AWARD
Scaling autonomous logistics

D8.5
Market opportunities, barriers and solutions

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2.0	04/10/2023	Julien Collier	EM	Quality review

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List of acronyms

ADAS	Advanced Driver Assistance System
ADS	Autonomous Driving System
AI	Artificial Intelligence
AGT	Automated Guided Transport
AGV	Automated Guided Vehicle
AHDV	Automated Heavy-Duty Vehicle
AV	Autonomous Vehicle
BSI	British Standards Institution
CAGR	Compound Annual Growth Rate
CAV	Connected and Autonomous Vehicle
EE	Electrical and Electronic
FMS	Fleet Management System
GDPR	Global Data Protection Regulation
HDV	Heavy-Duty Vehicle
ICT	Information Communication Systems
IFR	International Federation of Robotics
LiDAR	Light Detection and Ranging
ODD	Operational Design Area
OEM	Original Equipment Manufacturer
OS	Operating System
PAS	Publicly Available Specification
QA	Quadrant analysis
SAE	Society of Automotive Engineers
SAM	Serviceable Addressable Market
SOM	Serviceable Obtainable Market / Share of Market
SW	Software
T	Task
TCO	Total Cost of Ownership
TOS	Terminal Operating Systems
TAM	Total Addressable Market
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
WP	Work Package

1. Executive summary

The market for automated vehicles in logistics is expanding rapidly due to the benefits they provide, such as lower labor costs, increased productivity, and reduced product damage. It is predicted that by 2024, there will be more than 54 million vehicles with at least some level of automation in operation worldwide[1]. However, scepticism about the idea of autonomous vehicles driving around in everyday traffic still exists. Nonetheless, logistics provides an ideal environment for the use of autonomous vehicles, and it is expected that in the near future, they will be widely used within controlled environments such as ports, distribution centres, and production plants. Therefore, logistics professionals must prepare for their arrival to gain a competitive advantage.

The AWARD project's objective is to develop a safe autonomous driving system that improves efficiency in adverse weather conditions, with a particular focus on four heavy-duty vehicle use cases. These cases include outdoor forklift operations (loading and unloading in warehouses, construction sites, industrial plans, etc.), hub-to-hub shuttle service on open roads, automated baggage dispatching in airports, trailer transfer operations and vessel loading in ports.

This document aims to expand the market analysis performed in "D8.1 Market opportunities, barriers and solutions". D8.1 includes a thorough examination of the technological, commercial, organizational, and social possibilities of connected and automated heavy-duty trucks in real-world logistics operations. The analysis revealed potential opportunities by identifying the limitations and drivers of automation in logistics. Collecting information from all other WPs to better understand the AWARD solutions, conducts analyses, and provides comments and advice to the technical WPs to align market demands with project technology advancements.

Based on D8.1 and with updated insights, this document performs a comprehensive desk research and literature review for the market analysis, which is structured by autonomous heavy-duty vehicles (AHDVs) and Fleet Management Systems (FMS). However, market trends and market size have been performed joining heavy-duty and FMS to compact and provide a more general analysis for automated vehicles with some inputs for both.

An analysis of market segments, drivers, competitive landscape, and Porter's five forces is provided separately for FMS and autonomous heavy-duty vehicles. This exhaustive competitive landscape research was carried out, focusing on the key players in outdoor logistics automation, primarily in Europe. In contrast to long-distance applications in public areas, such as platooning, solutions for logistics procedures within a private location or confined area are considered. For the four use cases in AWARD, Porter's five forces were used to identify and evaluate the competitive forces that influence the market and establish the industry's weaknesses and strengths.

In order to identify viable solutions for all-weather autonomous operations, a comprehensive benchmarking of existing market solutions, with a specific focus on AWARD, has been

[1] *Topic: Autonomous vehicles worldwide*. (n.d.). Statista. https://www.statista.com/topics/3573/autonomous-vehicle-technology/

conducted. This benchmarking analysis provides valuable insights into the capabilities and features of AWARD, which are crucial for understanding its potential in the industry. Additionally, we identify and analyse the barriers and opportunities that complement the previous analysis, offering a comprehensive perspective on the subject. Furthermore, to delve deeper into the factors influencing the adoption of autonomous vehicles in logistics, we conducted interviews, workshops, surveys, and social media polls to further analyse the market dynamics. A quadrant analysis for both barriers and opportunities of AHDVs and FMS was conducted to understand which factors are more important, difficult, and feasible to obtain. This market study culminates with a SWOT analysis. This strategic analysis aids in identifying the strengths, weaknesses, opportunities, and threats that shape the landscape of autonomous vehicle adoption in the logistics sector; however, due to confidentiality reasons, such analysis is not included in the present deliverable but in D10.4: Final monitoring Final Innovation Management Monitoring and Assessment, that is available only for the consortium.

2. Introduction

The material handling process in industrial contexts is crucial to the success of logistics systems. Automated Guided Transport (AGT) systems and Automated Guided Vehicles (AGVs) have been utilized since the 1950s to optimize material flow and increase productivity through improved work processes. The modernization of production, driven by management's increased reliance on technology, has led to the envisioning of total automation.

Recent technical advancements in the development of Autonomous Vehicles (AVs) have been considered the next revolution in mobility and transportation. AVs have enormous potential for an industry facing a manpower shortage and seeking faster delivery times, particularly with the growth of e-commerce. Aside from economic benefits, AVs offer unrivalled flexibility when it comes to integrating into existing or evolving contexts, leading to increased reliability and lower operational costs.

The introduction of AVs has the potential to revolutionize mobility and transportation logistics. Connected and Automated Vehicles (CAVs) can open new business opportunities for the logistics industry. AVs must be able to acquire data about their surroundings, evaluate it, and utilize interpretation to plan the most feasible actions. Vehicles are equipped with several technologies and extensive backup systems to monitor their components' operation.

There are two major methods of achieving these capabilities, according to Shanker et al. (2013)[2]. The first relies primarily on V2V and V2I communication technologies, where the infrastructure informs the vehicle about its environment, and the vehicle adds its own LiDAR observations. The second approach allows the vehicle to observe and analyse its surroundings without relying on environmental input. While the former has the advantage of being relatively low-cost, it has limited capacity to react to sudden changes and requires the construction of road infrastructure. The latter is more costly but can respond more quickly to changes in the environment and is less dependent on infrastructure. However, combining both techniques would result in better safety and self-driving capabilities than either option alone.

Similarly, with the emergence of autonomous heavy-duty vehicles and other cutting-edge technologies like fleet management systems that boost the AVs use, a paradigm change in the world of transportation is currently under way. The convergence of automation and logistics is altering businesses and redefining the potential for effective and sustainable transportation as technology continues to grow at an unprecedented rate.

The dynamic world of autonomous heavy-duty vehicles is explored in this market analysis. Autonomous heavy-duty vehicles are ready to change the industry as conventional transportation models struggle with issues of efficiency, safety, and environmental effect. These commercial carriers, which include trucks, buses, and other vehicles, use cutting-edge technologies like artificial intelligence, sensors, and advanced processing to navigate and drive

[2] Shanker, Ravi, Adam Jonas, Scott Devitt, Katy Huberty, Simon Flannery, William Greene, Benjamin Swinburne et al. "Autonomous vehicles: Self-driving the new auto industry paradigm." Morgan Stanley blue paper, 2013: 1-109.

on their own. Also, the market for fleet management systems is analysed in this report, since this technology is essential to the smooth operation of fleets, operational efficiency, cost savings, and safety enhancement.

This analysis seeks to offer a comprehensive view of the variables influencing the acceptance and integration of these ground-breaking technologies by looking at deterministic elements in the market such as segmentation, drivers, competitors, trends, size, barriers, and opportunities.

2.1. Aim of AWARD

AWARD aims at developing and enabling to deploy a safe autonomous transportation system in a wide range of real-life use cases in a variety of different scenarios. This encompasses the development of an autonomous driving system (ADS) capable of handling adverse weather conditions such as heavy rain, snowfall, fog. The ADS solution will be based on multiple sensor modalities to address 24/7 availability. The ADS will then be integrated into multiple vehicle types used in low speed, mostly in confined areas.

Finally, these vehicles will be demonstrated in a variety of real-life use cases to validate their value in the application and identify any limitations. Logistics operations will be optimized thanks to a new fleet management system that will act as a control tower, gathering all information from subsystems (vehicles, road sensors, etc.) to coordinate the operations and protect vulnerable road users. This work should then enable commercial exploitation of the technology and policy recommendations for certifications processes.

2.2. Scope of T8.1 and relationship with other WPs

This task delivers a comprehensive business focused analysis of all different deployment opportunities related to connected and autonomous heavy-duty vehicles in real logistics operations. Additionally, all potential technical, business, organizational, social, or other barriers are investigated, identified and suitable solutions found. A broad consultation with key stakeholders was done, in close cooperation with WP2 (especially with T2.2), WP7 (Particularly T7.3 and T7.4) and WP9 (both regarding gathering necessary input, as well as regarding dissemination of the deliverables). The goal of consultation was to receive inputs on opportunities, barriers, and solutions from stakeholders, through direct interviews, local workshops, and an online survey.

Some inputs of WP2 to T8.1 are:

- the use cases' specifications,
- the definition of AWARD system,
- identified key stakeholders, and end-users needs and requirements.

Taking these inputs and combining them by identified key exploitable results from WP9, T8.1 performs the market analysis of the target market for AWARD solutions. Moreover, for benchmarking performed in this delivery, some inputs are obtained from D10.3 (updated for D10.4) and T10.4. AWARD has three technical WPs, namely WP3, WP4 and WP5. The innovative system is developed in these WPs and used for the demonstrations in WP6. T8.1 gets inputs from all these WPs to better understand the solutions AWARD offers, perform

analysis and provides feedback and inputs to the technical WPs in order to match the market needs with the technological developments of the project.

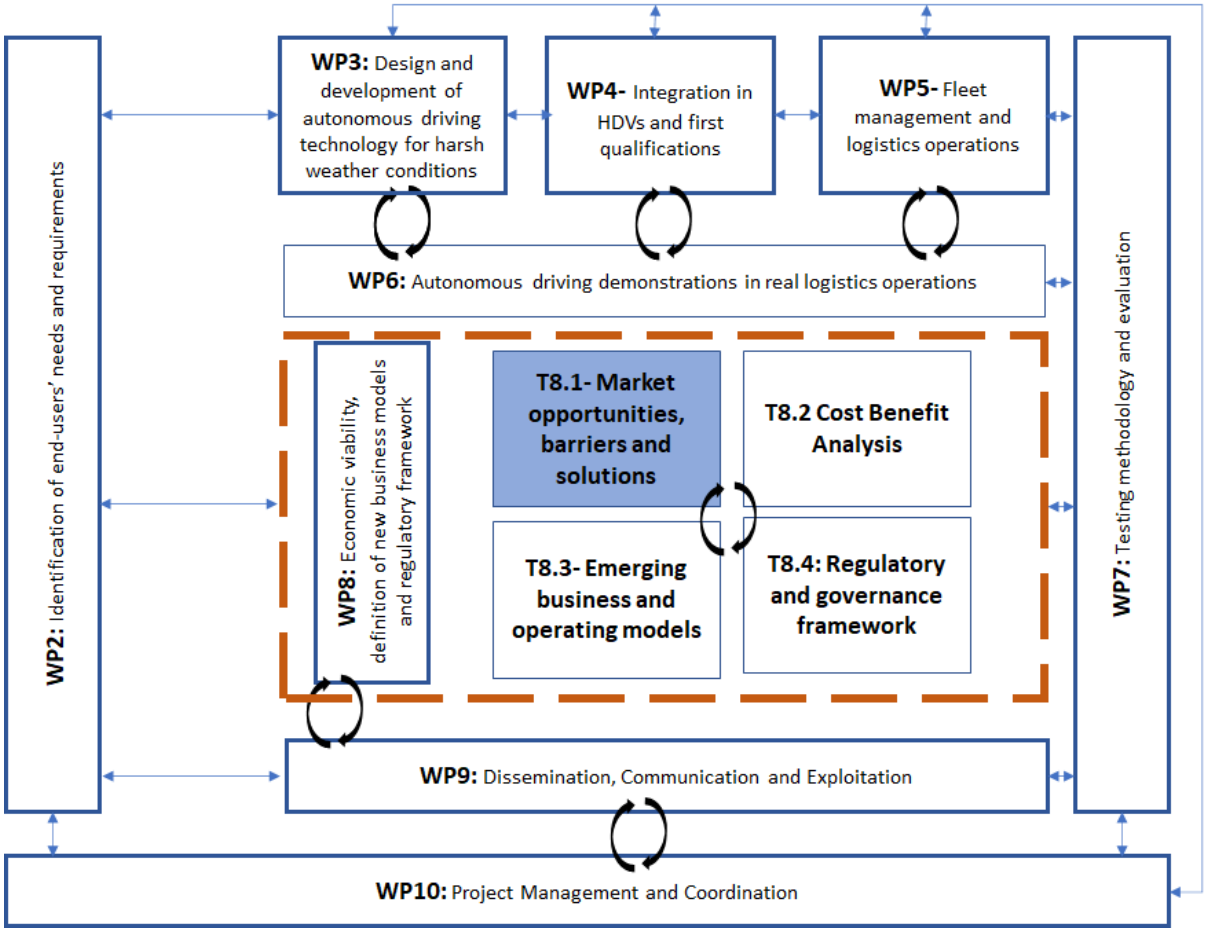

Figure 1 Task 8.1 relationship with other WPs

The results of T8.1 will be used as inputs for the other tasks in WP8 and will also contribute to WP7, mainly the impact assessment of the project results. Furthermore, WP8 and WP9 are closely related as market and competitive analysis performed in T8.1, and T8.4 as the regulatory and governance frameworks highly impact the adoption of the technology.

2.3. Intended audience

This is a public report, which means that in addition to internal use by consortium partners (as explained above in the context of this task and other work packages), external stakeholders such as policymakers, researchers, private companies, and members of the general public who are working on mobility and logistics can utilize the analysis presented in this report. Furthermore, inputs from these stakeholders will be received to gain a better understanding of the market.

2.4. Structure

The report is structured as follows:

- Chapter 3 explains the methodology used.

- Chapter 4 contains the market analysis of autonomous heavy-duty vehicles in real logistics operations, including market segmentation, market drivers, competitive landscape, and Porter's five forces.
- Chapter 5 contains a complete market analysis of logistics operations and fleet management systems, including market segmentation, market drivers, competitive landscape, and Porter's five forces.
- Chapter 6 presents the market trends analysis for fleet management, logistics and autonomous vehicles.
- Chapter 7 presents the market size analysis and forecast; separated between global and Europe market, and with estimations for each use-case.
- Chapter 8 presents the final competitive analysis, including information on key market players, existing products, and their features.
- Chapter 9 presents the barriers and opportunities for autonomous heavy-duty vehicles and fleet management systems.
- Chapter 10 refers to the SWOT analysis that is included in D10.4: Final Innovation Management Monitoring and Assessment.
- Chapter 11 concludes and summarizes the market analysis stated in this report.

3. Methodology

There are different approaches to conduct market research. But as any other research process, it starts with preparation and setting objectives followed by determining the research approach, data collection, analysis, and reporting. To acquire insightful data, we actively carried out a variety of research activities, such as workshops, questionnaires, social media polls, and interviews, mentioned above. The outcomes of these actions are included in the comprehensive analysis. Figure 2 shows the market research approach.

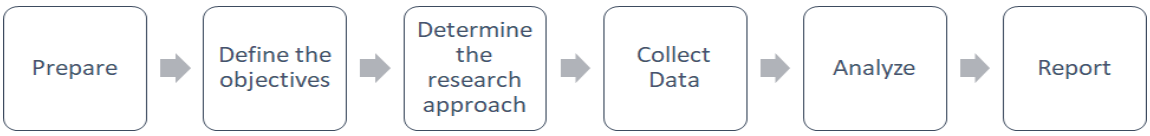

Figure 2 Market research approach

In the preparation phase, the project objective, identified problem and the proposed solution were revised to better understand the project and the market it targets. Two target markets were identified to be studied, the market for autonomous vehicles in logistics with a specific focus on the AWARD use cases and the market for logistics operations fleet management. The objective of the study is to identify the most pertinent aspects of the market and provide insights regarding the market dynamics, size, and competitors. These insights can be used to effectuate better business decisions at consortium level as well as help partners with their individual exploitation plans at partner level. Then, the research and analysis method are defined to obtain the necessary qualitative and quantitative data. In the AWARD, both secondary and primary data is collected to get enough information about the market. Since the nature of this task is exploratory, qualitative analysis is used to get as much information as possible with predefined constraints. The collected data is then analysed and is reported in D8.1 and D8.5.

Aligned with this methodology, T8.1 uses an interactive approach to study the market opportunities, barriers, and solutions. As the first step, an intensive desk research and literature review is conducted to investigate the autonomous vehicles in logistics market. Secondary data is compiled to segment the market, understand the market dynamics, and define the market size. This market analysis is combined with a competitive analysis followed by Porter's five forces analysis that provide insights into the attractiveness of the industry. An internal workshop and a survey are organized to get insights on drivers, barriers, and opportunities. The survey is sent to external advisory board members as well. An analysis is performed based on these inputs and is reported in this deliverable.

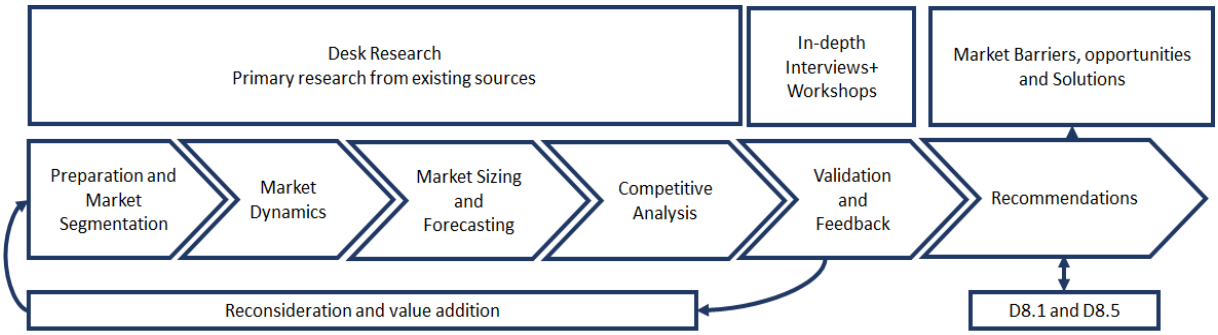

Figure 3 Task 8.1 methodology for market barriers, opportunities and solution analysis

Further, some in-depth interviews are conducted with key opinion leaders to gather inputs on barriers and opportunities to connected and autonomous heavy-duty vehicles in real logistics operations. Also, some workshops are organized with both internal and external stakeholders to discuss and align the market barriers and opportunities with solutions. The primary data gathered from these interviews and workshops will help us validate our research findings and provide us with first-hand data on market dynamics and size for both automated vehicles in logistics and logistics operation fleet management.

The analysis reported in this deliverable is updated and communicated with partners, specifically solution providers, to ensure the competitiveness of the project outcomes.

4. Market analysis of autonomous heavy-duty vehicles in logistics operations

The market analysis for autonomous heavy-duty vehicles (AHDVs) in the logistics industry is a comprehensive and in-depth chapter that thoroughly examines the current state of the market. This chapter is divided into several subsections, each focusing on different aspects of the market. It builds upon the market research conducted in "D8.1 Market opportunities, barriers, and solutions," incorporating the latest updates and insights.

Within this chapter, we provide a detailed analysis of various key factors, including market segmentation, market drivers, competitive landscape, an AWARD strategic analysis focusing on heavy-duty vehicles. By synthesizing this information, we aim to present a comprehensive summary of the market research conducted for AHDVs, offering valuable insights and updated perspectives.

The analysis focuses on market segmentation by level of autonomy, vehicle type, geography, and application, providing a thorough understanding of the market from various perspectives. Additionally, the report analyses market drivers, to offer insights into the factors driving the market's growth. Moreover, a competitive landscape and a Porter's five force analysis are also included to give a holistic view of the market's competitive environment. With this information, businesses and investors can make informed decisions and develop effective strategies to enter or expand their operations in this sector.

4.1. Market segmentation

The market for automation in logistics can be segmented in different ways. In AWARD, we have segmented the market based on automation level, vehicle type, geography, and application as described in the sub-sections below.

For more detailed information and insights for each segmentation type, please refer to section "*4.1 Automation in logistics – market Segmentation*" in the document "*D8.1 Market opportunities, barriers and solutions*."

4.1.1. Market segmentation by level of vehicle autonomy

The market opportunities and progression of vehicle automation levels are discussed. The Society of Automotive Engineers (SAE) has defined five levels of automation. The different levels of automation are described in Figure 4.

