
Major	– Equipment to equipment, equipment to infrastructure collision – Personnel injured or equipment damaged as result of jet blast – Aircraft damage resulting in delay due to required maintenance – Aircraft braking rapidly as a result of vehicle crossing in front, leading to cabin crew injury – People being hit and injured by equipment – Strong winds resulting in movement of equipment – Operation in extreme adverse weather conditions resulting in damages or injuries
Minor	– Aircraft braking rapidly as a result of vehicle crossing in front – Minor aircraft damage not resulting in significant delay or maintenance – Minor damage to airport infrastructure – Tow bar shear pin breaking resulting in operational delay – Communication issues resulting from multilingual and multicultural staff – Confusion resulting from conflicting/different standard operating procedures
Negligible	– Failure to follow procedures not leading to any of the above – Inadequate resources leading to poor service delivery – Poorly maintained equipment stuck on the aircraft stand

This useful list need be adapted as it does not cover all hazards on the apron and the same type of occurrence may have consequences of various severity; for example, the consequence of a personnel being hit by an equipment may range from major to catastrophic. Hence the severity categorization shall be made case by case. A revised list is proposed hereunder.

1. Staff or passenger falling from equipment
2. Staff or passenger being hit by equipment
3. Fire causing aircraft, infrastructure or equipment, or personnel damage
4. Misuse of equipment restraint area
5. Collision with aircraft/puncturing of aircraft skin

6. Collision with infrastructure or equipment
7. Damage or injuries resulting from jet blast
8. Damage or injuries resulting from adverse weather conditions (strong winds, etc.)
9. Aircraft braking rapidly as a result of ADV crossing in front
10. Communication issues
11. Confusion resulting from conflicting/different Standard Operating Procedures (SOPs)
12. Failure to follow procedures
13. FOD
14. Jeopardy of operations

Regarding the manoeuvring area, guidance can be obtained from PANS Aerodromes, ICAO Doc 9981 and notably its Part II, Chapter 8. Runway Safety. Two lists of safety occurrences are proposed below for the manoeuvring area including or excluding runway(s).

<u>Manoeuvring area including runways</u>

15. Collision with aircraft
1. Damage to infrastructure or equipment
2. Fire of ADV
3. Runway incursions
4. Runway excursions (by ADV)
5. Runway or taxiway confusion
6. Taxiway excursion (when leaving the runway)
7. Communication issues
8. Failure to follow procedures
9. FOD
10. Jeopardy of operations

<u>Manoeuvring area excluding runways</u>

11. Collision with aircraft
1. Damage to infrastructure or equipment
2. Fire of ADV
3. Aircraft braking rapidly as a result of ADV crossing in front
4. Taxiway confusion
5. Taxiway excursion
6. Communication issues
7. Failure to follow procedures
8. FOD
9. Jeopardy of operations

To assess the risk for each scenario various Matrices may be used to evaluate the risk tolerability.

The list of hazards and safety occurrences as well as the values in the Matrices are expert choices and should not be considered as approved given. Other hazards, safety occurrences, Matrices and values may be chosen according to the subject and its context, to local conditions, regulatory requirements and guidance, and to the time and resources available to perform the safety assessments.

11.2. Annex 2 - Methodology for Automated Driving Systems Safety Assessment Method (SAM) based on SORA

The development of a recommended safety assessment methodology derived from SORA for the introduction of Automated Driving Systems at aerodrome pursues certain objectives:

- To facilitate the performance of safety assessments
- To support a commonality of approach and documentation of the safety cases enabling sharing and reuse of experience
- To facilitate the performance of safety assessments
- To support a commonality of approach and documentation of the safety cases enabling sharing and reuse of experience
- To provide consistency with the safety assessment methodology for RPAS (Remotely Piloted Aircraft Systems).

For ease of writing, the proposed safety assessment methodology will be named SAM in the rest of this note.

Meanwhile, there is a difference in perspective between SORA developed by JARUS and SAM. SORA assesses the risks of damages or injuries that RPAS may cause in operation to third parties on the ground or in the air. The function of an aerodrome is to provide a reliable and consistent service to all aircraft, their users and interested parties, and to prevent or mitigate risks inherent to aviation activities to aircraft, users and third parties within the scope of the aerodrome responsibilities.

Hence SAM should address three aspects:

- The compatibility of ADS operations with the aerodrome infrastructure and procedures (including IT and security aspects)
- The assessment of risks within the scope of the Safety Management System of the aerodrome
- Impact assessment of ADS build and operation failures which may impair the continuity and consistency of aerodrome's operations or create risks to adjacent areas.

The following presents the logic and steps of the proposed methodology and introduces the specific details which shall be addressed at a later stage.

The proposed SAM comprises five steps:

- Development of the Concept of Operations (ConOps) which includes verifying the compatibility with the aerodrome infrastructure and operations
- Assessment of the safety risks and of the risks to aerodrome operations

- The determination of a Safety Assurance and Integrity Level (SAIL) which sets the required robustness required from the ConOps, the associated mitigations and the stringency of the verifications
- The identification of the relevant Operational Safety Objectives together with their means of verification
- The development of a safety portfolio.

ConOps

The first step requires the applicant to collect and provide the relevant technical, operational and system information needed to assess the risk associated with the intended operation of the ADS. Annex 12.1.1. of this document provides a detailed list of items for data collection and presentation.

The ConOps description is the foundation for all other activities and should be as accurate and detailed as possible. The ConOps should not only describe the operation, but also provide insight into the operator's operational safety culture. It should also include how and when to interact with other parties such as the aerodrome operator, Air traffic Control (ATC) or Apron Management Service (AMS). Therefore, when defining the ConOps the operator should give due consideration to all steps, mitigations and operational safety objectives.

The ConOPs should also refer in the appropriate paragraph the ISO or industrial standards, regulations and other provisions the ADS and its operation are complying with. A provisional list of standards is attached as Annex 12.1.2.

When developing the ConOps, the applicant should also provide sufficient information to ensure that:

- the ADS would not interfere, or would be compatible with radio communications and air navigation systems
- the ADS communication systems would not interfere or are compatible with the radio communications and air navigation systems (e.g., ASMGCS) at the airport
- the communication procedures with the Air Navigation Service Provider (ANSP) and the Apron Management Service comply with the required response time to instructions, notably in case of emergency
- the airport infrastructure, including visual and non-visual aids enable the ADS to access the identified areas of operations
- changes to the operating conditions (driving routes or rules, airside layout and equipment, operating locations, …) are accounted for timely and consistently
- coordination with relevant third parties are established and maintained across time.

Developing the ConOps can be an iterative process; therefore, as the SAM process is applied, additional mitigations and limitations may be identified, requiring additional associated technical details, procedures, and other information be provided/updated in the ConOps. This should culminate with a comprehensive ConOps that fully and accurately describes the proposed operation as envisioned.

More detailed guidance should be developed at a later stage.

Assessment of the safety risks and of the risks to aerodrome operations

The performance of a safety assessment at an aerodrome is a unique exercise that cannot be directly used for another aerodrome because every aerodrome differs from another due to its geographic location, its physical characteristics, and its environmental, economic and social context.

Potential risks which should be assessed in the performance of a safety assessment for the introduction, and later during test or current operations, of an ADS should be listed according to the intended areas of operations. Guidance to identify the relevant hazards and their associated risk categorization is given in the ICAO provisions (PANS aerodromes (doc 9981) and Ground Handling Manual (doc 10121) for the apron, the manoeuvring area excluding runways (taxiways and service roads) and the manoeuvring area including runways and discretion is advised when using them for a specific safety assessment.