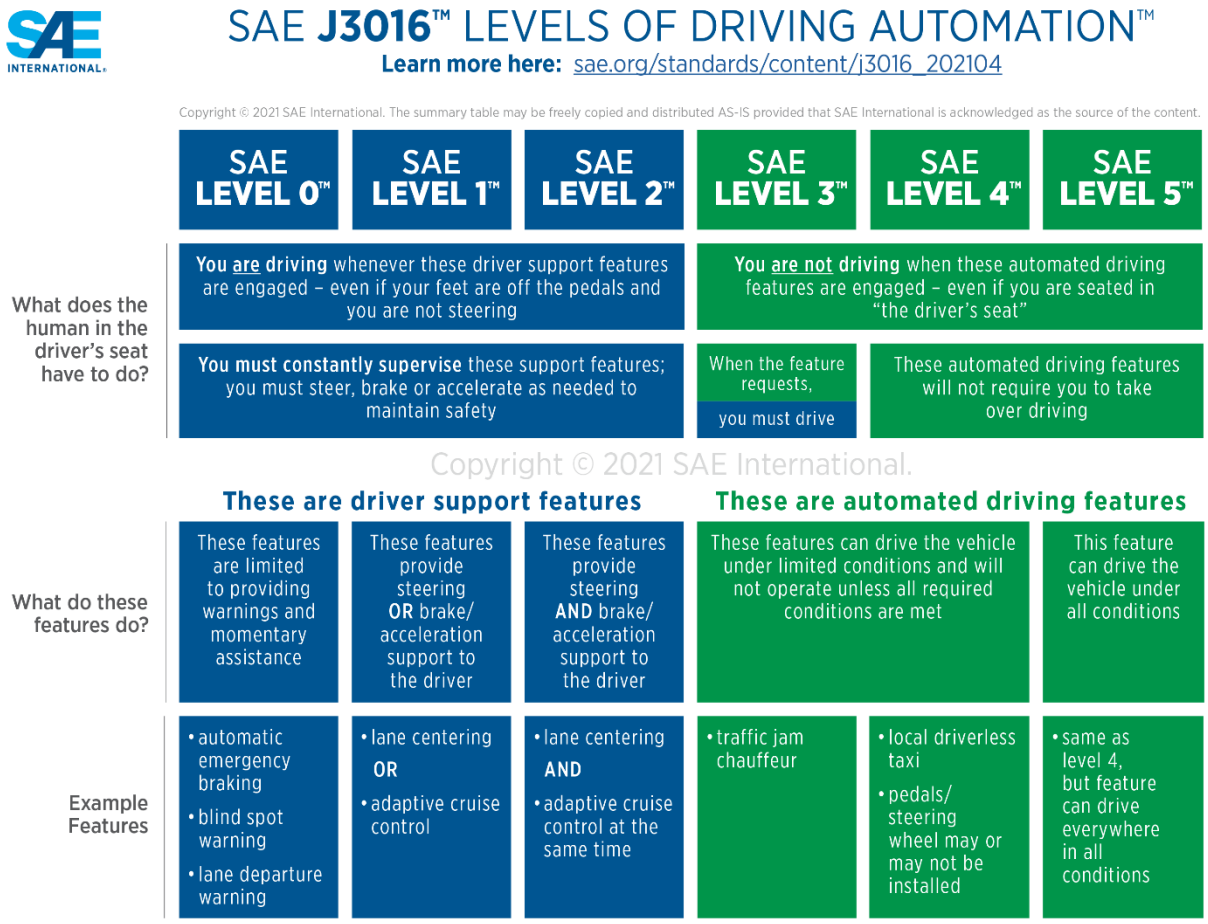

Figure 4 SAE Levels of Driving Automation[3]

According to industry predictions by SAE[4], levels 0-2 are already present in the market, while market uptake of levels 3-5 is expected to happen between 2020 and 2030. Similarly, according to ERTRAC CCAM Roadmap[5], low-speed automated vehicles for transporting goods in restricted areas are anticipated to be highly available by 2040. Level 4 automation is projected to be driven by logistics business use-cases and is expected to have significant penetration. Affordability plays a crucial role in the market uptake, and it is anticipated that the manufacturing costs of automated vehicles will decrease by 2030. The alignment of the project's use-cases with the abovementioned CCAM roadmap from ERTRAC must be highlighted, which involves testing highly automated freight transport vehicles in various confined areas and defining the future roadmap for highly automated vehicles on open roads.

[3] SAE International. (2021, May 3). SAE J3016 Update. SAE International Blog. https://www.sae.org/blog/sae-j3016-update

[4] *J3016_202104: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles - SAE International*. (2021, April 30). J3016_202104: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles - SAE International. https://www.sae.org/standards/content/j3016_202104/

[5] Connected Automated Driving Roadmap. (2019, March 8). ERTRAC. Retrieved May 25, 2023, from https://www.ertrac.org/wp-content/uploads/2022/07/ERTRAC-CAD-Roadmap-2019.pdf

Moreover, according to McKinsey report in January 2023[6], L3 and L4 systems will become more common in the private-passenger-car segment by around 2025 in Europe and North America. However, the high up-front costs for developing these systems might initially limit commercialization efforts to premium-vehicle segments. This report adds that in order to mitigate costs and increase commercial potential, offering L2+ systems, which blend ADAS and automated driving capabilities, can be a strategic approach. Several OEMs already offer L2+ systems, with many more launches planned. The technology developed for L2+ systems can contribute to the development of L3 systems, as demonstrated by some Chinese disruptor OEMs equipping vehicles with pre-equipped LiDAR sensors. Finally, the report points out that in cases where true L3 systems are not yet available, developers may offer a combination of L2+ and L3 features. This hybrid approach includes automated driving on highways and in cities with L2+ capabilities, complemented by L3 features designed for use in traffic jams. As the industry advances, the goal is to introduce more advanced autonomous features across a broad range of vehicles, making hands-free driving a widespread reality.

4.1.2. Market segmentation by vehicle type

The market is segmented into road passenger vehicles and road freight commercial vehicles based on vehicle type. The focus of the AWARD project lies on road freight commercial vehicles. These vehicles are classified into eight classes based on their gross vehicle weight (GVW), ranging from light duty to heavy-duty trucks. The number of classes and weight ranges for each class are shown in Table 3 (ACT Research, 2021)[7]. However, the AWARD project mainly concentrates on the medium duty and heavy-duty segments.

Weight Class	Light duty				Light Medium Duty	Medium Duty		Heavy-Duty
	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
From (lbs.)	--	6,001	10,001	14,001	16,001	19,501	26,001	33,001
To (lbs.)	6,000	10,000	14,000	16,000	19,500	26,000	33,000	--

Table 1 Vehicle classes and weight ranges for each class

Automated Guided Vehicles (AGVs) are another category of vehicles that come in various forms, including automated forklifts. In the forklift vehicle category, the market for electric counterbalance forklifts in the EMEA region was projected to reach approximately 120,000 annual sales by 2021. Major European Original Equipment Manufacturers (OEMs) in this industry include Linde MH, Still, Jungheinrich, Toyota, Hyster, and Crown.

[6] Autonomous driving's future: Convenient and connected. (2023, January 6). McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected

[7] What are the different types of commercial vehicles? (n.d.). ACT Research. https://www.actresearch.net/resources/knowledge-center/what-are-the-different-types-of-commercial-vehicles

Despite setbacks and delayed customer adoption, the mobility community agrees that autonomous driving (AD) has the potential to transform transportation, consumer behaviour, and society as a whole. McKinsey research[8] shows that AD could generate significant value for the auto industry, amounting to hundreds of billions of dollars (between 300 and 400 billion dollars) by 2035. To realize the benefits of autonomous driving, auto OEMs and suppliers must develop new sales and business strategies, acquire technological capabilities, and address safety concerns.

4.1.3. Market segmentation by geography

In this subsection for market segmentation by geography market is segmented by different regions. A brief summary of them is provided in this section.

When considering different regions, Europe, North America, and China have taken an early lead in the development of automated vehicles. Europe, in particular, has intensified funding for collaborative research in connected and automated vehicles. However, the European Union faces the challenge of harmonizing regulatory frameworks to enable testing of autonomous vehicles across European roads, although some countries like France have taken steps to regulate them. China, considered a late starter, is now pushing to accelerate the development of automated vehicles, benefitting from support from the central government. More information for each country can be found in section 8 and "*D10.3 Intermediate Innovation Management Monitoring and Assessment"* and "*D10.4 Final Innovation Management Monitoring and Assessment".*

In terms of advanced countries in AHDVs in real logistics operations, Singapore, the Netherlands, and Norway are highlighted as the top three countries in terms of readiness by KPMG in a 2020 report [9]. Singapore excels in its policy environment and testing sites for automated buses, while the Netherlands has implemented laws and exemptions for the experimental use of self-driving vehicles. The Netherlands also boasts high-quality roads and has been actively testing truck platooning operations. These examples showcase the progress made by countries in terms of policy, infrastructure, and consumer acceptance for autonomous vehicles.

Overall, Europe, North America, and Japan have established themselves as early leaders in the development of automated vehicles, while countries like Singapore and the Netherlands serve as notable examples of advanced adoption and implementation in real logistics operations. More information about the market in different countries can be found in section 8.1 "Status of all-weather autonomous operations across the world".

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[8] Autonomous driving's future: Convenient and connected. (2023, January 6). McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected

[9] 2020 Autonomous Vehicles Readiness Index (No. 136956-G). (2020, July). KPMG International Cooperative. Retrieved May 24, 2023, from https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf

4.1.4. Market segmentation by application

The section highlights the distinction between indoor and outdoor automated transport systems[10], with a specific emphasis on outdoor systems in logistics. The four main applications and use cases identified are outdoor forklift operations, hub-to-hub, port, and airport. These use cases represent the main applications of autonomous vehicles (AVs) in the logistics sector.

To provide a visual representation of the use cases, Figure 5 displays the AWARD use-cases matrix, encompassing five key dimensions: geographic areas, roadway types, traffic conditions, weather conditions, and incidents. The matrix helps in understanding and analysing the various scenarios and environments in which autonomous transport systems operate. The following figure refers to AWARD's 4 use cases: hub-to-hub, outdoor forklift operations, airport (luggage handling) and port.

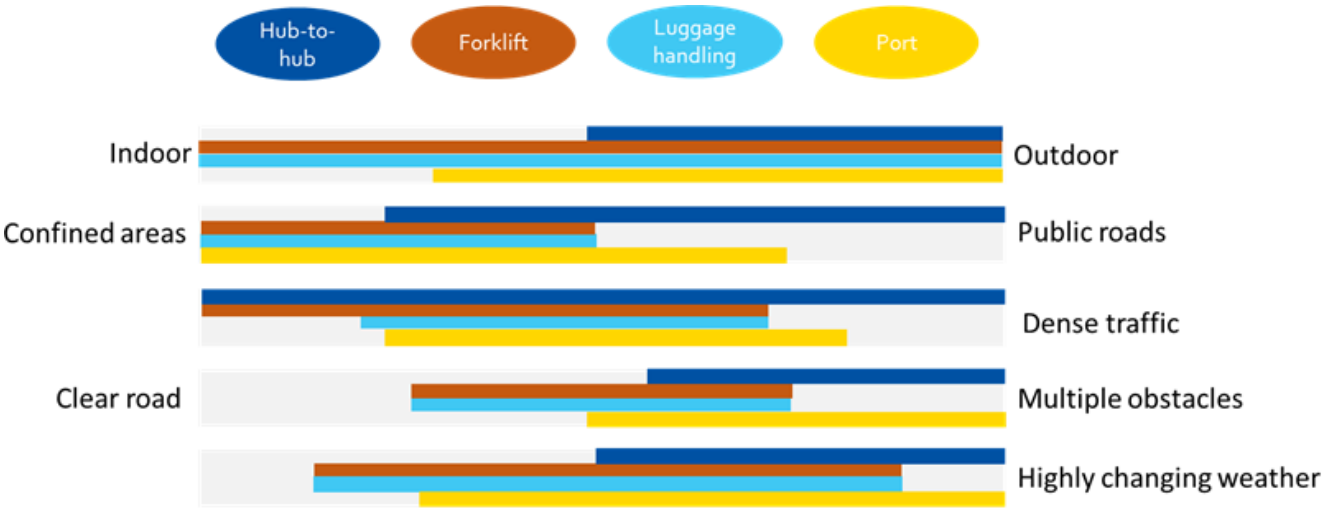

Figure 5 AWARD use-cases matrix – 5 key dimensions

In the outdoor forklift operations use case, the project aims to address technological challenges related to logistics operations in different scenarios such as warehouses and construction sites. The hub-to-hub use case involves demonstrating autonomous heavy-duty vehicles operating between the Engine Factory of BRP-Rotax and the Logistic Hub of DB Schenker in Austria. Luggage handling at Avinor OSL Gardermoen airport in Norway showcases an automated baggage tractor operating in an extended operational design domain (ODD). Lastly, the port use case focuses on trailer transfer operations and automated ship loading at a DFDS port terminal in the Port of Rotterdam, validating the developed AWARD technology. These use cases serve as essential demonstrations to test different scenarios and environments in logistics operations.

[10]Flämig, H. (2016). Autonomous Vehicles and Autonomous Driving in Freight Transport. In: Maurer, M., Gerdes, J., Lenz, B., Winner, H. (eds) Autonomous Driving. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-48847-8_18

4.2. Market drivers

We have conducted comprehensive research, utilizing both primary and secondary data, to identify the key drivers and enablers of autonomous heavy-duty vehicles (AHDVs) in the logistics industry. In November 2021, a workshop was organized involving various consortium partners representing diverse stakeholder groups, including manufacturers, research institutes, consultancy firms, technology providers, associations, and end users such as representatives from ports, airports, and industrial companies. The workshop was designed to delve into the drivers, barriers, and opportunities pertaining to AHDVs in logistics. It comprised two main components: an interactive survey using Mentimeter to gauge the participants' sentiments and a collaborative teamwork session to gather detailed opinions using Metroretro, which have been included in the Annex section *13.3 Market drivers*.

The results of the workshop were combined with the secondary data collected through desktop research of academic publications and online resources to reach a comprehensive conclusion about the most influential drivers toward AHDVs in logistics.

The drivers have been classified into categories: technological, social, economic, environmental, and legal and political. Figure 6 provides a summary of the drivers identified:

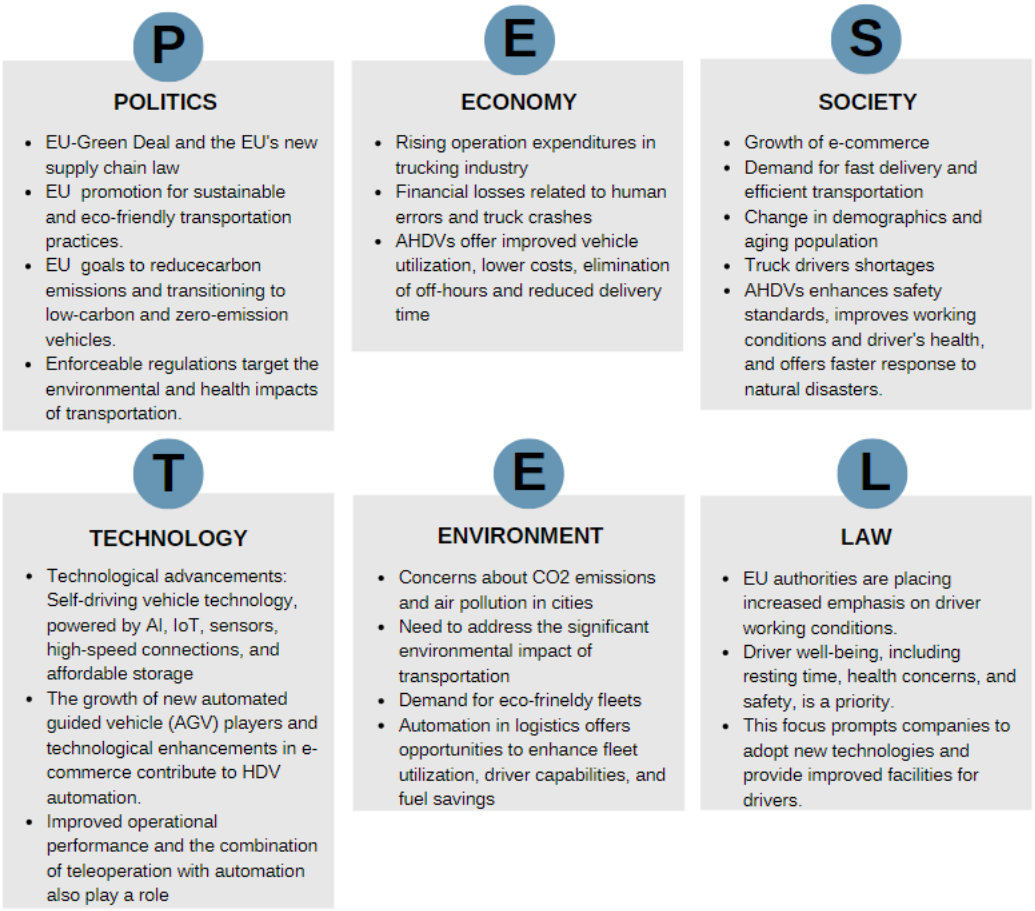

Figure 6 PESTEL analysis for AHDVs

Political and legal drivers

Legal and political drivers for autonomous heavy-duty vehicles (AHDVs) in logistics stem from initiatives such as the **EU-Green Deal**, the EU's new supply chain law, and the demand for safer vehicles. EU policymakers and the automotive industry are actively promoting the rapid and successful deployment of connected and automated technologies across Europe. Additionally, EU authorities are increasing pressure on driver working conditions, including resting time, health issues, and safety concerns, prompting companies to adopt new technologies and provide better facilities for drivers. The EU's policy focuses on reducing **carbon emissions** from vehicles, transitioning to low-carbon and zero-emission vehicles, and improving operational efficiency in transportation. Enforceable regulations target the **environmental and health impacts of transportation**, leading companies to innovate and adopt new technologies to comply with sustainability and eco-friendly transportation requirements.

Economic drivers

The economic driver for the adoption of autonomous heavy-duty vehicles (AHDVs) in logistics is fuelled by rising **operational expenditures** in the trucking industry. Over the years, the costs of trucking, including truck/trailer payments, have significantly increased in both the United States and Europe. This upward trend in costs, combined with financial losses resulting from human errors and truck crashes, has led freight companies and transport operators to seek innovative solutions for improved efficiency and cost savings. The use of AHDVs offers benefits such as **improved vehicle utilization**, **lower costs**, **elimination of off-hours**, and **reduced delivery time**, which are key incentives for logistic companies looking to enhance their competitive advantage in a rapidly evolving market. The results from the workshops, highlighting the Incentives behind the use of autonomous heavy-duty vehicles in logistics, are presented in Annex section mentioned before.

Social drivers

Social drivers of autonomous heavy-duty vehicles (AHDVs) in logistics stem from the growth of e-commerce and changing demographics resulting in **a truck driver shortage**. E-commerce expansion has raised expectations for speedy delivery, necessitating efficient transportation solutions. Europe, China, and the US have experienced substantial e-commerce growth. Demographic shifts, including an aging population and fewer HDV licenses, have led to a shortage of truck drivers in the EU, worsened by wage concerns, poor working conditions, and health issues. The COVID-19 pandemic has strained the supply system and increased transportation demand, particularly due to e-commerce growth. The key social drivers for AHDV adoption include enhancing **safety standards**, addressing **driver health** concerns, improving **working conditions for the younger generation**, **responding timely to natural disasters**, and promoting **equality and diversity**. More details can be found in the Annex section mentioned, featuring a comprehensive figure illustrating the factors contributing to the trucking industry's driver shortage.

Technological drivers

Technological advancements are serving as a major market driver for the automation of heavy-duty vehicles (HDVs) in logistics. The progress in self-driving vehicle technology, driven by artificial intelligence (AI), IoT, sensors, high-speed connections, and affordable storage, is enabling the collection and analysis of vast amounts of data. Participants in the industry recognize **AI, machine and computer vision**, **geo-localization**, **big data**, and **radar**

advancements as key technological drivers for autonomous vehicles in logistics. The growth of **new automated guided vehicle (**AGV) players, technological enhancements in e-commerce, **improved operational performance**, and the combination of **teleoperation with automation** also contribute to the automation of HDVs. While these advancements hold the potential to enable autonomous vehicles to operate in various environments, **widespread acceptance** and trust in AI-based decision-making remain crucial for their mass adoption. The results from the workshops, highlighting the important technological enablers of automation in real logistics, are presented in the Annex section for the market drivers.

Environmental drivers

Environmental drivers for autonomous heavy-duty vehicles (AHDVs) in logistics arise from the need to address the significant environmental impact of transportation. The EU's reliance on oil for transportation leads to high greenhouse gas emissions and air pollution, particularly in cities. Logistics and transport contribute significantly to **pollutant generation**, posing risks to human health and the environment. A substantial portion of CO2 emissions in the EU and Spain is attributed to the logistics industry. To mitigate these environmental challenges, companies are transitioning to more eco-friendly fleets, with electric vehicles being a prominent solution. **Optimizing routes** and **prioritizing automation** and software solutions also help reduce emissions and improve efficiency. Environmental concerns drive the adoption of technologies aimed at reducing CO2 and greenhouse gas emissions. Ultimately, automation in logistics offers opportunities to enhance fleet utilization and fuel savings, addressing environmental issues while meeting the increased demand driven by e-commerce and other factors in the industry. More details can be found in the Annex section, featuring a graph for the share of GHGs in the EU transport sector.

4.3. Competitive landscape

This competitive analysis section focuses on key players in outdoor logistics automation, primarily in Europe. It excludes long-haul applications and indoor solutions such as AGV or AMR. The analysis primarily examines European companies, with brief mentions of interesting companies from North America and Asia. Market share analysis is not feasible due to the early development phase and limited competition in the outdoor automation market. The objective is to assess the competition among companies primarily catering to OEMs and outdoor ADS providers. The goal is to analyse the AWARD autonomous solution in relation to existing options; however, due to the current stage, conducting detailed performance comparisons is not yet feasible. The available data is limited and primarily sourced from company websites and project communications, forming the basis of the analysis.

4.3.1. Heavy Duty Vehicle OEMs

To analyse the original equipment manufacturers (OEMs) relevant to the AWARD use cases, the consortium collected information about manufacturers located in Europe who produce or are involved in the development of heavy-duty vehicles for outdoor logistics automation. These OEMs are presented in a table summary within the report, specifically in "*D8.1 Market opportunities, barriers and solutions*" and in the *Annex section 13.5* (Table 3 Heavy Duty Vehicle OEMs). This table provides a comprehensive overview of each OEM, including essential information related to their heavy-duty vehicle offerings in the context of outdoor logistics automation.

In terms of experience and founding year, Volvo Group, established in 1928, boasts a nearly century-long presence in the industry, building a strong reputation and expertise over time. SANY can be also highlighted as an experienced company with more than 34 years in the market. In comparison, Palfinger, founded in 1932, is a well-known player that has been in the market for many years. During their long history, Palfinger has managed to establish themselves as a significant competitor in the industry. On the other hand, VDL Group, established in 2016, is the youngest among the three competitors but has achieved substantial growth and market presence despite being a relatively new player.

Moving on to turnover, Volvo Group leads the pack with a remarkable turnover of €20.6 billion in 2020, reflecting their extensive operations and market presence. Their significant revenue establishes them as the clear industry leader. In contrast, SANY generated a turnover of $16 billion in the same year, a notable figure that shows their substantial market presence and financial performance. Although smaller than its two rivals, Palfinger's turnover of €1.53 billion in 2020 shows their growth over time.
In terms of the number of employees, Volvo Group stands out once again with a workforce of 96,194, the highest among the three competitors. The large number of employees signifies the scale of their operations and the resources they can dedicate to various aspects of their business. Closely following Volvo, we can find SANY, with nearly 90,000 employees. Despite having fewer workers than Volvo Group (approximately 11,000), Palfinger nevertheless has a sizable workforce, proving their capacity to carry out activities well. With 15,464 workers, VDL Group has the smallest workforce compared to the other three, but despite this, they have managed to grow and succeed in the market.

Overall, Volvo Group's long-established history, high turnover, and large workforce position them as the industry leader. Although Volvo's extensive experience and resources give them a significant advantage over their competitors, the Chinese experienced company (SANY), which focuses more on logistics with respect to Volvo, is also an important competitor in Asia. However, both Palfinger and VDL Group have shown remarkable growth and market presence, with Palfinger excelling in endurance over the years and VDL Group making notable strides in a relatively short period. As the industry evolves, these three competitors continue to shape the market landscape with their unique strengths and contributions.