Table 7: Table E-11 from ICAO Doc 10121 Ground Handling Manual

Table E-11. Tolerability matrix

		TOLERABILITY				
		Catastrophic	*Hazardous*	*Important*	*Minor*	*Insignificant*
		A	B	C	D	E
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Highly improbable	1	1A	1B	1C	1D	1E

RISK	*ACTION*
HIGH	Cease or cut back operation promptly if necessary. Perform priority risk mitigation to ensure that additional or enhanced preventive controls are put in place to bring down the risk to the moderate or low range.
MODERATE	Schedule performance of a safety assessment to bring down the risk index to the lower range if viable.
LOW	Acceptable as is. No further risk mitigation required.

After assessing the individual risks associated to each relevant hazard using the following tolerability matrix which categorizes the risks as Low (L), Moderate or Medium (M) or High (H), a Consolidated Risk Level is determined using the highest value (L, M or H) amongst them.

When performing this analysis particular attention should be paid to the impact on the capacity and coherence of airport and aircraft operations of the intended ADS operations and safety mitigations. This would substantiate the analysis of the risk of jeopardy in airport operations that would impair the performance of the air navigation system at the airport and its surrounding airspace. It would also give a qualitative level of this impact (Operational Impact Level, Low (L), Medium or Moderate (M) or High (H)) which may imply a revision of the ConOps and increase the stringency of the required verifications.

SAIL Determination

The Safety Assurance and Integrity Level should be qualified as Low (L), Medium (M) or High (H).

The SAIL is based on the Consolidated Risk Level possibly increased or tempered by:

- The Operational Impact Level and
- The appraisal (expert judgement) of the airport context: geography, proximity of dangerous installations, traffic level, required connectivity and regularity of operations, economic, social and environmental context.

Identification of Operational Safety Objectives (OSOs)

The assigned SAIL will determine which Operation Safety Objectives should be complied with and with which level of robustness. A list of OSOs is provided in Annex 12.1.3. This list is derived from the list established by JARUS for SORA applicable to RPAS and provisional guidance on the use of the OSO as provided in JARUS SORA Annex E, although discretion should be applied when considering the ADS case.

Safety portfolio

The content, structure and format of the safety case to be submitted by the applicant (manufacturer or ADS operator) may differ according to the approval authority (airport operator, local or national body). Meanwhile the applicant should develop a safety portfolio to substantiate the required safety case or to serve as evidence in case of audit or incident/accident investigation.

This portfolio should contain documentation of:

- The ConOps, including changes records
- The assessment of safety risks and of the risks to airport operations
- The SAIL determination and the compliance with the relevant OSOs
- Any other documentation deemed critical or useful for the understanding of the safety case(s) and in case of audit or investigations.

Summary

The above provisional guidance requires peer reviews and additional work before being proposed for adoption. However, the core principles of SAM consist of 5 steps derived from the SORA methodology and are proposed for agreement as guidelines:

- Development of a ConOps
- Assessment of a recommended list of risks
- Determination of a Safety Assurance and Integrity Level (SAIL) amongst 3 values (L, M, or H)
- A list of OSOs to be met or declared not relevant according to the SAIL
- Development of a safety portfolio.

At later stages, Predefined Risk Assessments, containing standard scenarios and their risk assessments should be developed to cross check the pertinence of the proposed provisions and eventually appended to this guidance.

11.3. Annex 3 - Guidelines on collecting and presenting system and operation information for an ADS operation

Guidance for collection and presentation of operation-relevant information
1.1 Definitions
1.2 Organisation overview
1.2.1 Safety
1.2.2 Design and Production
(a) If the organization is responsible for the design and/or production of the ADS, describe the design and/or the production organization
1.2.3 Training of staff involved in operations
1.2.4 Maintenance
1.2.5 Crew
1.2.6 ADS Configuration Management
1.2.7 Other position(s) and other information
1.3 Operations
1.3.1 Type of operations
1.3.2 Standard Operating Procedures
1.3.3 Normal Operation Strategy
1.3.4 Abnormal operation and emergency operation
1.3.5 Accidents, incidents and mishaps
1.4 Training
1.4.1 General information
1.4.2 Initial training and qualification
1.4.3 Procedures for maintenance of currency
1.4.4 Driving Simulation Training Devices (DSTD)
1.4.5 Training program
1.5 References