In terms of product offerings and characteristics, in the heavy-duty vehicle industry, competitors offer diverse options to meet customer needs. Palfinger focuses on operations with up to 2.5T payload capacity and diesel system. EK Robotics stands out with a 20T payload capacity and flexible diesel/electric power. KAMAG targets medium-sized loads with up to 17T capacity and diesel/electric options. Konecranes Group specializes in heavy-duty tasks with 70T capacity and both diesel/electric systems.

Kalmar matches Konecranes' 70T capacity with diesel/electric versatility. Einride prioritizes sustainability with electric-powered solutions up to 16T. Stäubli-WFT offers exceptionally high 500T capacity and electric-only operation. Terberg Group provides up to 36T capacity and multiple diesel/electric/hydrogen systems. Gaussin Group focuses on electric/hydrogen-powered options up to 65T. VDL Group offers a wide range up to 70T with electric/diesel

choices. Volvo Group combines strength and versatility with 36T capacity and electric/diesel systems.

Charlatte Manutention Fayat Group specializes in electric towing up to 30T. TLD Group offers electric towing up to 25T. Overall, these competitors offer a diverse range of heavy-duty solutions, including various payload capacities and drive systems to meet specific customer requirements.

It is important to note that the first version of this competitive analysis has been updated since the former partner KION appeared as the provider for the forklift. After changes within the project, this company has been replaced by Palfinger and is included in the project as a stakeholder; hence, the aforementioned entity is not a partner in the project but is the OEM for the outdoor forklift operations use case. Palfinger's forklift will be automated by AIT, but commercialization intentions are still under discussion.

4.3.2. Outdoor ADS providers for Logistics applications

The focus of this analysis is on autonomous driving system (ADS) providers that are developing technologies specifically for outdoor automation in logistic applications. While some of these solutions may also be applicable indoors, our study is limited to those that enable outdoor operations.

To provide a comprehensive understanding of the market landscape, several criteria have been considered for the competitive analysis. These include the retrofit versus integrated approach, OEM partnerships, safety compliance, autonomous navigation technology, funding profile, and operations footprint. A summarized comparison can be found in the table titled "Competitive landscape for autonomous heavy-duty vehicles" in Annex 13.5 of the report. AI Drivers, EasyMile, Götting, and Navya are prominent players in the autonomous driving systems (ADS) industry, each with its own unique characteristics and global presence.

AI Drivers, based in the United Kingdom, specializes in the port industry and operates globally. With headquarters in London and subsidiaries in Singapore, Shanghai (China), and Chennai (India), AI Drivers has a broad reach. The company, established in 2018, currently employs around 60 people.

EasyMile, headquartered in Toulouse, France, operates on a global scale. Founded in 2014, EasyMile has subsidiaries in Berlin (Germany), Denver (Colorado, USA), Singapore, and Adelaide (Australia). With approximately 250 employees, EasyMile has established itself as a significant player in the industry.

Götting, a German company founded in 1965, has been at the forefront of vehicle automation through its FOX department since 2000. While primarily focused on Germany and the European Union (EU), Götting has made notable contributions to the ADS field. The company, based in Lehrte, employs around 70 individuals.

Navya, another French company, operates globally, offering its autonomous solutions in various locations. Headquartered in Lyon, Navya has subsidiaries in Paris (France), Saline

(Michigan, USA), and Singapore. Established in 2014, Navya currently employs approximately 180 people.

While this comparison has highlighted the operations and characteristics of four significant European ADS providers, there are numerous other providers worldwide at different stages of commercialization. For example, Sensible4[11], a Finnish company, specializes in autonomous technology optimized for extreme weather conditions, particularly Scandinavian winters, but does not currently apply it to logistics vehicles or applications. In North America, both ASI Robotics and Outrider have a proven track record in autonomous yard operations. Additionally, Uisee, an Asian company, has demonstrated its autonomous technology on a tow-tractor at Hong Kong airport. These companies, along with many others, contribute to the diverse landscape of ADS providers worldwide, each focusing on unique applications and markets. Other companies are important in this sector as well, such as Tusimple and Waymo (more information about these two companies and latest projects can be found in Annex 13.7).

When comparing the footprint and focus of these ADS providers, AI Drivers stands out with its global operations and a specific focus on the port industry. They have established a presence in key locations such as London and Singapore. EasyMile, on the other hand, operates globally without a specific industry focus, ensuring a wide reach for their autonomous solutions. Götting primarily centres its operations in Germany and the European Union, demonstrating a regional focus within the industry. Finally, Navya operates globally, serving various locations worldwide. These comparisons highlight the different geographical scopes and areas of emphasis for each company in the ADS market.

4.4. Porter’s five forces (FHO and ITS Norway)

This section provides basic information on Michael Porter’s five forces[12] to set the scene for further AWARD-respective strategic analysis. To help the reader to get familiar with Michael Porter’s ideas, we provide in Annex 11.1 the original text published in the Harvard Business Review in 1979.

The following Figures 7, 8, 9 and 10 provide the complete final version of Porter’s 5-forces-analysis for each AWARD use cases.

[11] Sensible 4 signed bankruptcy this year (2023); however, it was included in this deliverable due to their advancements in the autonomous driving under extreme weather conditions.

[12] Porter, Michael E. "Competitive strategy: techniques for analyzing industries and competitors: with a new introduction.", 1998.

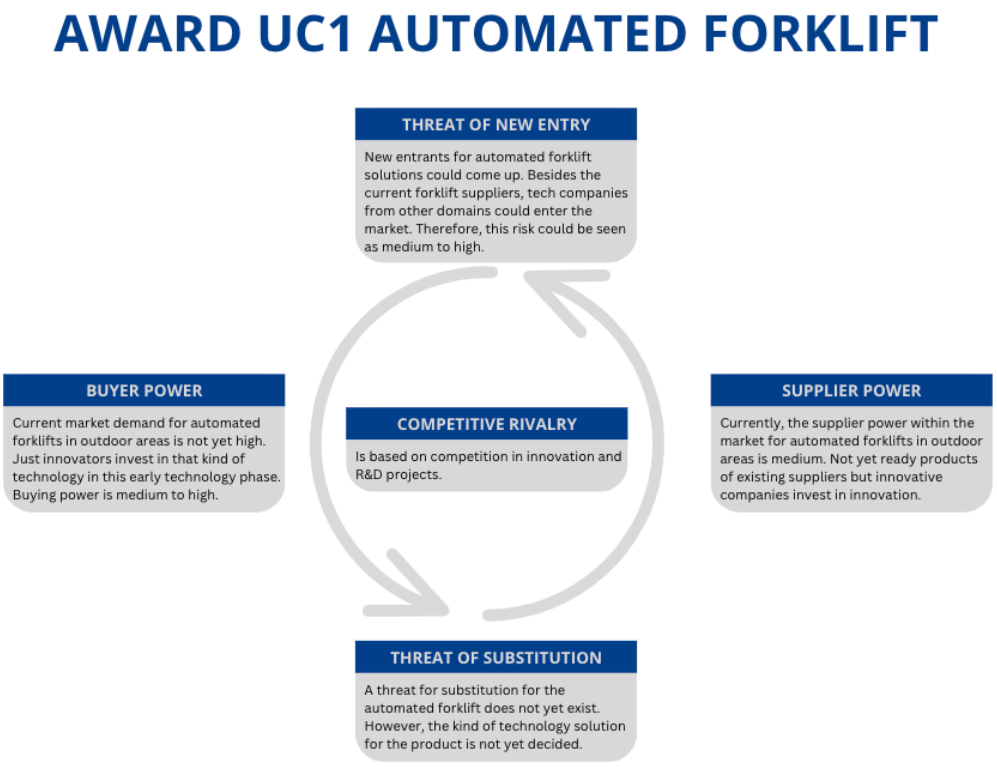

Figure 7 Initial Porter's Five Forces analysis for the AWARD UC1 "Outdoor Forklift Operations"

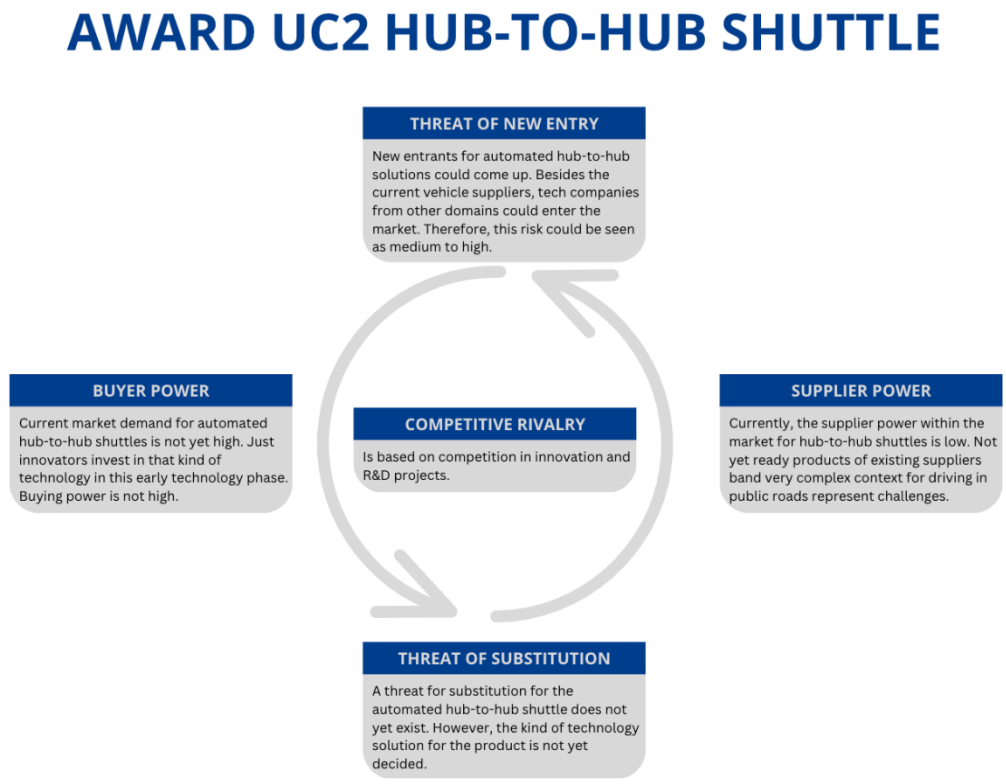

Figure 8 Initial Porter's Five Forces analysis for the AWARD UC2 "Hub-to-Hub shuttle"

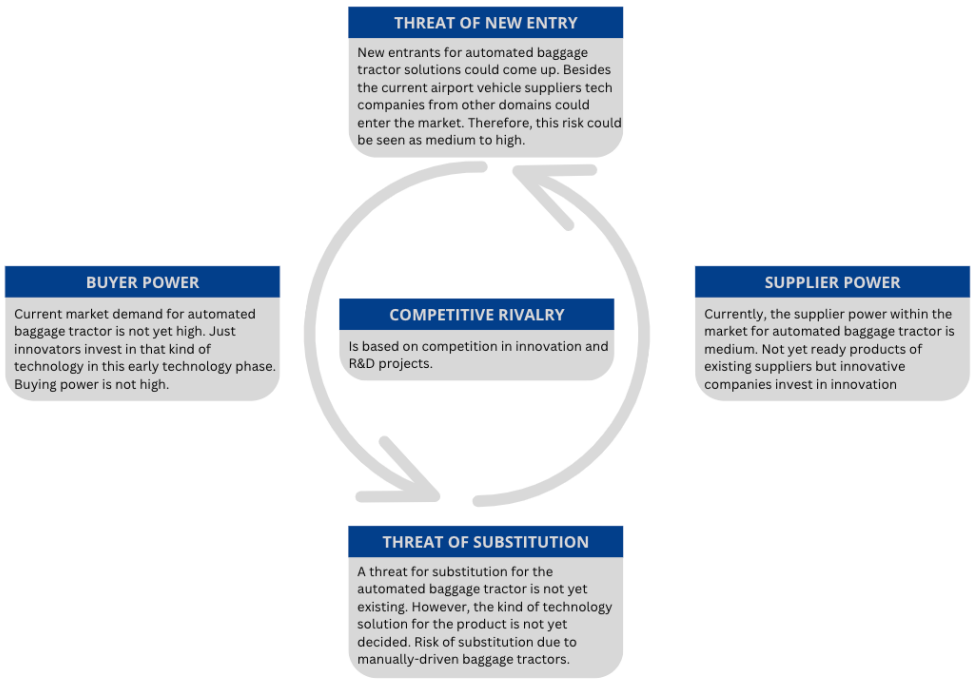

Figure 9 Initial Porter's Five Forces analysis for the AWARD UC3 "Automated baggage tractor in airports"

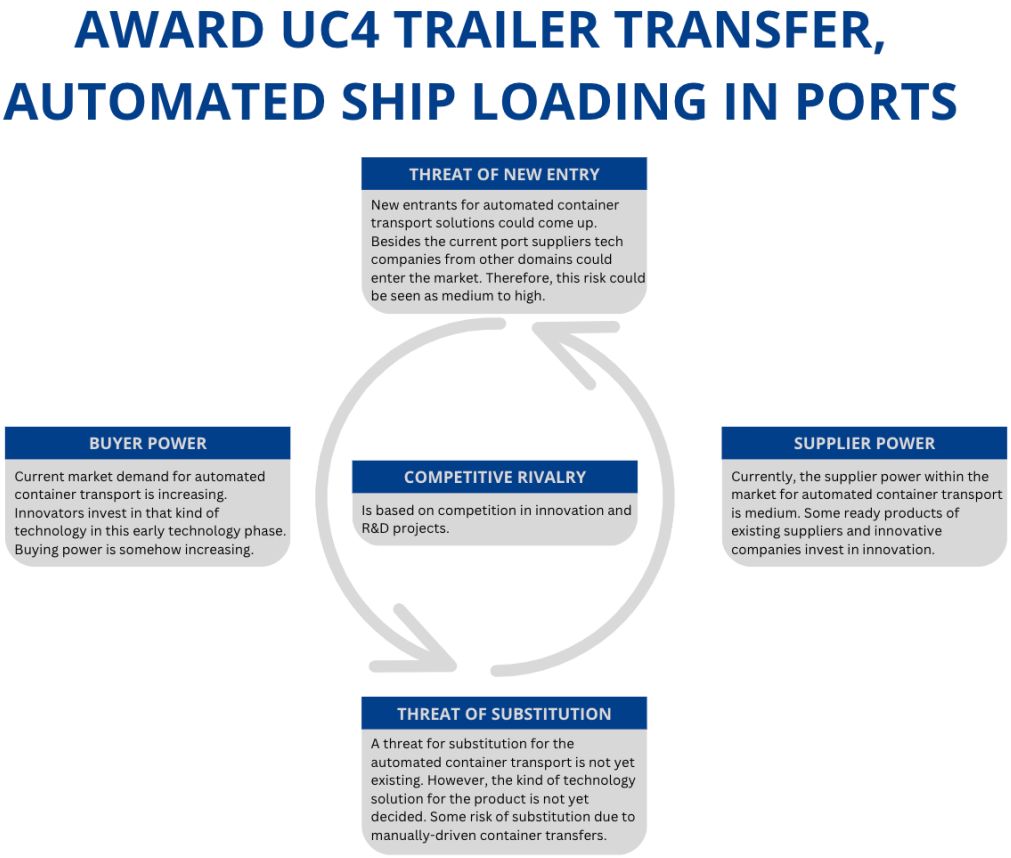

Figure 10 Initial Porter's Five Forces analysis for the AWARD UC4 "Trailer transfer, automated ship loading in ports"

In the market analysis context, an initial competitive landscape analysis was performed based on Porter's five forces (1979). Based on the four AWARD use cases, the main outcome for the five forces (Supplier Power, Buyer Power, Threat of New Entry, Threat of Substitution and Competitive Rivalry) is the following:

- Low supplier power due to products that are not yet ready for mass deployment.
- Low buyer power due to limited demand from innovators in the market.
- Medium to high risk of new market entrants due to a lot of possible new technology players, low risk of substitution based on the limited number of available products.
- The competitive rivalry is based on a competition between highly innovative companies and R&D projects.

Based on the AWARD-specific five forces analysis for the AWARD use cases, the following business strategy implications/recommendations have been derived.

Recommendations for potential customers of the AWARD-based solutions:

- Analysis of existing applications areas (routes, load, environment, un/loading time...)
- Cooperation with R&D projects to gain early insights in system capabilities
- Comparison of As-IS procedure with potential automated operation (To-BE)
- Cost-benefit analysis including potential implementation plan.

- Recommendations for technology providers:

- Testing of solutions in new application contexts (e.g., transfer Hub-to-Hub case from Austria to France)
- Increasing technology readiness level in R&D projects with potential customers
- Proof of operational domains and potential benefits of automated vehicles.
- Advertise AWARD lessons learnt to gain new projects and customers

Concluding the Porter's five forces, the market maturity is rather low for all use cases. Therefore, technology providers following R&D projects are the appropriate means to successfully reach a higher TRL level and enter the market. On the other hand, potential customers may gain early insights into new technology potentials and requirements by serving as a testbed for new solutions in R&D projects.

5. Market analysis fleet management systems

Applied Autonomy, leader of WP5 and vendor of the FMS, provides an agnostic fleet management system that gives fleet managers the tools they need to efficiently manage and optimize their fleet of autonomous vehicles. It provides flexibility by enabling fleet managers to make orders whenever they want, regardless of when a logistics system sends them. They now have total control over dispatching and scheduling to fulfil their unique operational requirements. The solution offers the fleet manager personalized alternatives based on their use case, ensuring they have pertinent options to pick from and increasing decision-making. AA's FMS has been customized and extended for the AWARD project. We will be referring to it as AWARD FMS in this deliverable, noting that we refer to the customized version of the FMS for AWARD.

Fleet managers can submit their orders into the FMS, and the system will produce offers of vehicles that are available and with matching times depending on variables like proximity, driver schedules, and availability. AWARD FMS optimizes fleet operations and resource use by streamlining the workflow for order development, offer generation, and confirmation. It equips fleet managers with the tools they need to properly manage and supervise their fleet, measuring efficiency, increase productivity, and making sure that everything is coordinated. In order to understand how AWARD FMS stands out in the market, we first will need to delve into its market characteristics.

The aim of this section is to provide a thorough analysis of the market for fleet management systems, in particular for AWARD Fleet Management System (FMS). We started our analysis by segmenting the market by region, component, fleet type/vehicle type and deployment type. Following, market dynamics were studied, putting emphasis on drivers. Following, a competitive analysis was conducted to understand the value added of AWARD FMS compared to the key players in the market. To conclude, Porter's five forces analysis was elaborated to have a broader view of the competitive landscape of AWARD FMS by analysing the number and power of competitors, potential new market entrants, suppliers, customers, and substitute solutions.

5.1. Market segmentation

Following the scope of WP5, the AWARD project's fleet management and control services perform the function of coordinating the operations of autonomous vehicle fleets deployed at the pilot sites. The Fleet Management System (FMS) gathers data from a variety of sources, including sensors and human users. To optimize task execution while making operations as safe as possible, taking both equipment and road users into account, it develops a complete picture of the activities and operating circumstances on site.
The primary responsibility of the fleet management system is to safely maximize the use of the available vehicles in accordance with transportation requirements and road conditions.
The main functions for logistics operations are

- dispatch, including handling orders
- asset management
- handling road conditions

- remote vehicle assistance
- monitoring operations and providing KPIs
- providing end user information.[13]

Fleet Management Systems are analytics platforms that allow fleet operators to track and control (alternative) fuel consumption, operational costs, vehicle equipment and maintenance, driver safety and compliance, and route planning. FMS take a macro view of logistics operations by focusing on performance evaluation and management rather than on the optimization of real-time driving.[14] The following market segmentation analysis focuses on so-called smart FMS (e.g., cloud-based software, devices, and analytics) to the extent that data is available. It intends to enable AWARD project partners and other stakeholders to target different groups of consumers in the market.

5.1.1. Market segmentation by region

By region, the smart fleet management market is divided into North America, Europe, Asia-Pacific, and the Rest of the World. Asia-Pacific accounted for the most extensive market share (42% in 2021), followed by North America (27%), Europe (20%) and others (11%). The North American region is expected to yield the highest CAGR (compound annual growth rate) in forecasts to the year 2030.

The Asia-Pacific region dominated market share in 2021 due to increasing competition, increasing penetration of smart devices and connected machines, and growing investments in smart cities. High economic growth in emerging nations, such as China, India, and Vietnam, has enhanced the number of related solutions that consist of sensors and RFID tags, resulting in exponentially growing data generation. TMS is a prominent feature in this region's growing transportation and logistics sector. North America is a leading early adopter of digital technologies and accounted for the second-largest market share in the market due to the large-scale deployment of real-time tracking solutions across industries for seamless business operations.[15]

5.1.2. Market segmentation by component

The smart fleet management market can be segmented based on the following components: operations management (further divided into fleet tracking, geo-fencing, routing, and scheduling), fleet maintenance and diagnostics, performance management (incl. subcategories of driver management and fuel management), compliance management, fleet analytics and reporting, and others.

Operations management tends to dominate market share and is expected to drive market growth. The main reason cited for this trend is that effective operations management is highly correlated with effective supply chain management. The performance management

[13] D5.1 Architectural model for fleet management and control services

[14] Boston Consulting Group (2021). Heading to A Future with Driverless Freight Transportation. https://web-assets.bcg.com/c5/a1/a6ba798d4f13b0fe45f3c0a44fb5/bcg-heading-to-a-future-with-driverless-freight-transportation-aug2021-eng.pdf

[15] Smart Fleet Management Market Size, Share, Growth Report 2030. (n.d.). Smart Fleet Management Market Size, Share, Growth Report 2030. https://www.marketresearchfuture.com/amp/reports/smart-fleet-management-market-5226

component is a second growth market due to the increasing availability of predictive maintenance technologies that monitor engines, tires, hydraulics, and other equipment.[16]

5.1.3. Market segmentation by fleet/vehicle type

There are different types of fleets depending on the business case and use by the operators. Some indicative types of fleets are:

- Commercial
- Trucking
- Delivery (couriers, sales)
- Public transport
- Emergency services
- Utilities
- Passenger cars (company fleets etc.)

FMS can be applied to all types of fleets with the necessary technological adjustments. In general, FMS providers structure their offerings by fleet size. The average cost for a fleet management software package starts at around $35 per month per vehicle or $3500-$6500 for a fleet of 10 vehicles per year.[17] Market forecasts highlight the growth potential for the commercial segment in light of increasing needs for supply-chain consistency and on-time delivery of goods.[18] While FMS software is currently commercially available mainly for conventional vehicles, it is likely that AV operations will drive future market growth. The adoption of AV technology coupled with advanced FMS solutions could eliminate certain constraints for commercial vehicles, such as driving time and rest period regulations, resulting in higher asset utilization and improved productivity.[19] Note that this is the case when there is a driver in the vehicle. When vehicle technology reaches Level 4 or 5 autonomy, the role of the FMS is modified from a planning tool to a tool for automating processes and maximising vehicle utility.