2 Guidance for collection and presentation of technical relevant information
2.1 Definitions
2.2 ADS description
2.2.1 ADS-AV segment
2.2.1.1 Vehicle frame
2.2.1.2 Vehicle Performance Characteristics
2.2.1.3 Driving Control Features and Actuators
2.2.1.4 Propulsion System
2.2.1.5 Sensors
2.2.1.6 Payloads
2.3 ADS Control segment
2.3.1 General
2.3.2 Navigation
2.3.3 Automated driving
2.3.4 Driving Control System
2.3.5 Control Station (CS)
2.3.6 Detect And Avoid (DAA) system
2.4 Geo-fencing
2.5 Ground Support Equipment (GSE) segment
2.6 Command and Control Link (C2 link) segment
2.7 C2 Link degradation

2.8 C2 Link Lost
2.9 Safety features
2.10 References

11.3.1. List of certifications and standards that may be applied to ADS vehicle/systems/component

Table 8: List of certifications and standards that may be applied to ADS vehicle/systems/component

Reference	Component
IEC 62443-3-3	Industrial communication networks. Network and system security
ISO 9001:2015	Quality management systems requirements
ISO/IEC/IEEE 12207:2017	Systems and software engineering – Software life cycle processes
ISO 10007:2017	Quality management – Guidelines for configuration management
ISO/IEC 17024:2012(en)	Conformity assessment – General requirements for bodies operation certification of persons
ISO 26262:2018	Road vehicles – Functional safety
ISO/ PAS 21448:2019	Road vehicles – Safety of the intended functionality
SAE J3016_202104	Taxonomy and Definitions for Terms Related to driving automation systems for on-road motor vehicles
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 62278	Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS)
ISO 14001	Environmental management systems
ISO/IEC 17000	Conformity assessment – Vocabulary and general principles
CMMI	Capability Maturity Model Integration
ISO 45001	Occupational health and safety management

11.3.2. Operational Safety Objectives (OSO)

Technical issue with the ADS

OSO #01 - Ensure the operator is competent and/or proven
OSO #02 - ADS manufactured by competent and/or proven entity
OSO #03 - ADS maintained by competent and/or proven entity

OSO #04 - ADS developed to authority recognized design standards
OSO #05 - ADS is designed considering system safety and reliability
OSO #06 - C3 link characteristics (e.g. performance, spectrum use) are appropriate for the operation
OSO #07 - Inspection of the ADS (product inspection) to ensure consistency to the ConOps

OSOs related to Operational procedures

OSO #08 - Operational procedures are defined, validated, and adhered to (to address technical issues with the ADS)
OSO #11 - Procedures are in-place to handle the deterioration of external systems supporting ADS operation
OSO #14 - Operational procedures are defined, validated and adhered to (to address Human Errors)
OSO #21 - Operational procedures are defined, validated and adhered to (to address Adverse Operating Conditions)

OSOs related to Remote crew training

OSO #09 - Remote crew trained and current and able to control abnormal and emergency situations (i.e., technical issues with the ADS)
OSO #15 - Remote crew trained and current and able to control the abnormal and emergency situations (i.e. human error)
OSO #22 - The remote crew is trained to identify critical environmental conditions and to avoid them

OSOs related to safe design

OSO #10 - Safe recovery from technical issue
OSO #12 - The ADS is designed to manage the deterioration of external systems supporting ADS operation

Deterioration of external systems supporting UAS operation

OSO #13 - External services supporting UAS operations are adequate to the operation

Human Error

OSO #16 - Multi crew coordination
OSO #17 - Remote crew is fit to operate
OSO #18 - Automatic protection of the driving envelope from human errors
OSO #19 - Safe recovery from Human Error
OSO #20 - A Human Factors evaluation has been performed and the Human-Machine Interface (HMI) found appropriate for the mission

Adverse Operating Conditions

OSO #23 - Environmental conditions for safe operations defined, measurable and adhered to
OSO #24 - ADS designed and qualified for adverse environmental conditions (e.g. adequate sensors, specific performance qualification)