5.1.4. Market segmentation by deployment

On-premises versus cloud-based are the two main categories in the segmentation of FMS by deployment. Thus far, the former is capturing the majority of market share, but the latter is expected to show a higher CAGR in the future due to expected improvements in cost-efficiency.[20]

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[16] Fleet Management Software Market Size, Share | Growth [2030]. (n.d.). Fleet Management Software Market Size, Share | Growth [2030]. https://www.fortunebusinessinsights.com/industry-reports/fleet-management-software-market-100893

[17] Orenstein, S. (2022, September 16). What Is Fleet Management & Why Is It Important? - Locate2u. Locate2u. https://www.locate2u.com/articles/what-is-fleet-management/

[18] Fleet Management Software Market Size, Share | Growth [2030]. (n.d.). Fleet Management Software Market Size, Share | Growth [2030]. https://www.fortunebusinessinsights.com/industry-reports/fleet-management-software-market-100893

[19] The True Value of Autonomous Driving. (n.d.). The True Value of Autonomous Driving. https://www.oliverwyman.com/our-expertise/insights/2015/jul/automotive-manager-2015/customer/the-true-value-of-autonomous-driving.html

[20] Fleet Management Software Market Size, Share | Growth [2030]. (n.d.). Fleet Management Software Market Size, Share | Growth [2030]. https://www.fortunebusinessinsights.com/industry-reports/fleet-management-software-market-100893

5.2. Market drivers

ENIDE performed an analysis of market drivers for AWARD FMS, with the help of desktop research and interviews conducted. We have identified key drivers pushing the demand for new technologies such as a fleet management system for autonomous logistics operations. It is worth noting that we aim to highlight those key factors influencing the adoption of fleet management systems for autonomous vehicles in logistics operations; still, because of market similarities, drivers for autonomous vehicles are also included since it also impacts the market for fleet management systems for AVs.

Figure 11 provides an overview of the political, economic, social, technological, environmental, and legal drivers.

Figure 11 PESTEL analysis for fleet management systems

1) Political drivers

Different EU policies and government regulations related to development, testing and deployment of autonomous vehicles that had been issued in the past years have impacted the implementation of technologies like fleet management systems.
For example, since 2016, the European Commission has been insistent on the adoption of Intelligent Transport Systems. They outline their strategies to reach higher levels of connectivity in the "**European Strategy on Cooperative Intelligent Transport Systems (C-ITS)"** which aims to advance the creation and implementation of automated and connected transportation systems in Europe. The strategy calls for the creation of uniform standards and rules as well as the testing and introduction of automated and connected vehicles on European roads.

Another example of European regulations betting for autonomous vehicles and adjacent technologies like FMS, is the European Union's **Intelligent Transport Systems (ITS) Directive,** which promotes the coordinated deployment of intelligent transport systems in the EU to improve road safety, traffic efficiency, and sustainability. Also, the regulatory framework for the approval and market surveillance of autonomous vehicles in Europe is laid out in the European Parliament's "**Regulation on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles**." The rule lays out specifications for the certification and approval of autonomous cars, as well as for the observation and reporting of safety-related occurrences. Furthermore, other regulations cover implementation of IoT and ITS for the progress of smart cities, such as the **Sustainable Urban Mobility Plans** and investment in 5G networks, which helps to create an adequate environment for developing technologies such as AWARD use cases.

In addition, each European country has its own laws and policies governing the usage of autonomous vehicles in the logistics industry. For instance, **Germany's "Autonomous Driving Act"** (2021) created a legal framework to implement autonomous vehicles as part of the Strategy for Automated and Connected Driving. The act aims to allow the deployment of motor vehicles with autonomous driving capabilities without a person driving in specified operating areas on public roads. Provisions concerning autonomous driving in appropriate operating areas correspond to level 4 of the Society of Automotive Engineers (SAE) driving automation levels. **France** has prioritized the development and promotion of smart mobility solutions as part of its **New Industrial France program.** The objective of the plan is to accelerate the adoption of connected and autonomous vehicles and to fortify the country's position in the worldwide market for smart mobility. The **United Kingdom** also is pushing for regulations for AVs with its "**Code of Practice for Automated Vehicle Trialling."**

2) Economic drivers

Demand for cost and operational efficiency is a key driver for logistic centres, since rising **operational and fuel costs** are forcing actors in the industrial sector to seek solutions that reduce costs elsewhere. Interviewees stated that any solution that will increase efficiency in logistic operations will be welcomed; however, implementations of new technologies such as AVs must be reliable enough so that they do not interrupt the operation flow. Interviewees highlighted that the main driver for implementing an FMS is the need for increasing coordination between different actors along logistic procedures. They stated that in the use case for airports specifically, there are several partners operating at the same time. It is the

case that airports subcontract companies for specific tasks, for instance, ground hauling operations. However, these actors communicate with each other mainly by radio; hence, there is a need for a solution that ensures better **and more efficient communication between all actors**, improving productivity for the whole process. On the other hand, there is an increasing trend in augmenting mobility budget not only from private companies but also from public authorities, which means more investing opportunities for FMS.

On the other hand, the current worldwide economic situation affects all sectors, including the logistics and transportation sectors. In Europe, **inflationary pressures and the energy crisis** due to the war in Ukraine impacted supply chains across countries. Still, according to Reuters[21], although the energy crisis and the war in Ukraine are no longer having a significant inflationary impact on European economies, 81% of frontline supply chain professionals still anticipate passing on costs to customers in 2023, while only 5% anticipate internalizing costs rather than doing so. Therefore, solutions such as AWARD FMS can be affected by these events.

3) Social drivers

The market for fleet management systems for autonomous vehicles may be impacted by modifications in **consumer attitudes and behaviours** in Europe and in the rest of the world. For instance, the expansion of e-commerce and home delivery services, as well as the rising need for environmentally friendly transportation options, may boost demand for these systems. Similarly, climate change awareness is changing consumer behaviour. From the interviews we conducted with experts in the field, most of the interviewees pointed out that in recent years and as a consequence of climate change, there has been an increase in the **demand for greener solutions**. Interviewees believe that this change of behaviour can enhance the adoption of new technologies like AWARD FMS, since it focuses on more efficient and lower energy consumption of vehicles.

Moreover, current issues faced by the industrial sector such as a **labor shortage** could be a driver for new technologies involved in automation. During interviews, experts highlighted that increasing demand for automation could boost implementation of novel technologies such as AWARD FMS. Interviewees stated that for this to be true, the new solutions entering the market have ensured an incremental increase in operational efficiency, must be highly reliable and cost-effective.

Interestingly, results from the survey revealed that another key factor pushing for automation in logistics will be to **improve working conditions**, since workers could be reallocated to other types of tasks that are less demanding and learn new skills. Clearly, from the point of view of a fleer manager, technologies such as AWARD FMS will ease the fleet manager work, thus becoming another driver that may be boosting the demand for our solution may be the **easing**

[21] Europe's inflation headache not yet over as 8 in 10 supply chain professionals expect to pass on further costs in 2023 | Reuters Events | Supply Chain & Logistics Business Intelligence. (2023, March 6). Europe's Inflation Headache Not yet Over as 8 in 10 Supply Chain Professionals Expect to Pass on Further Costs in 2023 | Reuters Events | Supply Chain & Logistics Business Intelligence. https://www.reutersevents.com/supplychain/technology/europes-inflation-headache-not-yet-over-8-10-supply-chain-professionals-expect-pass

and reduction of workload for workers involved in manual/repetitive operations, as one of the interviewees explained.

4) Technological drivers

Improvements in technology are pushing the demand for solutions such as a fleet management system for autonomous vehicles. As the world continues to develop new technologies, this will be a continuous factor that will positively impact AWARD's solutions. For instance, interviewees commented that improvements in wireless technologies like 5G, real time traffic information systems, predictive maintenance technologies, sensors and machine learning algorithms are indeed pushing the implementation of FMS for AVs in the logistic sector.

Professionals in the field also explained that we are currently seeing **efforts from the European Union to invest in R+D+I** projects to remain competitive. Some stated that the EU is competing on technological developments as it cannot compete on lower labor costs, thus creating a suitable environment for fostering innovations such as AWARD. The increasing number of European projects related to mobility and logistics will continue to be a driver for innovations like AWARD FMS in the foreseeable future, since new calls from Horizon Europe program are open.

Furthermore, the fact that more **automobile companies are investing in autonomous transportation** and similarly, the incremental demand for this type of vehicle will push the demand for fleet management systems in the future.

Another driver is the **need for a solution that is vehicle agnostic** such as AWARD. According to interviews, there is an increasing need in a system that can be integrated with manual and autonomous vehicle, since most of airports, ports and logistic hubs have mostly manual vehicles and they planned to slowly transition to semi-autonomous and autonomous vehicles; hence they need a solution that will cover all types of vehicles. Also, experts commented that there is an increasing **trend for containerization** in logistics centres. Therefore, as more container traffic arises, technologies that include automated processes such as fleet management systems will gain in importance soon.

Finally, according to our desktop research, **automation in logistic hubs, warehouses, ports and airports will be increasing in the forthcoming years** which will have a positive impact in the adoption of FMS for AVs in logistics. Still, some use cases will be ready before others. For instance, logistics hubs and warehouses are expected to reach a CAGR of approximately 13.67% during 2022 and 2027[22]. Also, some European ports are implementing some sort of autonomous systems, such as the Port of Rotterdam, where autonomous container transport vehicles and automated container terminals have been put in place. Moreover, automated container transport systems have been tested at the German port of Hamburg. The ports of Valencia in Spain, Gothenburg in Sweden, and Antwerp in Belgium are among those in Europe that have been experimenting with or deploying autonomous technology. Nevertheless, results

[22] Europe Warehouse Automation Market Size & Share Analysis - Industry Research Report - Growth Trends. (n.d.). Europe Warehouse Automation Market Size & Share Analysis - Industry Research Report - Growth Trends. https://www.mordorintelligence.com/industry-reports/europe-warehouse-automation-market

from interviews highlighted that there is still a long way to go until all ports, airports, and warehouses are automated, as it is further explained section 7.

5) Environmental drivers

Concerns about **CO2 emissions and climate change** awareness are pushing companies to invest in greener solutions and governments to apply legislations for propelling sustainable logistics. Thus, the increase in pollution is a key driver for FMS since it provides a smarter and greener option to manage fleets efficiently.

Similarly, the adoption of fleet management solutions for autonomous vehicles is gaining traction as more companies seek to **minimize their environmental footprint**. By increasing fuel efficiency and reducing emissions, the use of fleet management systems in logistics can reduce the environmental impact of transportation. Following, not only companies but citizens are also keen to reduce their impact on the environment, as we have seen an **increasing trend of shifting towards alternative fuel vehicles** is another interesting driver for solutions such as AWARD. A graph showing the share of GHGs in EU transport sector can be found in Annex section 13.3.

Following, **government regulations related to greener and smarter solutions** are pushing the implementation of technologies such as AWARD into the market. Some examples cover regulations concerning climate neutrality by 2050 to achieve net-zero greenhouse gas emissions as part of the European Green Deal. To do this, the European Green Deal establishes goals to achieve climate neutrality by 2050 and reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels[23]. These goals necessitate considerable adjustments in a number of industries, including agriculture, energy, and transportation, among others. By enabling more effective resource utilization and lowering emissions, the use of technologies like AWARD can aid in the achievement of these goals.

Safety is another factor that can be linked to environmental efficiency. By eliminating accidents brought on by human error, fleet management systems in autonomous vehicles can increase road safety. This may result in **lower car emissions** and an all-around more **environmentally friendly transportation system**.

6) Legal drivers

Related to **liability, safety, and insurance regulations**, depending on the country, the regulatory environment can differ, and companies must abide by the laws in the jurisdictions where they conduct business, which may have an impact on how autonomous vehicle fleet management systems are implemented. For instance, the “General Safety Regulation” and the “Product Liability Directive” are two laws and regulations in the European Union that deal with safety requirements and liability concerns for autonomous cars.

Also, increasing concerns on **data privacy and cyber security** are an important factor to consider when analysing the market for AWARD. Large amounts of data must be gathered and used for fleet management systems for autonomous vehicles to function properly.

[23] *European Climate Law*. (n.d.). Climate Action. https://climate.ec.europa.eu/eu-action/european-green-deal/european-climate-law_en

Sensitive information like the location of vehicles and the identity of the drivers may be included in this data. Companies are required to follow data privacy laws and have cybersecurity measures in place to safeguard sensitive data from unauthorized access, for example, the Global Data Protection Regulation (GDPR), which governs the gathering, storing, and processing of personal data, is one of the most significant pieces of legislation that businesses handling confidential data must comply with.

According to interviewees, as we move forward in the market for FMS and AVs, a well-defined regulatory framework for liability, insurance, data privacy and cyber security coming from the European Union will have a great impact on the industry and further commercialization of systems such as a fleet management system.

5.3. Competitive landscape

This section aims to provide an overview of the competitive landscape for fleet management of AWARD. Since there are different type of companies providing fleet management systems, we have divided the competitive landscape into three big groups:

1. Fleet operators/OEMs,
2. ADAS providers,
3. FMS software companies.

For each group, we have identified the advantages and disadvantages of developing a fleet management system, since different groups have distinct objectives, perspectives, circumstances, and business models for the commercialization of their fleet management systems. Also, a list of key players and competitors is detailed for each group. In order to have a better understanding of each group perspective, a workshop was conducted with different partners within the consortium that belongs to the different groups mentioned before. This section shows the results of the workshop, and it is complemented with additional information from desktop research.

5.3.1. Fleet operators and OEMs

We define fleet operators and vehicle manufacturers (OEMs) as companies that own and manage a fleet of vehicles, including autonomous vehicles. For the purpose of enhancing the efficacy, safety, and cost-effectiveness of their operations, they might participate in the creation of fleet management systems.

As end-users of fleet management systems, fleet operators and OEMs might be interested in developing their own FMS to manage their vehicles. Insights from different fleet operators and vehicle providers (OEMs) within the consortium help us to identify the advantages and disadvantages of developing their own FMS.

We have divided the advantages and disadvantages for fleet operators (with a focus on AWARD use cases) from the advantages and disadvantages for vehicle providers, as shown in the following subsection.

5.3.1.1. Advantages and disadvantages for fleet operators

Partners have identified which advantages and disadvantages of developing a FMS can be related to the ports, airports, and logistics use cases, which are reflected below.

5.3.1.1.1. Ports and Airports

Fleet operators in specific sectors such as ports and airports may have specific reasons for developing an FMS by themselves. Some advantages of an in-house FMS for ports/airports are:

- **Complete control of service, features, and development of FMS**: by developing their own FMS, fleet operators in ports/airports can have self-control over their internal operations without the need of relying on a third-party that may not be aligned with the needs and requirements of their day-to-day operations.
- **Customized and tailored solutions for internal needs**: the software can be adapted to fit unique operational requirements, regulations, customer wants and needs.
- **Integration into existing TOS (Terminal Operating System)/add-on to existing TOS:** the FMS developed by fleet operators can be added to or integrated to their existing Terminal Operating System easily. This represents an advantage for operators in sectors like ports since it enables the seamless integration of data, procedures, and workflows across many platforms, enhancing transparency, precision, and effectiveness.
- **Geo-reference:** having an FMS developed in-house allows fleet operators to manage geo-reference by themselves which can improve the collection geolocation data and thus, improve mapping, fleet routing, dispatching and tracking. Additionally, the adoption of new changes in their environment is easier because the FMS do not rely on external sources.
- **Possibility of integrating different vehicles and OEMs:** developing an FMS also reliefs the concerns about compatibility with third party systems, which allows to integrate the FMS with different types of vehicles and brands. This gives them more flexibility and scalability as they grow their fleet and capabilities.
- **Improvements in the dispatchment of vehicles**: the main purpose of an FMS is to dispatch vehicles. For the port case, connecting TOS and missions with vehicles is possible with an in-house FMS, which allows for customization and optimization of the dispatch process to meet specific requirements, enhance fleet utilization, cut idle time and boost fleet productivity. Hence, the importance of an FMS in this context relies on the fact that a fleet management system is the communication tool between vehicles and TOS.
- **Competitive advantage**: having an FMS produced in-house represents a competitive advantage because it is an extra capability for fleet operators that can help them to improve its operations (i.e., location of the vehicle, integration between different platforms/systems, etc.).

On the other hand, there are also **disadvantages** of developing an FMS from the fleet operators in ports and airports perspective:

- **High costs and high risks of not being state of the art:** in-house development of a fleet management system (FMS) can be expensive and risky because it necessitates a sizable investment in infrastructure, technology, and skilled employees. Furthermore, there is a chance that the FMS will not be cutting-edge because it might not take advantage of recent technological advancements or industry best practices; in this sense, an FMS developed by a technology company could have smart features that the FMS developed by a fleet operator in a port could not have due to prior research and investments.

- **Common agreement on features needed:** fleet operators may find it challenging to ensure that their internal FMS has all the features and capabilities required to satisfy the needs of all their vehicles and OEMs participating in their environment. To determine the crucial features and functionalities, this calls for a detailed analysis of the present and future needs, as well as strong cooperation with stakeholders and end users.
- **Maintenance cost:** not only developing but maintaining an in-house FMS can be costly to fleet operators since it requires continuous investment in new technologies, employees and equipment**.** This includes the price of bug fixes, software updates, and preserving data privacy and security, all of which can mount expensive over time and may need specialist knowledge.
- **Integration challenges:** a concern from fleet operators is that integrating vehicles to an FMS may be challenging. Similarly, integrating a new FMS with existing systems such as TOS in ports might represent a challenge since different OEMs use different standards, protocols, or interfaces, which can increase the cost of integration. Furthermore, it might not be evident from an OEM standpoint how much control fleet operators have over their vehicles, which might restrict the range of potential integrations.
- **Varying perceptions of what an FMS is and does**: integrations to vehicles are needed to get data, locations of the vehicles, maintenance, etc.; nevertheless, there are different points of views about what an FMS is and what it should do, the features that are needed, among other indicators. A lack of common definition for an FMS might be a disadvantage for fleet operators due to the misalignments in objectives and priorities when developing the system.

5.3.1.1.2. Logistics

Similarly, logistics operators can develop a fleet management system by themselves. This represents both advantages and disadvantages, which will be detailed in the following subsections.

The **advantages** identified during the workshop were:

- **Independent solution**: for a fleet operator in a logistic hub, creating their own FMS might be advantageous because it ends reliance on external providers. As a result, fleet operators can fully customize their FMS to match their unique needs and priorities.
- **Easy integration into overall system at the hub:** since the in-house FMS is developed following the specific needs of a particular fleet operator in a logistic centre/hub, it could be easily incorporated to other systems and interfaces, without encountering compatibility or security issues. Also, more flexibility and control over data management and sharing can be achieved; hence the in-house FMS is a good solution in situations where information sharing is sensitive.

By contrast, some **disadvantages** for fleet operators in logistics also arise:

- **High costs:** the cost for development of the fleet management system is high. As mentioned before, it can be the case that the integration of the FMS with existing systems can increase development costs, representing a challenge.
- **FMS development is not their core business**: since fleet operators are not experts in software development, specialists could achieve better software. It is possible that it lacks the knowledge and resources needed to be as successful and

robust as those offered by specialized third-party providers. Specialized FMS providers benefit from being able to concentrate entirely on FMS development and may make investments in the newest technology and best practices to provide high-quality software that satisfies their clients' demands and expectations. Furthermore, specialized suppliers might offer insights and recommendations that in-house development teams might not have access to due to their significant expertise and knowledge of the business.

- **Limited flexibility and adaptability**: in this approach, the logistics operation systems provider takes on the responsibility of connecting CAVs to their FMS. While this can streamline the integration process for the customer, it is crucial to note that it may limit the flexibility and adaptability of the FMS. Additionally, it could result in longer development timelines and increased integration costs (as mentioned previously) since each customer-CMV integration may require unique solutions.

5.3.1.2. Advantages and disadvantages for OEMs

A distinction for OEMs/vehicle provider was necessary, given that this subgroup could have another perspective as fleet operators in ports and logistic hubs.
After discussing with vehicle providers, **advantages** for developing their own FMS were highlighted:

- **Single solution:** having only one supplier contact for the vehicle and for the FMS, which represents an advantage for the vehicle provider because all the required data for the FMS comes from their own vehicles. Also, as vehicle providers can rely on a single point of contact for all of their needs, including hardware, software, maintenance, and support, this helps streamline the procurement and management process.
- **Integration of different services and functionalities:** services can be easily integrated, and further functionalities can be implemented such as forecasting, automatic purchase of replacement parts, precise location, information about loading places, etc. With access to all vehicle data, the provider may implement forecasting and automatic part purchases, ensuring that vehicles are maintained at the highest standards, cutting down on downtime, and increasing operational effectiveness.
- **Accurate and complete "digital twin" of the vehicles possible as we have access to all the data of the vehicle**: the provider may build a detailed digital model of the vehicle that includes all its features, performance information, and maintenance needs thanks to access to all the vehicle data. Fleet managers may be able to better comprehend their vehicles, monitor their performance, and maximize their use thanks to this tool.
- **Utilization of the vehicle can be precisely integrated in the FMS**: every basic and specific functionality of the vehicle is known allowing for a more efficient process and vehicle usage.

Conversely, a few disadvantages for vehicle providers were also discussed during the workshop:

- **Different vehicles need different modifications and currently lack common standards**: customized integration or standards need to be defined if the FMS needs to be integrated in further logistic systems, meaning that vehicle providers might be

specialists on their specific vehicle, but if there are other types of vehicles, they will need to modify their FMS.

5.3.1.3. Main players

Different fleet operators and vehicle manufacturers are developing their own FMS and offering it as part of their solution, which are identified as potential competitors for AWARD FMS. We have gathered information about the key players within this group and analysed if the offered FMS is capable of different features (i.e., vehicle agnostic, data integration, analytics), as well as indicating which target customer and market are mostly focused on. Daimler Trucks, PACCAR, Scania, Mack Trucks, and Navistar sell fleet management systems to its own customers, who are businesses that buy trucks and other vehicles from them. Zoox and Cruise do not provide fleet management services to outside clients and instead concentrate on creating autonomous vehicle technologies. Customers in a variety of industries, including ports, airports, and logistics firms, who employ their material handling equipment and autonomous cars, purchase the fleet management systems from Gaussin and STILL.
It is worth noting that Table 6 in Annex section 13.6 provides a non-exhaustive list, and there are other vehicle providers developing FMS by themselves; some develop CAVs without a driver (i.e., Zoox), while others are OEMs developing vehicles with autonomous functions, but the driver is still needed (i.e., Daimler trucks).

5.3.2. ADAS providers

Adaptive cruise control, collision alerts, and lane keeping assistance are just a few of the ways that advanced driver assistance systems (ADAS) can help a driver of a car. As fleet management systems for autonomous vehicles can be used to track and improve the performance of ADAS technologies, ADAS suppliers may also be involved in their development. In this sense, ADAS providers develop and provide autonomous technology that enables fleet management. In the following subsections, we are going to analyse the competitive landscape of fleet management systems from the point of view of an ADAS provider, starting from explaining the advantages and disadvantages of elaborating a fleet management by themselves, as well as highlighting the key players in the field.

5.3.2.1. Advantages and disadvantages for ADAS providers

During the workshop conducted, ADAS providers partners had the opportunity to discuss the advantages and disadvantages of an in-house fleet management system from the perspective of an ADAS company. Participants categorized the advantages and disadvantages according to the technical, economic, and strategic decisions.

5.3.2.1.1. Technical advantages and disadvantages

Given the nature of the solution, there are multiple technical advantages that an ADAS provider can be benefited from:

- **Mission assigned to a vehicle:** the ability to assign missions to vehicles depending on their availability and location is one of the most important features a fleet management system has to offer since it assist the fleet manager to know where the vehicles are moving and when it will be needed to, in other words, the FMS provides

position of all vehicles on site, resulting in streamlining processes and effective deployment of their vehicles.

- **Data:** having access to geographic information of the vehicle and other types of data is a big advantage for ADAS providers. In order to optimize vehicle routing, lower fuel consumption, and boost overall operational efficiency, this can incorporate real-time traffic information, weather information, and other pertinent information.
- **Independence of a third party:** in the event of a problem on-site, developing an FMS internally by an ADAS provider can also avoid the need for external parties. With total command over the FMS, the provider can swiftly locate and address problems, cutting downtime and enhancing overall operational effectiveness.
- **Interoperability**: integration with other systems is an advantage for ADAS providers**.** For a complete picture of the fleet and simple system communication, this may involve integration with various software platforms, gadgets, and sensors.

As there are advantages, there are also technical **disadvantages** from the point of view of an ADAS provider**:**

- **Difficulty in managing other vehicles from other providers:** the interoperability feature can also be seen as a disadvantage. The FMS requires several resources to build and operate since managing various vehicle types and integrating data from many sources can be difficult and time-consuming.
- **Managing and sorting information in large sites (i.e., ports):** the amount of data of big sites like ports or airports can be challenging for the development of an FMS. It can be difficult to manage and integrate all the pertinent data into the FMS when several vehicles are operating in a complicated and dynamic environment, which makes it tough for fleet operators to make decisions regarding their operations.
- **Complexity:** developing a fleet management system in-house can be a complex, drawn-out process needing resources and knowledge. It is possible that ADAS suppliers lack the resources or the requisite fleet management knowledge to create and maintain an extensive FMS. In order to make the FMS dependable and functional, it can be difficult to integrate many technologies and systems. As a result, creating an FMS internally can be a challenging task that requires considerable resources and skills to be effective.

5.3.2.1.2. Economic advantages and disadvantages

Economic benefits and challenges can also arise from developing a fleet management system internally for an ADAS provider company.

Among the economic advantages, we can encounter:

- **Possibility of obtaining the complete revenue associated to the function:** one benefit of having an ADAS provider create a fleet management system (FMS) is that they can continue to have complete control over the system and the money it makes. This enables the provider to create and modify the FMS to their precise standards, guaranteeing that it satisfies their clients' demands while also producing cash for the business. Additionally, having total control over the FMS can assist ADAS providers in better understanding and streamlining their business processes, enhancing their productivity and profitability.
- **Commercially exploitable outside the normal AVs FMS:** the ability for an ADAS supplier to financially exploit an FMS outside of the typical autonomous vehicle (AV)

industry is another benefit of doing so. ADAS suppliers can broaden their clients based outside the AV sector by creating an FMS that is compatible with a variety of different vehicles and applications, creating new income streams and raising overall profitability. Additionally, by being able to give their clients a more adaptable and complete solution, ADAS providers can keep one step ahead of their rivals by creating an FMS that is broadly applicable.

Of course, developing a new software outside the normal business of an ADAS provider can also have economic **disadvantages:**

- **Customers have specific requirements:** one drawback of having an ADAS provider create a fleet management system (FMS) is that customers could have certain requirements that call for customized development, interfaces, and languages. As a result, the ADAS supplier may need to allocate extra funds to accommodate each client's particular needs. In order to guarantee that they completely comprehend their customers' needs and can supply a solution that is specially tailored to satisfy those needs, ADAS providers may also need to build a staff that is physically close to their clients.
- **High investment:** the high expense of creating and maintaining the system is another drawback for an ADAS provider. An FMS might represent a high cost to maintain over the long run, and its development can demand a major time and resource commitment. In order to create and support the FMS, ADAS providers may also need to invest in specialist employees, tools, and software. Despite the potential advantages of creating an FMS, many ADAS suppliers may find it difficult to enter the market due to the high cost and continuing maintenance requirements.

5.3.2.1.3. Strategic advantages and disadvantages

Strategic decisions play an important role when deciding on investment and development of a fleet management system. Partners have stated some advantages and disadvantages from the strategic point of view of an ADAS provider.
Some of the **advantages** are:

- **Resiliency to the failure of external parties:** by not being dependent on an external provider, the risk of failure by another party is eliminated. An ADAS provider developing its own FMS has control over the development and maintenance of the system; hence, it is aware of the weaknesses of its system and in case of an issue can address the problem without having to wait for external support.
- **Data ownership:** having control over the data generated by the system is an advantage for ADAS providers but also for any other group, as mentioned during the workshop. Data is becoming increasingly useful in the transportation sector since owning the data enables the ADAS provider to use it to enhance the FMS, create new features, and provide consumers with better services.
- **Customizable solution:** an advantage of developing its own FMS can be that it is easily customized and can quickly create functions according to the customer request. This can create a competitive advantage for ADAS provider among other competitors offering transport solutions.

On the other hand, strategic **disadvantages** can be analysed as well:

- **Lack of expertise or resources to develop an FMS:** one drawback is that the ADAS provider can lack the knowledge or resources needed to create an extensive FMS. The staff of the ADAS supplier might not have the specialized expertise and

skill set needed to develop an FMS. This might result in a system that takes longer to develop, is of lesser quality, and costs more money.

- **High costs and time-consuming:** it can be expensive and time-consuming to develop an FMS internally, diverting resources from the ADAS provider's core skills. Their major business areas may suffer from a loss of concentration and competitiveness as a result. The ADAS supplier may also miss out on prospective collaborations with already-existing FMS providers by investing in the creation of their own FMS, hence reducing their market penetration and possibility for revenue development.
- **Missed partnership opportunities:** as an ADAS provider, one strategic drawback of building a fleet management system in-house is the potential for lost collaboration opportunities. The ADAS provider may pass up chances to collaborate with established FMS providers or other businesses in the transportation sector by concentrating on creating their own FMS. These collaborations may result in more market share, new commercial prospects, and access to cutting-edge knowledge or technology. Additionally, by merging their ADAS technology with an established and tested FMS, ADAS providers may be able to give their clients a more complete solution with the assistance of FMS providers. However, if the ADAS provider chooses to build their FMS in-house, they might not have the resources or know-how to do so, or they might not give them the priority they need in favour of their own development initiatives. This can restrict their ability to expand and put them at a disadvantage to rivals that have built partnerships within the sector.

5.3.2.2. Main players

ADAS providers represent an important group in this analysis; therefore, we have gathered some key ADAS companies that are currently developing their own fleet management system as part of AWARD FMS competitive landscape. Some of the companies mentioned, including Robert Bosch GmbH, Continental AG, and ZF Friedrichshafen, sell fleet management solutions to clients in a variety of industries, including logistics and transportation.
Other companies, including WABCO, Siemens, and EasyMile, concentrate primarily on fleet management for commercial vehicles and offer their systems to clients and partners in the transportation sector.

Table 7 in Annex section 13.6 provides a non-exhaustive list of important ADAS providers.

5.3.3. FMS software companies

Companies that build fleet management system (FMS) software are experts at creating software solutions, including those for autonomous vehicles. These companies could provide a variety of services, such as driver performance evaluation, maintenance management, and vehicle tracking. Additionally, they might incorporate ADAS systems and other technology into their software solutions. They create and offer the tools and services that fleet managers need to manage their fleet.

5.3.3.1. Advantages and disadvantages for FMS software companies

We took advantage of the workshop to address which advantages and disadvantages are available for FMS companies. Since developing fleet management systems is the core

business of this group, we have identified the benefits and challenges of an in-house FMS not only from the software provider perspective but also from the customer perspective.

5.3.3.1.1. Advantages and disadvantages from software provider perspective

In the context of connecting Connected and Autonomous Vehicles (CAVs) to fleet management systems (FMS), it is essential to acknowledge the complexity that arises due to the lack of standard interfaces provided by CAV vendors. This challenge presents an opportunity to explore viable solutions that can bridge this gap and ensure seamless integration, a role played mainly by software providers. We can explore the development of a specialized integration solution designed to act as a versatile FMS for various types of CAVs. This integration solution should be agnostic to both the autonomous driving systems (ADS) and the vehicle providers. By adopting this approach, we can achieve several key advantages:

- **Agnostic solution:** a fleet management system that is agnostic to ADS and the vehicle provider is a main advantage and provides a competitive advantage for the fleet management system company. This indicates that regardless of the technology or producer, their solution may be used with any class of autonomous vehicle. This is a key benefit since it makes the fleet management system more flexible and responsive to shifting market dynamics and technological trends. Additionally, it enables fleet managers to streamline operations and cut expenses by using a single fleet management system for a variety of autonomous vehicle types.
- **Flexible integration of different environmental sensors (i.e., weather, traffic, UVAR, availability of parking slots…) and data sources:** the ability to incorporate various environmental sensors and data sources into a fleet management system is another benefit of having the system developed by a fleet management system software business. It follows that the system can be modified to fulfil the unique requirements of the fleet operator, such as taking traffic or weather conditions into account. Additionally, the integration of various data sources enables more thorough and accurate data analysis, which can enhance fleet management and operational efficiency.
- **Independence of optimization algorithms:** the flexibility to adapt optimization and to configure optimization criteria is an important advantage for fleet management system companies. As a result, they are able to create and modify their own algorithms to match the unique requirements of the fleet operator. The operator will have more control over their fleet management system thanks to their ability to create additional optimization criteria as needed. Due to the system's ability to be customized to the specific requirements of the operator, flexibility can result in improved performance and efficiency.
- **Integration with teleoperation providers** (i.e., Ottopia, Fernride, Outriders, etc.): as fleet management systems, the teleoperation feature is a significant advantage for their business. This enables the autonomous vehicles to be operated remotely, which may be advantageous in some circumstances, such as when the vehicle runs into an unanticipated obstacle or must navigate a particularly difficult environment. The fleet management system gains an additional layer of security and dependability with the integration of teleoperation providers, which can boost user confidence and enhance operational efficiency.

Similarly, there are **disadvantages** for the fleet management system company that need to be addressed:

- **Deep integration might be challenging:** the flexibility of the agnostic solution in working with various vehicle and ADS types may be advantageous, but it may also make the process of integrating them into the FMS more difficult. Longer development delays and greater integration costs may result from this, which may be detrimental to both the fleet operator and the FMS supplier. Moreover, the capacity to thoroughly connect with vehicle types or ADS providers may be constrained by the agnostic approach, which can make it simpler to interact with many vehicles and ADS. The FMS's capacity to optimize fleet operations may be constrained as a result of limited access to some features or data.
- **Integration costs:** costs linked to integration features might also be a drawback for a software provider of fleet management systems. Although an agnostic solution can make it simpler to interface with many vehicle types and ADS providers, it might also take more time and money to design and maintain. Both the fleet operator and the FMS supplier may incur increased costs as a result. Additionally, the price of integration could be higher than the costs of integrated systems, which might disadvantage the FMS supplier in the market.

5.3.3.1.2. Advantages and disadvantages from customer perspective

Customers of fleet management systems may see advantages and disadvantages of buying the FMS directly from the software company developing it. The workshop conducted helped to grasp these insights.

Among the **advantages** from the FMS customer perspective, we can highlight:

- **Single FMS for all vehicles:** if the FMS is vehicle agnostic, a key advantage for the customer is not having multiple systems in parallel, but to have a single solution for all types of vehicles, which can reduce costs, improve operations and efficiency.
- **Independence between ADS solution and vehicle:** the independence of the solution provider from ADS and vehicle providers is another benefit of having a fleet management system software firm create an FMS. This means that any form of autonomous driving system (ADS) or vehicle may be created to integrate with the FMS, giving fleet operators more flexibility and options. Additionally, without having to worry about compatibility issues, fleet managers can select the finest ADS and vehicle providers for their unique needs.
- **Fleet optimization:** FMS software offers automated dispatching, route optimization, and fuel savings capabilities that can help a fleet run more efficiently. FMS software can assist in cutting expenses, boost efficiency, and enhance overall fleet performance by automating these processes. For instance, FMS software may automatically allocate cars to tasks based on their location, availability, and job specifications, maximizing fleet utilization and minimizing downtime.
- **Flexible configuration of dispatching:** additionally, FMS software can be set up to handle diverse dispatching circumstances, such as varying road conditions or traffic congestion. FMS software can modify dispatching and route optimization in response to predicted delays or impediments by analysing real-time data and making predictions about them. With this flexibility, fleet operators can react swiftly to shifting circumstances and guarantee that their fleet is operating as efficiently as possible.

Contrary, the **disadvantages** from the customer perspective are:

- **Customers might prefer standard system providers:** some customers might favour their “standard” system supplier over a fleet management system software provider, which might lead to less sales for the latter. Some businesses could already have a working arrangement with a standard system provider, and they might be unwilling to change. Concerns about compatibility and integration between the current system and a new FMS solution may also exist. For instance, fleet operators might have agreements with OEMs that have their own FMS which can make it difficult for them to change to a separate solution.
- **Discounts and bundles offered from AVs companies with their own FMS:** customers can be eligible for savings if they buy both AVs and FMS from the same vendor. There will probably be increased competition among businesses as the market for AVs and FMS expands. Some businesses might provide bundled packages that include both AVs and FMS at a discounted price to entice clients to buy their products. Companies that develop fleet management system software may find it challenging to compete if they simply provide FMS and no AVs. Additionally, companies can be more inclined to select a packaged product to streamline their management and procurement procedures.
- **Deep integration might be challenging and costly due to agnostic solutions:** same as with software companies, for customers, integration to different vehicles and ADS can be both an advantage and disadvantage. Although an agnostic solution can make it simpler to interface with many vehicle types and ADS providers, it might also take more time and money to design and maintain.

5.3.3.2. Main players

As the demand for fleet management solutions continues to increase, competition in the market has intensified. For a company that provides fleet management software, analysing the competition is critical to staying ahead of the curve and ensuring that its product offering remains relevant and competitive. In Table 8 in Annex section 13.6, we examine some key players in the fleet management software market.

5.3.4. AWARD FMS

After understanding the competitive landscape for fleet management systems, we can continue to assess how AWARD fleet management system (FMS) stands out in the market.

The AWARD FMS distinguishes itself from other fleet management solutions with several essential value-added features and advantages. The numerous features that make AWARD FMS a useful tool for businesses looking to optimize their fleet operations will be covered in this analysis.

Firstly, AWARD FMS stands out for its capacity to gather data from a variety of sources, enabling thorough **data integration**. This involves learning about the state of the roads and using historical vehicle information, including CO2 reductions. By utilizing various data sources, AWARD FMS offers insightful information that can help with decision-making and fleet performance optimization.

The **vehicle agnostic capability** of AWARD FMS is another important benefit. AWARD FMS may be connected to any kind of vehicle, whether it is a manual or autonomous vehicle, unlike some other fleet management systems that are restricted to a few different kinds of vehicles. With this versatility, companies and operators with various fleets can visualize and control every vehicle in one system, reducing processes and increasing productivity. This sets apart AWARD FMS from rival systems that need identical software, regardless of vehicle variances, for all vehicles.

Another important value added of AWARD FMS is its great degree of **adaptability.** The system can be customized to match the particular needs of different clients, ensuring that it complies with their particular specifications. Customers may precisely tailor their fleet management procedures in accordance with their operational objectives and preferences thanks to this level of customization.

AWARD FMS offers **cutting-edge capabilities** that bring value in addition to the conventional fleet management operations. One feature of the system is **driver behaviour monitoring**, which enables fleet operators to track and evaluate driver performance and ultimately encourage safer and more effective driving habits. However, it is important to acknowledge that certain operators may encounter resistance from drivers who are reluctant to undergo such monitoring. Another noteworthy aspect is **route optimization,** which permits route optimization, lowers fuel consumption, and boosts total fleet effectiveness. With the help of **real-time data analysis tools**, decision-makers can make informed decisions and move quickly as operating conditions change.

Another area where AWARD FMS brings value is in **regulatory compliance**. The technology takes into account changing regulations and offers continuous or real-time updates on speed restrictions and regulatory modifications. By ensuring that customers continue to follow the most recent rules, this feature improves compliance and lowers the chance of infractions. The intention to adhere to regulations is further strengthened by the upcoming installation of pop-up speed limit alarms.

Additionally, AWARD FMS broadens its value proposition to include **mobility and logistics solutions** in addition to fleet management. AWARD FMS maintains a transversal strategy, addressing all use cases connected to logistics, while other competitors may concentrate only on mobility initiatives, such as micro-transit and passenger transportation. This expanded reach makes it possible to automate repetitive logistics tasks, which boosts productivity and lowers costs for businesses.

The target market of AWARD FMS initiates in Norway and the Nordics, notably Denmark and Finland. Then, the rest of Europe, the United States and the Middle East are also targeted. This tactical move capitalizes on a market where rivals are now more interested in providing consulting services than a comprehensive platform like AWARD FMS. Although AWARD FMS does offer certain consulting services, its main focus is on commercializing the platform in order to establish itself as a market leader.

The customers that AWARD FMS targets include Original Equipment Manufacturers (OEMs) and industry operators like ports, airports, and logistic centres. The system’s capacity to

integrate with a variety of vehicle types, regardless of the vehicle supplier or OEM, is a significant value proposition for clients. Because of its adaptability, AWARD FMS can be implemented across a client's entire fleet, independent of the source or kind of vehicle. This is especially helpful for ports, airports, and logistic centres which frequently use a variety of vehicles from various manufacturers, including autonomous and manual models.

In conclusion, the data integration capabilities, vehicle agnostic feature, customization choices, and extensive characteristics of AWARD Fleet Management System (FMS) offer great value. It distinguishes itself from other fleet management systems by providing cutting-edge features like route optimization and driver behaviour monitoring. The system targets a wide range of clients, including OEMs and industry sectors like ports and airports, and assures regulatory compliance. Therefore, AWARD FMS is a flexible and scalable solution that improves operational effectiveness and streamlines fleet management procedures.

5.4. Porter's five forces

This section provides an overview of Michael Porter's Five Forces framework[24] as a foundation for conducting a strategic analysis specific to the AWARD project. To familiarize readers with Porter's ideas, we have included the original text published in the Harvard Business Review in 1979 in Annex 1. The following figure presents a Porter's five forces analysis tailored to the AWARD fleet management systems, taking into account the market dynamics shaped by the AWARD approach. Figure 12 summarizes Porter's five forces for AWARD FMS service:

[24] Porter, Michael E. "Competitive strategy: techniques for analyzing industries and competitors: with a new introduction.", 1998.

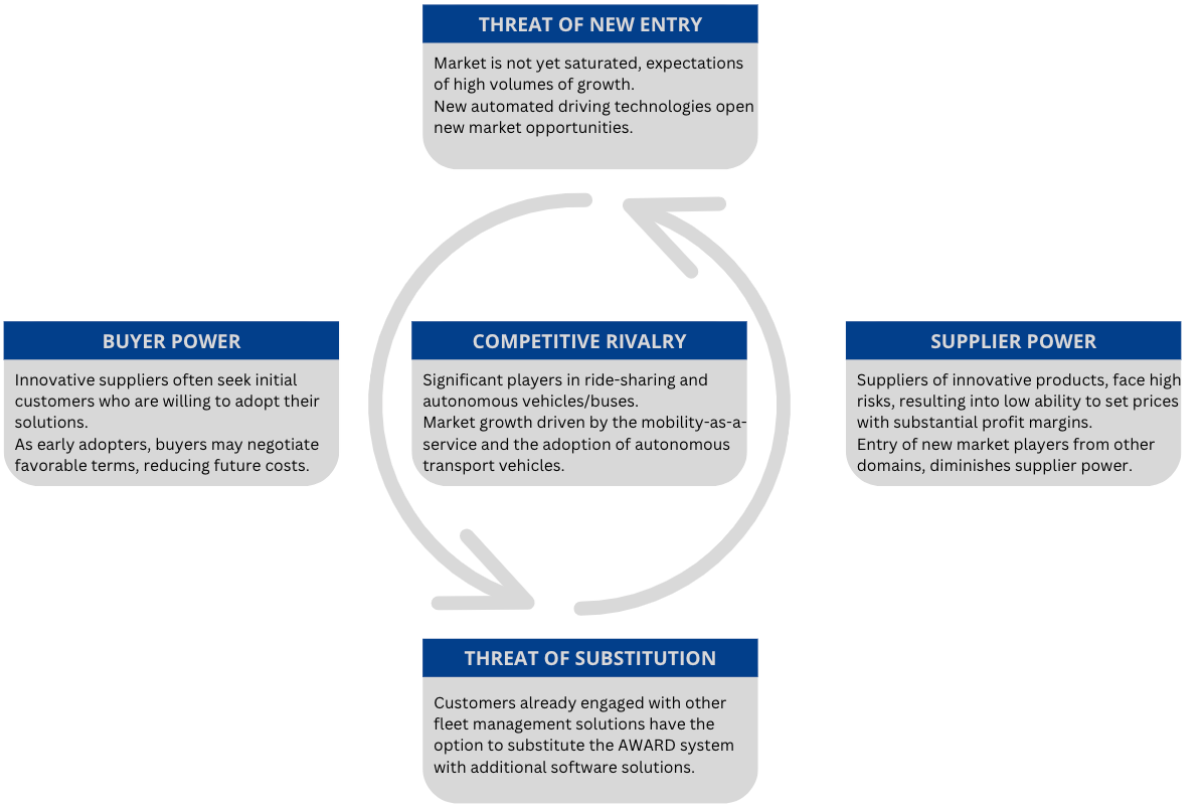

Figure 12 Porter's Five Forces for AWARD FMS service

- **Threat of New Entry:**

The market for fleet management systems exhibits a high threat of new entrants due to several factors. Firstly, the market is not yet saturated, and there are expected to be high volumes of growth in the near future. Moreover, advancements in automated driving technologies have opened new market opportunities, attracting potential new players to enter the industry. These factors contribute to the overall high threat of new entry.

- **Competitive Rivalry:**

In the fleet management sector, competitive rivalry is currently high and characterized by various research and development (R&D) projects. Different OEMs, ADS providers and FMS software companies are currently developing their own FMS. For instance, significant players in ridesharing and the management of autonomous vehicles/buses, such as Lyft, Uber, Ola, DiDi, and Lilee, are expected to leverage autonomous fleet management in the near future. Moreover, the presence of other systems such as Terminal Operating Systems (TOS) for industrial environments also increases competition. Consequently, the market growth will be driven by the implementation of mobility-as-a-service and the increasing adoption of autonomous transport vehicles. This intensifying competitive landscape underscores the importance of analysing competitive forces within the industry.

- **Buyer Power:**

Buyer power in the fleet management systems market can be considered moderate. Innovative suppliers often seek initial customers who are willing to adopt their solutions, even if they are not yet market ready. This situation provides buyers with some leverage to influence supplier

price settings. By being early adopters, buyers may negotiate favourable terms, potentially reducing future costs. Therefore, buyers have a certain degree of influence over suppliers, leading to medium buyer power.

- **Threat of Substitution:**

The AWARD system faces a high threat of substitution in the market due to existing customer relationships and the possibility of incorporating autonomous fleet management as an add-on to existing fleet management service packages/products. Customers already engaged with other fleet management solutions have the option to substitute the AWARD system with additional software solutions offered by competitors. Furthermore, existing use of TOS systems increases the threat of substitution for fleet management systems. This high threat of substitution highlights the need for AWARD to differentiate itself and provide unique value to retain its market position.

- **Supplier Power:**

Suppliers of innovative products, even those not yet ready for the market, face high risks. As a result, their ability to set prices with substantial profit margins is low. Suppliers must demonstrate successful implementations and secure early adopters among friendly and paying customers for their new systems. Moreover, the entry of new market players from other domains, such as managing autonomous vehicles, further diminishes supplier power. Overall, suppliers in the fleet management systems market have limited influence over pricing, resulting in low supplier power to increase market prices.

Based on the AWARD-specific five forces analysis, the following business strategy implications/recommendations are developed, for technology-agnostic FMS and technology-specific FMS.

For technology-agnostic FMS service providers for autonomous vehicles that offer various services like teleoperation, the following strategies are recommended:

- Cooperate with autonomous original equipment manufacturers (OEMs) or ADS (Autonomous Driving System) providers (e.g., TuSimple, EasyMile) to piggyback your solution onto the OEM/ADS provider’s offering. This collaboration allows you to integrate your FMS service into their solution, leveraging their established customer base and distribution channels.
- Alternatively, partner with existing FMS providers to sell your product as an add-on to their already implemented fleet management software solution. By aligning with established FMS providers, you can tap into their customer network and benefit from their industry expertise.
- Deploy demonstrators in real-world contexts, particularly within innovative buyer environments such as R&D projects. This approach allows you to showcase your technology’s capabilities and build credibility with potential customers. Collaborating with forward-thinking buyers in R&D projects can lead to valuable insights and early adoption opportunities.

For technology-specific FMS service providers for autonomous vehicles offering specialized services like teleoperation, the following strategies are recommended:

- Establish a strategic deployment cooperation with an innovative OEM/ADS provider. By joining forces, both partners can leverage their respective capacities and resources. This collaboration allows each partner to focus on their specific know-how, fostering specialization and enhancing the overall solution. Additionally, research resources can be pooled, enabling more comprehensive development and deployment capabilities.
- Similar to technology-agnostic FMS providers, deploying demonstrators in real-world contexts, particularly within innovative buyer environments like R&D projects, is crucial. Demonstrating the effectiveness and value of your technology in practical applications helps build trust and generates interest among potential customers. Collaborating with innovative buyers allows you to validate your solution's performance and adapt it to meet specific industry needs.

In conclusion, for both technology-agnostic and technology-specific FMS service providers, strategic partnerships, demonstrator deployments, and collaboration with innovative buyers are key recommendations. By leveraging existing industry players, aligning with OEMs or ADS providers, and showcasing their offerings in real-world contexts, these providers can position themselves for success in the competitive fleet management systems market for autonomous vehicles.

6. Market trends

The current and upcoming dynamics in the fields of autonomous driving, fleet management, and logistics are insightfully explored in this section. We explore the trends that have the potential to influence how industrial processes and transportation are conducted in the future by utilizing the Trendmanager tool's illuminating features. A nuanced study that uncovers the links and future trajectories has been made possible by the Trendmanager tool's systematic identification and tracking of trends pertinent to various domains, which will be explained in the upcoming subsections. Also, this trend analysis is complemented with secondary data from desktop research.

6.1. Trend radar analysis

Based on the Trendmanager tool[25] a trend analysis was performed for fleet management and heavy-duty vehicles. The online tool Trendmanager helps companies to identify and systematically monitor the trends that are relevant for them. An interactive trend radar shows the most important trends in relation to each other.

The following selection on trends is focused on "autonomous driving", "fleet management" and "logistics" topics and was done by the project partner University of Applied Sciences Upper Austria, with some modifications by ENIDE.

For extensive set of market trends, please refer to section "*4.2.1. Market trends*" and "*5.2.1 Market trends*" in the document "*D8.1 Market opportunities, barriers and solutions*."

1) **Autonomous Drive Systems:**

Autonomous vehicles on land, water and in the air will fundamentally change our understanding of mobility. With sensors such as radar, lidar and camera systems, they scan their surroundings more accurately than humans can. Automated or autonomous driving will fundamentally change the vehicle sector.

In the next few years, autonomous vehicles will fundamentally turn our understanding of mobility upside down. With their numerous radars, lidar and camera systems, modern cars already scan their surroundings far more accurately than human drivers can. Moreover, traffic will also change, when vehicles can communicate with one another, and artificial intelligence manages the flow of traffic. Systems that facilitate accident-free and legally safe driving already exist. Algorithms continuously calculate possible routes in transit with the aim of finding a route that is guaranteed not to cause damage.

However, for technology to make a breakthrough, it requires acceptance by society. Many people do not like relinquishing control. Plus, other drivers have to be convinced that the artificial intelligence will decide according to their moral code if, for example, an accident cannot be avoided. This code varies from region to region.

[25] Trendmanager Innovationssoftware. (n.d.). Trendmanager Innovationssoftware. https://www.trendmanager.com

2) Decentralized Computing:

Decentralized computing is gaining importance due to its distributed, dynamic, and complex infrastructure, contrasting with centralized processes. Companies are increasingly adopting decentralized cloud computing, where data storage, software applications, and services are hosted on the network instead of local computers. This shift allows organizations to flexibly adapt their processes to meet demand by leveraging cost-effective IT structures in the cloud.

Fog computing is gaining significance as network devices positioned between the cloud and end devices analyse data from various sources. Meanwhile, edge computing empowers end devices like sensors and machines with direct computer power.

3) Intelligent Infrastructure:

Extensive technological measures are needed to overcome the challenges facing infrastructure, for example, mobility and energy supply. Advanced network technology is essential for a functioning City OS operating a smart city.

Advanced network tech is required for a functioning smart infrastructure. It includes technologies such as 5G, NFC and laser, but also energy transmission. Smart cities make use of information and communications technologies along with sensor networks to control the flow of goods, people and traffic as well as energy consumption and infrastructure utilization.

Cooperative systems, which emphasize a collaborative approach to strategy development and evaluation. On-board driver assistance systems enable two-way communication between vehicles and road infrastructure, improving safety and traffic efficiency. Vehicles can also act as sensors to provide real-time information on weather and road conditions, enhancing information services.

4) Logistics 4.0:

Logistics involves the planning, control, and execution of the flows of goods, information, and people. In industries like automotive and space, logisticians are increasingly responsible for outsourced production stages and ensuring just-in-time and just-in-sequence delivery to the production line. **Hyperconnected Logistics Systems** is an important topic for this trend, that focuses on the integration of digital supply chains, traffic telematics (ITS), and automated driving to enhance logistics technology systems.

The advancement of robotics and automation, driven by digitalization and **Industry 4.0**, highlighting the digitalization of industrial production to make it future-ready through the integration of modern information and communication technology with industrial processes, enabling self-organized production and optimizing the entire value chain. Industry 4.0 has led to the emergence of warehouse robots that streamline the control and handling of goods throughout the supply chain. Standardized load units and smart containers equipped with real-time location visibility are enabling efficient material transportation and management in manufacturing environments.

5) Sustainability:

It is discussed as a significant factor in global debates across various sectors such as the economy, power generation, production, agriculture, and consumer goods. Consumers are increasingly prioritizing sustainability and making ethical choices when selecting products and retailers. The **Circular economy** is gaining traction as a solution for reusing objects and minimizing waste. Industries are also focusing on ecologically safe production processes, emphasizing resource conservation and emissions reduction. Additionally, energy harvesting, decentralized vertical farming, and smart agriculture are contributing to sustainable practices in the food industry. Additionally, **Jobs 4.0**, explores the implications of autonomous driving, digitalization, giga liners, and the future of truck drivers in the logistics industry.

6.2. Related work analysis

The trends revealed by the trend manager tool given in previous subsection are also reflected in existing market analyses related to forecasts of the fleet management market. This subsection serves as a complement to previous trend analysis focusing on fleet management due to its specificities, selected results from two market analyses are summarized.

Fortune Business Insights[26] states that "*The global fleet management software market is projected to grow from $20.73 billion in 2022 to $67.38 billion by 2029, at a CAGR of 18.3% during the forecast period.*" Moreover, Fortune Business Insights identifies the implementation of advanced connecting technologies with fleet management as a driving factor. Vehicle-to-infrastructure connectivity, driver-vehicle communications and the adoption of technologies, such as artificial intelligence, cloud computing, big data analytics enable advance solutions to get real-time insights into fleets and vehicles, e.g.,

- Vehicle / driver behaviour analyses
- AI to understand safety risks
- Optimize, track, analyse fleet operations based on real-time data

Aside to the adoption of new technologies fleet management system providers are entering into strategic partnerships, mergers and acquisitions with different car manufacturers to offer advanced fleet management solutions, for example, in January 2022 LILEE Systems, a provider of autonomous driving systems and transportation safety solutions, launched an advanced fleet management software and autonomous vehicle at CES 2022 in the U.S.

Transparency Market Research[27] also analysed the autonomous vehicle management service market. They identified the rise in use of ADAS (Advanced Drive Assistance Systems) technologies in vehicles as a driver for the global autonomous vehicle management services market. Transparency Market Research identifies three key drivers, i.e., trends in real-time monitoring, autonomous vehicle management services, AI to reduce human errors and enhance efficiency. However, as a restraint for autonomous vehicle management services they state that the high costs to equip a vehicle with an automated driving system (compared to

[26] Fleet Management Software Market Size, Growth | Report [2029]. (n.d.). Fleet Management Software Market Size, Growth | Report [2029]. https://www.fortunebusinessinsights.com/industry-reports/fleet-management-software-market-100893

[27] Autonomous Vehicle Management Services Market. (n.d.). Autonomous Vehicle Management Services Market Insights by 2030. https://www.transparencymarketresearch.com/autonomous-vehicle-management-services-market.html

traditional vehicle) are expected to hinder the autonomous vehicle management services market.

7. Market Size

In the following section, we will analyse and present the market size and forecasts for the fleet management for autonomous vehicles and autonomous heavy-duty vehicles in ports, airports, and warehouses. The analysis is a top-down approach: we will start with an estimation of the global connected car market and then specifically the market size of fleet management for the global market and European markets. Then, we narrow it to Total Addressable Market (TAM), Serviceable Addressable Market (SAM) and Serviceable Obtainable Market (SOM), where we draw our focus to autonomous vehicles and some specific insights for autonomous heavy-duty vehicles in logistics and fleet management for each AWARD use case.

Only limited publications exist to date on the economic developments of vehicle automation technologies and their impact on the different segments of the logistics industry. To perform a first market sizing exercise, the main source considered to assess the projected market value, being at global or regional levels, is adapted from a market study ordered by the UK Centre for Connected and Autonomous Vehicles. This market forecast was produced recently, taking into account the latest trends observed, such as the relatively slower rollout of connected and automated vehicles than anticipated a few years ago. Additionally, the hypothesis taken to build up this market forecast is aligned with the projected evolution of the segmentation of the market by level of vehicle autonomy presented in section 4.1 and 5.1.

7.1.1. Global

The global connected car market is expected to increase at an 18.1% CAGR from $59.70 billion in 2021 to $191.83 billion in 2028 over the forecast period of 2021-2028[28], with rapid technology development and moderate global CAV adoption rates. Global sales are expected to be around €196.97 billion in 2030[29]. However, these numbers are subject to uncertainties, such as varying uptake rates and technology costs. The estimates provided here are conservative compared to other analyses, which suggest that the global market for autonomous vehicles (AVs) is projected to reach approximately 1,808.44 billion by 2030[30], with rapid technology development and moderate global CAV adoption rates. The slower adoption of Level 3 and Level 4 CAVs in certain regions, particularly in Asia-Pacific, contributes to this more conservative view. Commercial freight vehicles, including vans and heavy goods vehicles (HGVs), are expected to have a limited share of the total CAV market in 2035. Vans are projected to account for approximately 20% of all CAVs sold, while the share of HGVs is

[28] Connected Car Market Size, Trends, Report | Key Players [2028]. (2021, August). Connected Car Market Size, Trends, Report | Key Players [2028]. Retrieved May 24, 2023, from https://www.fortunebusinessinsights.com/industry-reports/connected-car-market-101606

[29] Autonomous Car Market Size, Industry Share | Forecast 2030. (2022, August). Autonomous Car Market Size, Industry Share | Forecast 2030. https://www.strategicmarketresearch.com/market-report/autonomous-car-market

[30] Autonomous Vehicle Market Size to Hit USD 1,808.44 BN by 2030. (2023, March). Autonomous Vehicle Market Size to Hit USD 1,808.44 BN by 2030. Retrieved May 24, 2023, from https://www.precedenceresearch.com/autonomous-vehicle-market

expected to be around 3.1%. Please refer to the graph in the Annex section for the projected market value and regional sales segmentation.

Regarding fleet management, several reports with a base year of 2021 have been used to derive the following results. According to these researchers, the fleet management market size in 2022 was found to be at 24.95 USD Billion and in less than 10 years, the market size is estimated to more than double. As a result, we anticipate significant growth in the market.[31] This expansion is strengthened by the current situation marked by driver shortages and high fuel prices, which can further increase the global market potential for fleet management services. These solutions would, for example, facilitate cost-efficient transport by optimizing the fuel and route choice.

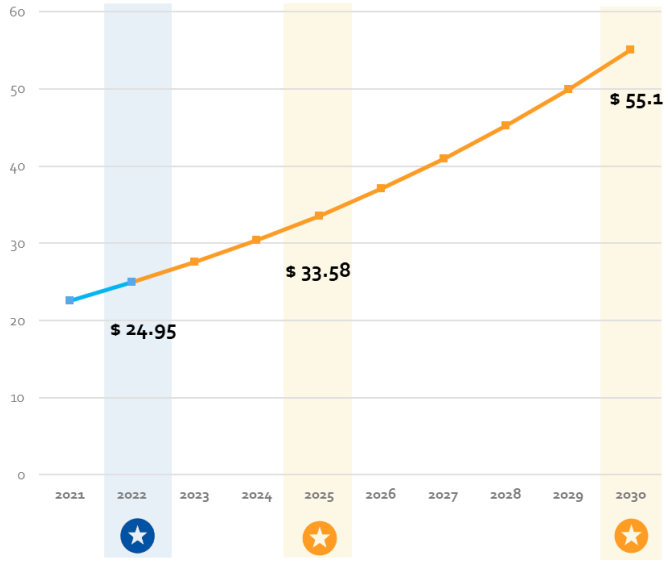

Figure 13 Forecasting fleet management market size

Regarding the market share by fleet type, the market could be divided into commercial fleets and passenger cars and was evaluated in 2020 respectively, at around 14 USD Billion and at 5 USD Billion. The largest market share, held by commercial fleets, reached almost 75%.
The market by vehicle types could be segmented into five vehicle types: light duty vehicles, heavy duty vehicles, aircraft, railway, and waterborne vessels. Based on several reports, the prominent vehicle types in fleet management in 2020 were aircraft, railway, and watercraft, followed closely by the light duty vehicles. In 2030, the forecasted market remains the same as in 2020, with aircraft vehicles standing out.[32] The forecast on the market for heavy commercial vehicles is not as strong as the other vehicle types, but it is expected to have significant growth in the next years.

[31] Fleet Management Market Size, Share, Growth, Report 2022-2030. (n.d.). Fleet Management Market Size, Share, Growth, Report 2022-2030. https://www.precedenceresearch.com/fleet-management-market

[32] Fleet Management Market Size, Growth, Leader, Trends, Report. (n.d.). Allied Market Research. https://www.alliedmarketresearch.com/fleet-management-market

7.1.2. Europe

Europe is poised to be at the forefront of CAV adoption, with a market uptake rate surpassing the global average. It is estimated that the European CAV market, including the UK, could account for up to 58% of the global market by 2035. This strong position can be attributed to the presence of prominent vehicle manufacturers, premium offerings, component suppliers, and an early emergence of testing and regulatory frameworks. However, it is important to note that the market size considered in this analysis is relatively limited compared to the global market, as it focuses on connected and autonomous heavy-duty vehicles in real logistics operations. The rapid evolution of the market readiness, particularly in terms of regulations and the ability to conduct large-scale tests, could potentially alter the current expectation of Europe leading the AV market.

Focusing on fleet management, our interest will be in the market shares by region. According to our research, the top 3 in market share in 2021 by region were North America, Europe and East Asia. North America held the highest share in 2021, which could be explained by the strong presence of service providers. Then, the largest shares are followed by Europe and East Asia.

In 2031, the top 2 should remain the same, but Europe is expected to have the largest share, up to 34%, followed by North America.[33] The popularity of cloud-based solutions could be one of the drivers of the rising growth of fleet management solutions and services. The adoption in recent years by small and medium-sized companies (SMEs) in European nations were seen for example in France, Germany, and the United Kingdom. South Asia and Pacific is projected to hold the third-largest share and takes the place of East Asia.

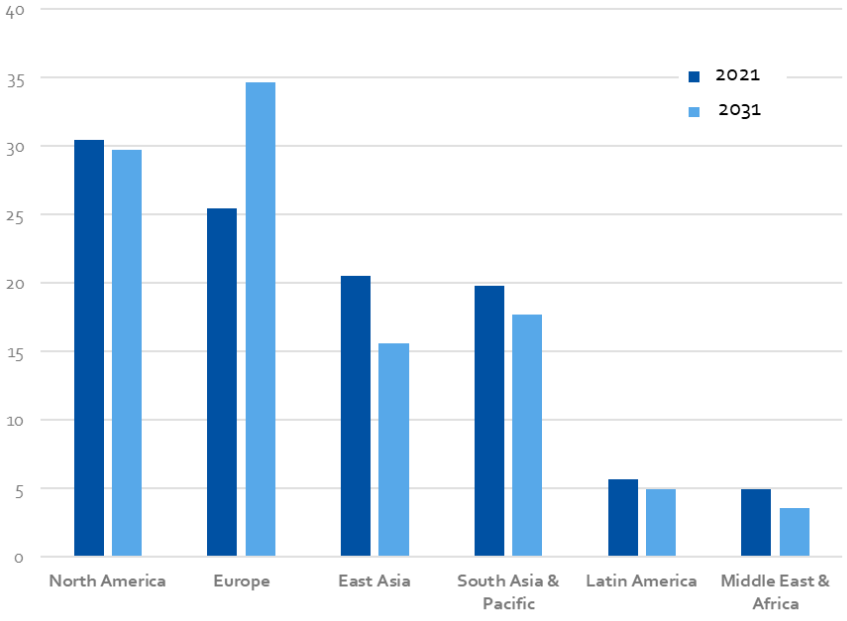

Figure 14 Market share

[33] Fleet Management Market. (2023, March 1). Fleet Management Market Size & Trends Report 2033 | by FMI. https://www.futuremarketinsights.com/reports/fleet-management-market

Following the market share by region, we are going to compare their market size. We assume that the forecast in 2031 is 60.29 USD Billion. From the results presented in table 7, we can observe the potential for growth of the fleet management solutions in only one decade. To take Europe as an example, in 2021, the market size was estimated to be at 5.65 USD Billion and is evaluated to reach 20.50 USD Billion in 2031.
This distribution of the share is strengthened by the result of our interviews. For example, one of the participants in the transportation services for fleets and mobility operators is working on the three regions mentioned above. For Europe, their scope is more specifically in the United Kingdom, France, Sweden, and Germany.

7.1.3. TAM, SAM, SOM

The projected market value presented in the previous sections provides an overall idea of the Total Addressable Market for automated vehicles. The Serviceable Addressable Market (SAM) is limited by AWARD's four use-cases: (1) hub-to-hub, involving vehicles used for first-mile delivery, (2) port and (3) airport trucks, and (4) outdoor forklift operations where the focus is on forklifts operating both in indoor and outdoor confined area. It is important to notice that even though the focus of this project is outdoor forklift operations, the analysis has included indoor operations as well since indoor operations is another possibility for the use of forklifts. Additionally, the serviceable addressable market for this project primarily targets the European market.

The literature on the market size for fleet management for ports, airports, hub-to-hub, and forklift operations (i.e., warehouses), has been found to be limited. The lack of information is more noticeable when the focus is on fleet management with autonomous vehicles in these four specific environments. In order to estimate the market size of fleet management for autonomous vehicles in ports, we will assume that the ports using autonomous vehicles are all using a fleet management system. The same assumptions will be applied for airports and warehouses.

To support our hypotheses and complete our answers, we will compare them to the results of the interviews that we conducted with industry stakeholders. The interviewees hold managerial positions in the ports, civil aviation, fleet management and automotive industry.

7.1.3.1. Ports

Europe has a significant presence in the port industry, with over 1,200 commercial seaports operating along its coasts. The Netherlands, particularly the city of Rotterdam, leads the ranking of main seaports in Europe. In 2021, around 3.5 billion tons of freight handled annually[34]. The yearly European market for Yard trucks, which is the focus of the AWARD project, is approximately 1,300 vehicles.
There is a distinction between container terminals and all ports. Container terminals have a unique advantage when it comes to automation due to their standardized processes,

[34]Maritime freight and vessels statistics - Statistics Explained. (2022, October). Maritime Freight and Vessels Statistics - Statistics Explained. Retrieved May 24, 2023, from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Maritime_freight_and_vessels_statistics&oldid=583292

predictability, and controlled environments. In comparison, the vast landscape of all ports encompasses a wide spectrum of operations, schedules, and cargo types, making automation more challenging. It's important to recognize that the analysis we've presented here acknowledges these differences. While container terminals serve as a valuable reference point for automation due to their pioneering role, we understand that a one-size-fits-all approach is not applicable to all ports. Each port type presents its own set of challenges and opportunities, which must be carefully considered when evaluating automation feasibility.
However, it is important to note that when we delve into the specifics of container terminal automation, we find that the level of automation varies significantly. Based on the 2022 study "Container Terminal Automation: Revealing Distinctive Terminal Characteristics and Operating Parameters"35, “only 3% of the world’s container terminals were found to be either fully or semi-automated”. As of early 2022, there were 62 container terminals in operation, and another one will be added in 2024. We can interpret 3% as a low proportion, meaning that automation is not widely implemented. The number of automated ports (fully or semi) is relatively small compared to the total number of global container terminal businesses. Based on this analysis, it was stated that not all container terminals are candidates for automation of their operations. There would be no set of specific characteristics to determine if a container terminal would be a good candidate for automation. The current container terminals that adopted this technology vary in different attributes, such as their size or container volumes.

The participants in the interviews believed that overall, the share of ports that are using fleet management, including all types of vehicles, is low. The estimation is below 30%. Additionally, there is some level of automation that is already in place at ports, but the use of automated vehicles is still low or non-existent. They estimated that less than 5% of ports implemented AVs, and they believed that the size of the port is a main factor that defines the adoption of the solution.

7.1.3.2. Airports

The AWARD project focuses on using autonomous baggage tractors for cargo transportation in both indoor and outdoor airport environments. Between January 2022 and September 2022, there were 615 million passengers carried at the EU level, a 64% growth compared with all of 2021[36], and around 15 million tons of freight and mail were loaded and unloaded in 2021. Paris Charles de Gaulle, Amsterdam Schiphol, and Frankfurt-am-Main are among the busiest airports in terms of passenger transport and freight handling. The European Union has 298 airports serving at least 15,000 passengers annually.

The focus of this section will be on baggage handling as this operation is considered in this study to be “one of the areas where airports should consider deploying AVs”.

[35] Knatz, G., Notteboom, T. & Pallis, A. Container terminal automation: revealing distinctive terminal characteristics and operating parameters. Marit Econ Logist 24, 537–565 (2022). https://doi.org/10.1057/s41278-022-00240-y

[36] Air passenger transport - monthly statistics - Statistics Explained. (2023, March). Air Passenger Transport - Monthly Statistics - Statistics Explained. Retrieved May 24, 2023, from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Air_passenger_transport_-_monthly_statistics&oldid=583824

In the chart below, the Total Cost of Ownership (TCO) between manual operations and automated vehicles was compared for a timeframe of 7 years. The comparison includes several airport sizes: from small airports (less than five million PAX/annum) to large hubs (more than 30 million PAX/annum). From their analysis, they drew the conclusion that the largest airports would be the most relevant for using automated vehicles. The cost savings could reach up to 30% compared to manual baggage handling. Regarding the smaller airports, the benefits of using automated vehicles should increase over time, while the cost of AVs decreases.

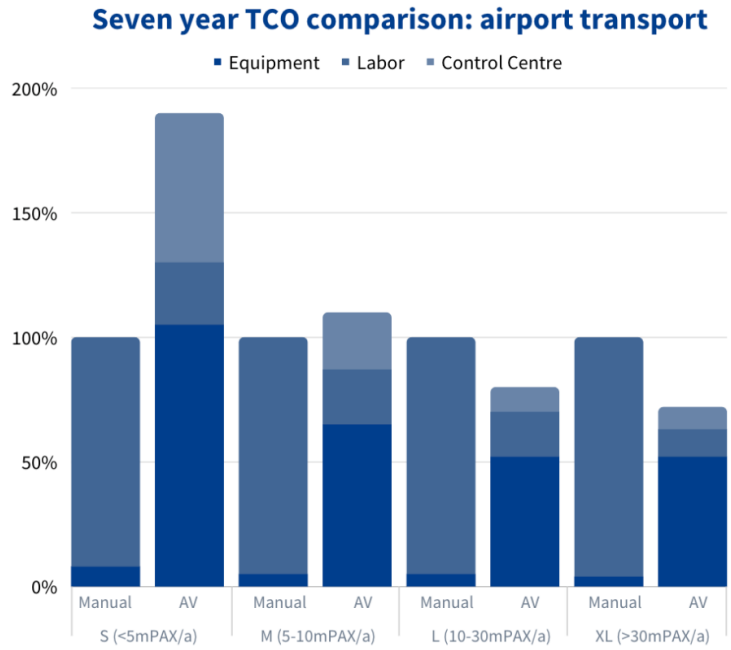

Figure 15 Comparison of manual vs AV luggage handling at airports of different size

Assuming that the busiest airports (more than 10 million passengers per year) would be interested in implementing AV, it would mean a total of approximately 55 airports across Europe. According to Eurocontrol, the top 10 European airports that have the highest average daily movements are presented in Table 3 below.

Name	Average daily movements (departure + arrival)
IGA Istanbul	1,156
Amsterdam	1,140
Paris CdG	1,122
Frankfurt	1,048
London Heathrow	1,042
Madrid Barajas	965
Barcelona	777
Munich	773
Palma de Mallorca	604
London Gatwick	596

Table 2 Europe 10 Airports 2022

From the interviewees' point of view, airports are not using a FMS related to managing manual vehicles. Additionally, there is a handful airports in a trial phase piloting automated vehicles and only a few are thinking about implementing this solution. Airports have several actors

collaborating on the runway and are communicating by radio. Fleet management could improve their coordination, but the current solution is believed to be insufficiently reliable. Implementation of autonomous vehicles in this sector could be possible in at least five years, but only if the scope of the application is specific and targeted. Since COVID-19, airports are trying to recover their losses before investing in R&D such as AV deployment.

7.1.3.3. Hub-to-hub

The transportation of completed goods from factories to distribution centres or warehouses, known as "first mile delivery," is an essential aspect of real logistics operations. In Europe, logistics operations were traditionally concentrated in the "Blue Banana" trading area. However, the expansion of the European Union, improved infrastructure, and growing manufacturing have led to the development of additional logistics corridors and distribution centres across Europe. According to Cushman and Wakefield[37], two additional corridors, among others, have emerged as part of the evolving logistics landscape:

- **Irish corridor** – A new short-sea shipping route is being established between the ports of Cork and Dublin in Ireland and the ports of Zeebrugge and Antwerp in Belgium. It's likely that the small capacity of Zeebrugge port will redirect demand for space to nearby Ghent, Belgium, or even Zeeland, Netherlands.
- **Baltic corridor** – The Baltic's growing importance as a manufacturing location will depend on the construction of TEN-T motorway road and rail networks that will connect this region with Finland, Poland, the Czech Republic, and Germany. Significant infrastructure investment is necessary, so this distribution corridor is likely to develop over the long term.

These new corridors complement the existing logistics corridors in Europe, expanding the distribution of logistics facilities and transportation networks.

7.1.3.4. Outdoor Forklift Operations

Outdoor forklift operations involve different use cases such as loading and unloading in warehouses, industrial plants, construction sites, among others. Even though the focus of AWARD is on outdoor forklift operations, the analysis in this deliverable includes indoor operations since it is another use case for forklift that must be taken into consideration if the study aims for a broader perspective of the market. According to the International Federation of Robotics (IFR)[38], the warehouse automation market size grew considerably in the last decade and is projected to continue at this pace. The global warehouse automation market size was valued in 2020 at USD 12.85 billion and is on course to reach USD 30.69 billion in 2028. The market size by region was led by North America, Europe and Asia Pacific in 2020 and is not expected to change until 2028. The following countries expanded significantly in terms of industrial automation and robotic technology: the United States, the United Kingdom, Germany, India and China.

[37] Progressio, P. (n.d.). CUSHMAN & WAKEFIELD REPORT REVEALS EUROPE'S EIGHT KEY FUTURE LOGISTICS CORRIDORS | News | FOCUS ON Business - Created by Pro Progressio. FOCUS ON Business. https://focusonbusiness.eu/en/news/cushman-wakefield-report-reveals-europe-s-eight-key-future-logistics-corridors/2662

[38] IFR's Latest World Robotics Report - Skyrocketing Growth. (2022, November 11). IFR's Latest World Robotics Report - Skyrocketing Growth. https://statzon.com/insights/ifr-world-robotics-reports-2022

Based on the white paper “Supply chains today – Global Trends in supply Chain Automation”, there are around 20,000 to 50,000 warehouses in the United States, and the range is estimated to be similar in Europe. Asia has a slightly higher number.
An increasing number of companies are automating their warehouse operations by using different types of robots or software and computerized systems. However, it is stated that most of the warehouses are not automated. Advanced automation systems are estimated to be found in less than 10% of the existing warehouses.

According to our interview results, warehouses are an environment where fleet management is more frequently used compared to ports and airports. The estimation on the share of fleet management, including all types of vehicles, is about 50%. Regarding the implementation of FMS for autonomous vehicles, the interviewees’ responses are consistent with the white paper’s results, most warehouses are not currently using FMS for autonomous vehicles.
According to ABI Research[39], in 2025, more than 4 million commercial robots will be installed in 50’000 warehouses.

In terms of the global market, Asia Pacific region accounting for approximately 47% of the market in 2022 and closely followed by Europe[40]. For instance, the market for electric forklifts in Europe was estimated to be worth USD 15.30 billion in 2021, and from 2022 to 2030, it is anticipated to develop at a CAGR of 13.0%[41]. Major European OEMs in this market include Linde MH, Still, Jungheinrich, Toyota, Hyster, and Crown.

[39] 50,000 Warehouses to Use Robots by 2025 as Barriers to Entry Fall and AI Innovation Accelerates. (n.d.). 50,000 Warehouses to Use Robots by 2025 as Barriers to Entry Fall and AI Innovation Accelerates. https://www.abiresearch.com/press/50000-warehouses-use-robots-2025-barriers-entry-fall-and-ai-innovation-accelerates/

[40] Forklift Market Size, Share & Trends Analysis Report, 2030. (2022). Forklift Market Size, Share & Trends Analysis Report, 2030. Retrieved May 25, 2023, from https://www.grandviewresearch.com/industry-analysis/forklift-market

[41] https://www.grandviewresearch.com/industry-analysis/europe-electric-forklift-market-report

8. Benchmarking of AWARD with existing market solution

In this subsection, an overview synthesizing the knowledge gained through a rigorous investigation of all-weather autonomous operations across particular pioneering countries is detailed. The central thesis of this research emphasizes a never-ending race toward autonomous driving that is sustained by a competitive attitude shared by the countries identified in this section. Advancements are driven by a combination of their finances, innovation environments, legislation, and technological maturity, as will be briefly explained. The analysis in this section helps to benchmark AWARD solutions with other competitors in the market.

8.1. Status of all-weather autonomous operations across the world

This subsection provides an overall summary for the information about all-weather autonomous operations in specific countries that are leaders in the sector, which was developed in T10.4 as part of *D10.3 Intermediate Innovation Management Monitoring and Assessment* and updated for *D10.4 Final Intermediate Innovation Management Monitoring*. The analysis covers the United States, the Asia Pacific region (Singapore and China mainly), and Europe (France, UK, Spain, Germany, and Finland). A general presentation of each country's key players can be found in Annex 13.7 Benchmarking by countries.

In the United States, the country has been a leader in the autonomous driving industry, with efforts to stay at the forefront of technology. Various companies, such as Waymo, Kodiak Robotics, and Embark Trucks, are developing all-weather autonomous trucks to operate in states like Montana, where heavy snow can be an issue. The United States Department of Transportation has also invested in Automated Driving System (ADS) projects, providing grants for testing and integration of autonomous technologies.

Regarding Asia Pacific region, Singapore stands out for its advanced technology and initiatives in the autonomous driving industry. Companies like AiDrivers and Venti Technology claim to operate in any weather condition, although evidence of successful projects is limited. The country's universities and research centres are actively conducting tests, including rain simulations, to assess autonomous vehicles' performance in harsh weather. Singapore has established regulations for autonomous vehicles, requiring authorization from the Land Transport Authority for testing and usage. On the other hand, China has experienced rapid growth and global competitiveness in autonomous driving. Companies like UiSEE and Pony.ai have developed autonomous vehicles capable of operating in harsh weather conditions, such as winter and heavy rain. Public funding initiatives in China, like Made in China 2025 and the National Artificial Intelligence Development Plan, support the development of high-tech sectors, including autonomous driving. The country has also been actively working on legislation for autonomous vehicles, with recent regulations favouring autonomous driving trucks.

Other countries in the Asia Pacific region, such as Thailand, Vietnam, Japan, and Taiwan, have also been developing pilots and proof of concepts for autonomous logistic operations. While some projects have emerged in important airports and ports, few have specific capabilities for harsh weather conditions.

In Europe, countries like France, Spain, UK, Germany, and Finland are considered leaders in the sector. Companies like Navya and EasyMile in France have conducted pilot projects and received government support for their autonomous solutions. Regulations in France have been updated to permit vehicles equipped with autonomous systems to operate on predefined routes or zones.

After analysing the situation in various countries, it is evident that the race for autonomous driving continues and is expected to persist in the future. The countries included in this analysis are highly advanced and regarded as leaders in this market, not only due to their technological readiness but also because of their favourable innovation ecosystems, including appropriate regulations and public funding.

When benchmarking the existing solutions against AWARD, Singapore emerges as a well-positioned country with a diverse range of companies developing autonomous vehicles capable of operating in harsh weather conditions. Several projects in Singapore are supported by the state. Germany and the United States also stand out as strong leaders in the sector, primarily due to their supportive regulatory frameworks for testing and deploying autonomous vehicles, as well as the government's financial backing for further advancements in autonomous driving technologies.

Although projects focused on harsh weather conditions have predominantly emerged in countries like Finland, where extreme weather is common, efforts to develop capabilities to operate in all weather conditions are also increasing in countries such as China and the United States. However, this analysis reveals that the number of pilots operating under harsh weather conditions remains relatively low, giving AWARD's technologies a competitive advantage in this regard.

9. Barriers and opportunities

The aim of this section is to highlight the barriers and opportunities identified for autonomous heavy-duty vehicles in logistics and fleet management systems. With the help of literature review and desktop research, this section was elaborated. Interviews with experts in the field, surveys, and social media polls complemented the secondary data and improved our findings.

9.1. General barriers

Below we present general barriers for autonomous heavy-duty vehicles and Fleet Management Systems. Within section 9.1.1 the barriers of the four identified use cases (outdoor forklift operations, Hub to Hub, Port and Airport) are also included, since we noticed that there are no significant differences with the general barriers of AHDVs, so we considered to put all general barriers in one section. In Section 9.1.3, the quadrant analysis of barriers was elaborated, relative to AHDVs and FMS; barriers and opportunities were placed in the respective quadrants based on information from workshop partner responses and desktop research.

9.1.1. Autonomous heavy-duty vehicles in logistics

Automated HDV operations in logistics can create new opportunities for society, trade and transport operators by bringing goods to the customers more efficiently and at a lower cost. However, as a result of each new technology, a few barriers were identified. In order to make the transition to automated vehicles in logistics, safety, cyber-security and other issues will have to be discussed during the course of the project.

It is important to note that a few barriers identified are expected to become opportunities as technology gets more mature and users' acceptance improves. Such a barrier is safety where the majority of partners expect automation to become an opportunity instead of a barrier in the next 10 years.

According to the literature and some research, the following are the barriers that have been identified in the context of AHDVs:

- **Technological barriers**: technology is still not mature for automation to become available in non-protected environments, especially when infrastructure is not suitable (Roland Berger, 2016)[42]. There may be technological barriers that need to be addressed before the system can be deployed at a large scale, such as GPS connectivity issues and a lack of reliable 5G networks. Another technological barrier is the difficulty in integrating different types of sensors, such as LiDAR, cameras, and radar, which are essential for ensuring the safe operation of autonomous vehicles. However, there are some specific technological related to ADS features barriers such as reversing, loading/unloading and gate transits that are expected to be solved in logistics environments when implementing autonomous vehicles. Still, reliability and

[42] Berger, Roland. "Automated Trucks-The next big disruptor in the automotive industry." Roland Berger, 2016.

trust of the system continues to be a barrier. Following, most of the present AHDVs, still lack flexibility in their features, for example, current AVs are able to drive on one route, which can be an issue when operating in public roads.

- **Security and safety:** such as the potential for collisions with pedestrians and other vehicles and the need for emergency stop systems to prevent accidents are essential considerations in the implementation of safe autonomous vehicles. Robust cybersecurity measures are essential to safeguard AHDVs from cyber threats and unauthorized access. Ethical considerations also arise, with the challenge of defining AI decision-making in unavoidable accidents. Same as with any novel technology, safety risks and low operational efficiency are one of the main barriers to adopting autonomous vehicles. After conducting interviews with experts in the field, safety concerns were one of the main barriers reported by them, since the use of autonomous vehicles for logistic operations is still on an early stage, many worried that is not safe and reliable enough to maintain a consistent and interrupted logistic operation. They explained that if activities stop due to malfunctioning of the system or vehicle, the costs will be extremely large and most airports, ports and logistic hubs cannot afford low operational efficiency.
- **Infrastructure:** Lack of adequate and infrastructure to enable AVs to be massively commercialized without the need for investment in expensive technologies for data collection by each vehicle (Roland Berger, 2016) [43]. Furthermore, the costs related to infrastructure investments may not be a priority for logistics operators since it is not their core business, resulting in opting for vehicles thar can fit their current infrastructure.
- **Regulatory and legislation:** in the EU, the Treaty of Rome requires that a driver is responsible at all times for a vehicle on public roads, which creates uncertainties regarding the usage of AVs that effectively hinder their adoption. Though, the usage of AVs in logistics is subject to fewer laws and regulations as the vehicle is used in a confined area most of the time.
    - Also, lack of criteria for verifying whether a system is safe enough to be licensed. The British Standards Institution (BSI) has issued a Publicly Available Specification (PAS), "Assuring Safety of Automated Vehicle Trials and Testing," PAS 1881[44], to aid in the promotion of safe public trials and development testing of automated vehicles such as driverless vehicles. Therefore, regulatory frameworks lack uniformity, posing complexities across various jurisdictions. **Lack of uniform regulations and standards** for the use of AVs in different scenarios is a big barrier for this type of technology. Implementation of autonomous vehicles in confined areas is currently a possibility; however, how this technology will be deployed outside controlled environments is still an open question in most of the countries, in which legislations do not address detailed rules for their usage on public areas with mixed traffic. In fact, results from our polls show that most voters believe that it will take approximately 5 years for AVs to operate in mixed traffic environments. The following 50% of participants

[43] Berger, Roland. "Automated Trucks-The next big disruptor in the automotive industry." Roland Berger, 2016.

[44] *PAS 1881 released for safe testing of automated vehicles*. (2020, March 3). Environmental Engineering News Online. https://www.environmentalengineering.org.uk/news/pas-1881-released-for-safe-testing-of-automated-vehicles-11815/

think that autonomous vehicles will operate only in confined areas and after some years, in mixed traffic areas. Therefore, until there is not a common legal framework and standards for the use of AVs, this issue will continue to be a barrier for adoption of autonomous vehicles.
    - **Liability:** it is not clear who is to be held accountable in the event of an accident. Generally, it is expected that liability will shift away from drivers to manufacturers as automation advances. However, before vehicles with automation Level 4 become common, many vehicles will be controlled in part by both the human driver and the automation system. Though, it is argued that the liability issue would be less severe when transporting goods rather than people.
- **Ethics and social:** It is sometimes stated that the judgments made by AVs in cases where an accident is unavoidable may be challenged in court. There is a discussion over how to deal with the ethical concerns of developing AVs because there is no clear answer. Hence, ethical challenges arise from AHDVs' decision-making in inevitable accident scenarios. As the adoption of autonomous vehicles may result in the displacement of human operators and the need for new skills and training programs for maintaining and operating the autonomous system. Furthermore, implementing a new automated system involves a **restructuring of employment and organizational changes** since some tasks formerly done by a worker would be able to be automated. Thus, employees will be reallocated to new tasks and will need them to learn **new skills**, which in the short term can be seen as a barrier to applying new technologies, because it will entail costs for **training employees**. Also, it could be a barrier because it could mean that some employees lose their jobs due to automation of their tasks. On the other hand, interviewees stated that in some use cases such as ports, **labor unions** have large influence in the sector, which will be a barrier for implementing automation in operations, since it is not clear how the collaboration between humans and autonomous systems will operate or how automation will be integrated into traditional workflows. Therefore, it is the case that logistics centres are refraining from implementing automation to avoid employment issues. Also, some professionals in the field expressed their concerned of moving away from manual operations to automated operations since in some cases workers have **specific and valuable information** that is **not documented**, and it will take time and efforts to record that information in the system, which can be considered as another barrier to adopt autonomous vehicle in logistics environments.
- **Privacy issues:** related to the collection and use of data by autonomous vehicles and the potential for cyber-attacks on the autonomous system pose additional challenges.
- **Economic barriers** such as **high manufacturing costs** and the need for significant investment in infrastructure may also limit the widespread adoption of autonomous vehicles. Additionally, the cost of training and hiring qualified personnel to operate and maintain the autonomous driving system can also be a significant economic barrier.

Currently, the employment of AVs in a regulated and private outdoor setting is more appropriate since there is considerably less ambiguity, fewer restrictions apply, the liability problem is not as complex, and an efficiency-driven business rationale applies.
The AWARD partners consisting of OEMs, research institutes, associations etc. ranked the following predefined barriers in order of importance as presented in Figure 16. Safety concerns

is the most important barrier according to the 16 partners participating at the workshop, followed by high manufacturing costs, lack of digital infrastructure and restructuring of employment (new skills required etc.). The least important barriers included data privacy and market uptake. It was noted that the market is quite ready to adopt automated HDVs in logistics.

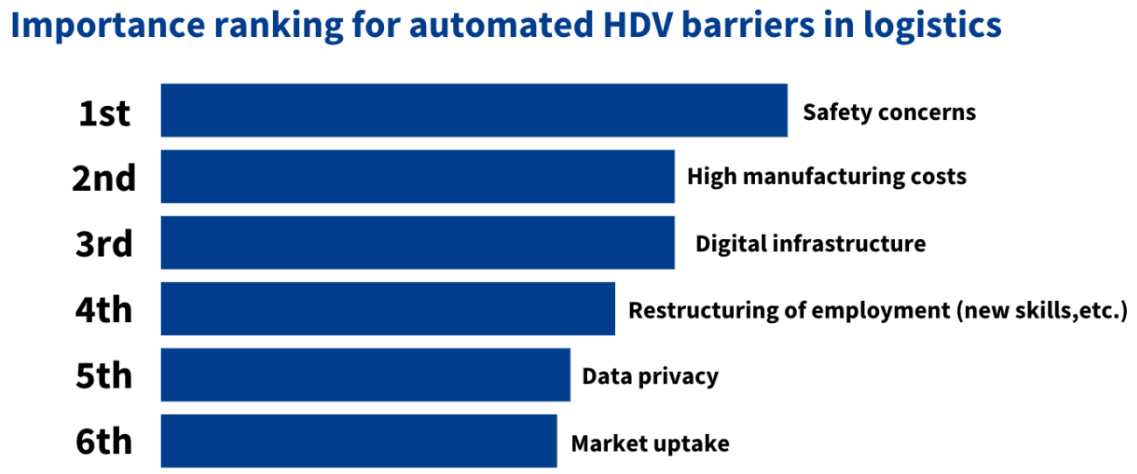

Figure 16 Barriers of automated HDVs in logistics, importance ranking by AWARD partners.

The AWARD partners identified the barriers of automation in logistics using an online survey tool. Those included safety, costs, infrastructure, user acceptance, legal, technical etc. as in Figure 17.

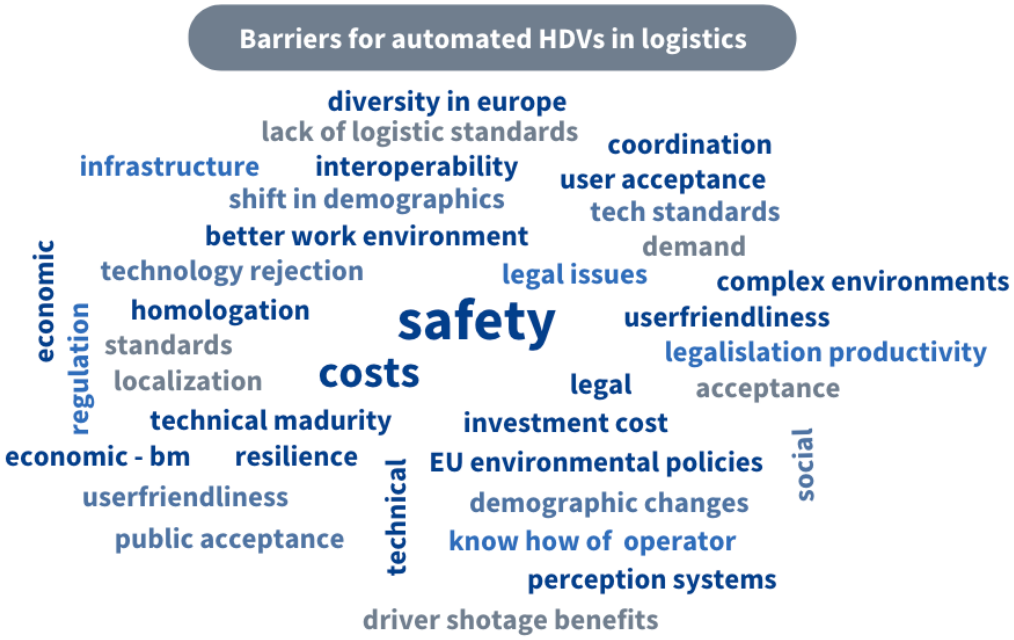

Figure 17 Barriers identified by the AWARD partners

Regarding the four AHDVs use cases, we have noticed that one of the most relevant barriers should be the regulatory and legislative barriers.
Hub-to-hub involves both public and confined outdoor areas, forklift for indoor and outdoor confined areas, port and airport trucks for outdoor confined areas. Hence, in this scenario we have:

- Confined Areas:
  - Airport,
  - Port.

- Mixed situation (confined + public roads):
  - Logistic Warehouses.

Regulations surrounding autonomous driving systems can vary widely across different jurisdictions, and navigating these regulations can be challenging, leading to regulatory and legal barriers. The lack of a uniform regulatory framework for the use of autonomous vehicles in different scenarios may create uncertainty and legal challenges for the implementation of the system, particularly if the system is to be deployed across multiple jurisdictions.

In the AWARD project, which focuses on four use cases (outdoor forklift operations, hub-to-hub, airport, and port), regulatory and legislative issues arise in different scenarios, such as industrial areas, public secondary roads, public main roads, and public crossing areas.
In industrial areas, the use of AHDVs raises concerns about the safety of workers and equipment, as well as liability issues in case of accidents. Regulatory frameworks need to be developed to ensure that AHDVs are designed and operated safely in these environments, considering specific factors such as the layout of the facility and the presence of other vehicles and pedestrians.

On public secondary roads, AHDVs need to comply with existing traffic laws and regulations, while also ensuring that they can operate safely and efficiently in mixed traffic environments. In this case, the regulatory and legislative issues revolve around the integration of AHDVs with other vehicles and the development of standards for communication and coordination between them.

On public main roads, AHDVs need to be able to navigate complex traffic scenarios, such as merging, overtaking, and changing lanes, while also ensuring safety and efficiency. Regulatory and legislative issues in this case relate to the certification and testing of AHDVs, as well as the development of standards for their communication with other vehicles and with the infrastructure.

In public crossing areas, AHDVs operating in public crossing areas, such as the ones used for automated baggage dispatching in airports, need to comply with safety regulations and ensure the safety of passengers and airport workers. The regulations may include the requirement for collision avoidance technology, speed limits, and proximity sensors, among others.

9.1.2. Fleet management systems

New technologies usually face challenges when entering the market. Barriers to adopt fleet management systems have been identified and described in this section. Notice that some barriers that are hindering the adoption of autonomous vehicles can also be included in this section, given that AWARD FMS primary target are AVs.

Privacy issues are an important reason that discourages end customers from using telematics solutions.[45] The increase in cyber threats and exposure of sensitive data could be hindering the adoption of this type of technologies, since the introduction of telematics in fleets has resulted in generation of large volumes of data that could be maliciously exploited by hackers. **Economic barriers** play an important role since changing traditional fleet management systems to automated ones could involve **high switching costs and high prices** for end users. Similarly, **restricted budgets** must be considered, since medium and small logistic centres do not own large amounts to invest in new FMS which in general, request high capital requirements; therefore, the rate of adoption has been slow for them. According to the interviews, most airports are experiencing financial constraints and revenue shortages as they continue to recover from the financial implications of COVID-19. As a result, investing in a fleet management system (FMS) is not currently a top priority. Additionally, for many airports, ports, and logistic hubs, the prospect of investing in a new technology like an FMS for autonomous vehicles viewed as a risky endeavour due to the technology's lack of maturity of AVs.

Furthermore, the interviewees highlighted that ports and airports typically refrain from allocating substantial funds to research and development (R&D) projects. Instead, they prefer to invest in technologies that have already proven their effectiveness and reliability. Size of operations is another barrier for adopting a new fleet management system; interviewees stated that for logistic hubs, airports, and ports if the **size of operations** is not large enough, it could be the case that investing in an FMS will not be necessary. Only if it represents a small cost for them will it be implemented. However, professionals also commented that in the long term, acquiring a fleet management system will depend on the usability and effectiveness of the system rather than the size of operations. Moreover, results from surveys highlighted that **business partners acceptance** could be hindering implementation of such technologies when not all partners are technologically ready or willing to invest in new systems.

Other factors obstructing the adoption of a fleet management system for autonomous vehicles could be related to **technology readiness** of the vehicles**.** Interview inputs revealed that ports and airports in Europe do not have any use case of implemented autonomous vehicles in their operations and hence, not any use case for FMS for AVs. There are some trials of AVs and FMS in specific airports such as Oslo and Toulouse-Blagnac, but still experts are quite sceptical about the efficiency of the use case. Similarly, polls show that 40% of participants think that it will take another 5 years for logistic hubs, airports, ports, and warehouses to start using autonomous vehicles in their daily operations. Also, as mentioned before, most of the experts believe that these technologies (FMS for AVs) are **not mature enough** and have not been proved in real world scenarios; hence, until technology is not at a higher stage, most ports and airports will not probably invest in such initiatives. One of the interviewees commented that the biggest barrier is not the adoption of the FMS per se, but the change from manual to autonomous operations that makes it difficult. Likewise, as for other technologies, the **infrastructure** must be changed or improved for a proper performance of a fleet management system; however, changes could take large periods of time and be expensive, hampering the use of the system. Similarly, polls disseminated by LinkedIn showed that 31% of voters believe that infrastructure will be highly difficult to automate.

[45]Fleet Management Market Size, Drivers, Opportunities & Challenges. (2015, November 2). MarketsandMarkets. https://www.marketsandmarkets.com/Market-Reports/fleet-management-systems-market-1020.html

Additionally, **issues in GPS connectivity and lack of 5G connection** are also considered as a barrier, since atmospheric inference hampers the connection, resulting in inaccurate GPS signal and non-precise location.

9.1.3. Quadrant analysis (QA) of barriers

Quadrant Analysis (QA) was used in order to have a more in-depth dynamic of the barriers and to be able to prioritize them. A quadrant analysis is a data visualization technique that allows us to divide a two-axis graph into four quadrants based on the values of the two variables that represent the axes; in this case the two variables are: **importance** and **difficulty**.

A barrier's importance reflects how much of an impact it will have on the project's success, results and market. High-importance barriers are ones that could seriously obstruct achievement or progress. Focusing on importance allows you to pinpoint the barriers that must be overcome in order for the project to succeed as a whole.

Effort and challenge needed to reduce or remove a barrier are reflected in how difficult it is to overcome. Technical difficulties, budget limitations, and other complexities may be present. You assess the viability of removing the barriers by taking difficulty into account. High-difficulty obstacles might need a lot of money or innovative thinking to get over.

The average importance score was plotted on the x-axis while average difficulty scores were plotted on the y-axis for each item measured. The interpretation of the QA of barriers is summarized in Figure 18 and 19.

Quadrant I (High Importance and High Difficulty): these are the barriers that are both highly important and difficult to overcome. They represent the most significant challenges to the success of the project, results or market of AHDVs and FMS.
Quadrant II (High Importance and Low Difficulty): these barriers are highly important, but relatively easy to overcome.
Quadrant III (Low Importance and Low Difficulty): these barriers are of low importance and low difficulty. They represent minor issues that are unlikely to have a significant impact on the success of the project.
Quadrant IV (Low Importance and High Difficulty): these barriers are of low importance, but difficult to overcome. They represent challenges that are not critical to the project's success, but still require significant effort to overcome.

It makes sense to consider importance and difficulty as the determining factors for barriers since it allows for a more nuanced understanding of the challenges at hand. Due to their potential to affect the project's performance, barriers that are both extremely significant and challenging (Quadrant I) necessitate prompt attention and resource allocation. Barriers with low relevance and difficulty (Quadrant III) may not require urgent attention, whereas barriers with high importance but relatively easy to resolve (Quadrant II) can be tackled first to achieve speedy progress. If resources are available, obstacles of low relevance but high difficulty (Quadrant IV) might be tackled after dealing with barriers with higher priority.

The identified barriers reflect the complexity of AHDVs and FMS integration, spanning technological, regulatory, safety, security, ethical, and economic dimensions. These challenges underscore the need for robust technological maturity, standardized regulations, enhanced safety measures, and ethical decision-making frameworks. While certain barriers may eventually evolve into opportunities with technological advancement and growing acceptance, immediate action is required to mitigate concerns related to safety, liability, infrastructure, and workforce restructuring.

Below is the quadrant analysis of the barriers identified in sections 9.1.1 and 9.1.2 for AHDVs and FMS:

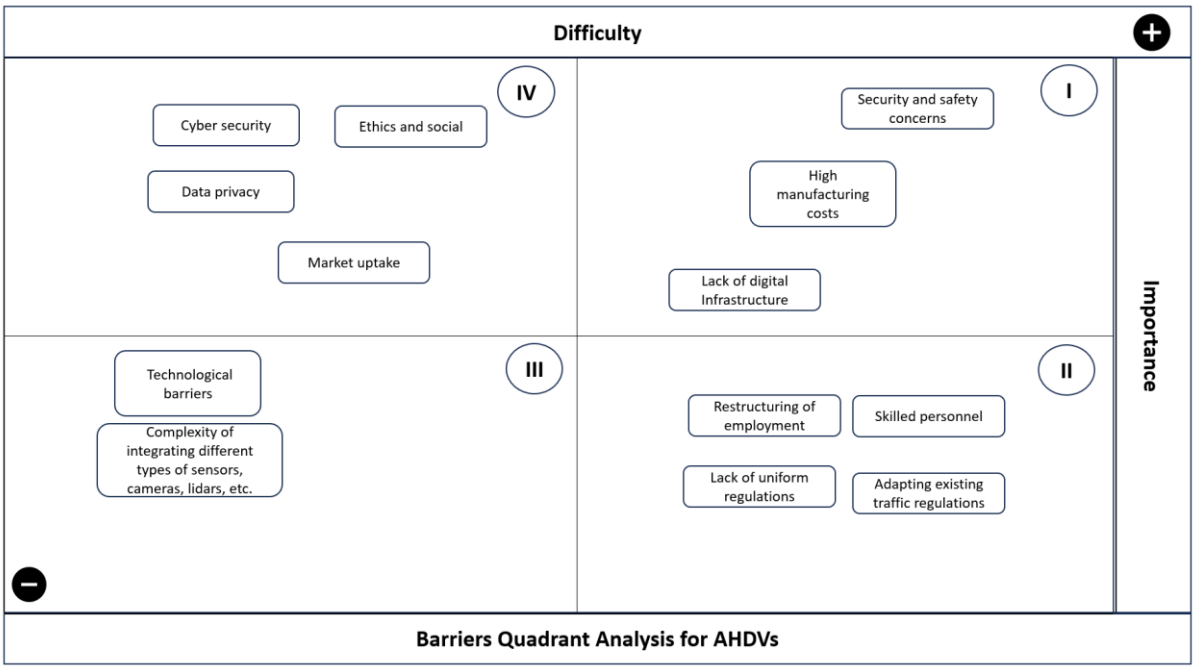

Figure 18 Quadrant Analysis of the barriers for AHDVs

Quadrant I (High Importance and High Difficulty): When it comes to AHDVs, the barriers with high importance and high difficulty are the most critical ones to address, as they will have the most significant impact on the success of the adoption of autonomous heavy-duty vehicles. Hurdles in this quadrant that are both crucial and challenging to get past. These barriers must be removed because they seriously jeopardize the project's success. For instance, large scale adoption may not be feasible due to high expenses of developing AHDVs, infrastructure challenges due to lack of digitalization also makes it difficult for this innovation to spread among individuals, and public concerns about how safety is to drive an autonomous vehicle also difficult its adoption.

Quadrant II (High Importance and Low Difficulty): Moreover, the barriers with high importance and low difficulty are the low-hanging fruits that can be addressed first to make progress quickly. For instance, restructuring of employment and the development of new skills among the personnel due to entrance of automation in the workplace, lack of uniform regulations and adaptation of existing ones to address the use of autonomous vehicles on public roads are some of the barriers that lay within this quadrant since even though these factors are quite significant, dealing with them may be easier in the short run than solving other technical problems.

Quadrant III (Low Importance and Low Difficulty): Barriers with low importance and low difficulty can be addressed in the short run, for example, technology barriers such as the complexity of integrating different types of sensors, cameras and lidars is a challenge that can be solved with the sufficient resources and management.

Quadrant IV (Low Importance and High Difficulty): Some factors are highly difficult to solve but are less important, because of the real impact that has on the adoption of AHDVs. Ethical challenges that arise from AHDVs' decision-making in inevitable accident scenarios and relatively low social acceptance lie within this quadrant. Even though these barriers are quite significant, dealing with ethical issues and societal acceptance may be difficult in the short run given that is still uncertain who is liable in the case of an accident. Others like cyber security threats and data privacy are also a challenge since they are not properly regulated yet. Also, innovative technologies like AHDVs may take some years to become mainstream in the market; hence, the uptake of this market could be categorized with high difficulty and less importance. The mass adoption of AHDVs is expected to come in the long term; hence, tackling this barrier is not the first one to address, making it less important than others. Therefore, challenges considered as high difficulty, but low importance are not considered that way because are not significant to the development of AHDVs, but because are issues that might be addressed in the far future; hence, in the short term, other barriers should be tacked first due to their urgent nature.

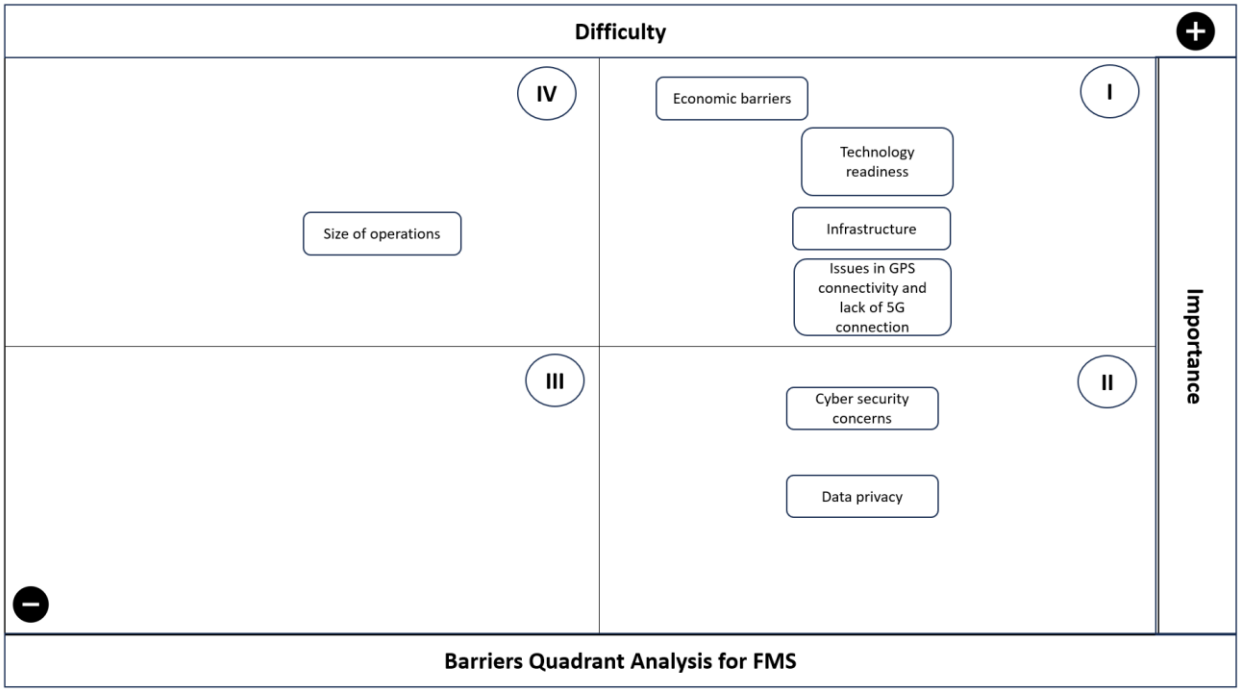

Figure 19 Quadrant Analysis of the barriers FMS

Quadrant I (High Importance and High Difficulty): For fleet management systems, barriers with high difficulty and high importance are crucial to take into account to prevent them from obstructing the FMS' success. Several major barriers to the adoption of fleet management systems for autonomous cars are located in Quadrant I (High Importance and High Difficulty). These include: Changes in Infrastructure, requiring complex and time-consuming adaptations to move from manual to autonomous operations; Technology Readiness, involving the crucial

maturity and efficacy of autonomous vehicle technology fundamental for successful AV fleet management; Finally, GPS Connectivity and Lack of 5G Connection, which pose significant accuracy and efficiency challenges to fleet management systems due to atmospheric interference and connectivity issues,

Quadrant II (High Importance and Low Difficulty): Barriers in Quadrant II play an important role in the FMS market, still their removal can be less challenging than other barriers. Data privacy is a notable example, which is a crucial concern when dealing with the significant amounts of data created by telematics and the requirement to protect sensitive information. Addressing data privacy issues is crucial for assuring secure and moral data processing in fleet management systems, although it is reasonably doable compared to certain other important barriers. For instance, the presence of data privacy guidelines that FMS companies need to follow can reduce the difficulty of tackling this barrier.

Quadrant III (Low Importance and Low Difficulty): The study finds no barriers in Quadrant III that satisfy the requirements of both low importance and low difficulty. This quadrant emphasizes that the difficulties raised primarily have varied degrees of importance, which affects how important they are in terms of ranking in the overall adoption of fleet management systems.

Quadrant IV (Low Importance and High Difficulty): As we move into Quadrant IV, we can find challenges that may not have a direct impact on the project's success but still are difficult to tackle them. For example, the size of operations can provide significant hurdles for smaller entities due to resource constraints, increasing the complexity of technology uptake inside such organizations, even while it may not have as much of an impact on adoption decisions based on operational scale.

9.2. General opportunities

Below we present general opportunities for autonomous heavy-duty vehicles and fleet management systems. As done in section 9.1.1, within section 9.2.1 the opportunities of the four identified use cases (outdoor forklift operations, Hub to Hub, Port and Airport) are also included, since we noticed that there are no significant differences with the general opportunities of AHDVs, so we considered to put all general opportunities in one section.

9.2.1. Autonomous heavy-duty vehicles for logistics

The opportunities of automation in logistics are well known from both research and industry sides.

The main opportunities of automated HDVs in logistics include "*decreasing transport costs, higher safety, efficient use of resources, tackling the lack of drivers and an overall more efficient service performance"* (Neuweiler, L., & Riedel, P. V., 2017)[46]. A more customer-

[46] Neuweiler, Lukas, and Pia Vanessa Riedel. "Autonomous Driving in the Logistics Industry: A multi-perspective view on self-driving trucks, changes in competitive advantages and their implications.", 2017.

focused supply chain avoiding bottlenecks such as driver rest time and human caused accidents can increase efficiency and add value to the logistics industry.

Roland Berger, 2016[47] indicates a few opportunities from the automation of HDVs in logistics:

- **Increased safety**: automation will eliminate human-related mistakes and accidents. With the ability to operate in a more controlled and predictable manner, the risk of accidents and injuries can be reduced, thereby improving the overall safety of logistics operation. This translates into a safer working environment, safeguarding human lives, and minimizing the risk of costly disruptions (Roland Berger, 2016).
- **Decreased transportation and labour costs**: more economic transport assignments and less costs for the transport operators and the consumers. The use of autonomous vehicles can also lead to reduced labour costs in every use case operation, as there is no need for human drivers to operate the vehicles. AHDVs' capacity for optimized route planning and efficient driving behaviour can lead to decreased fuel consumption and operational expenses. Additionally, the elimination of the need for human drivers can result in significant labour cost savings, making logistics operations more financially viable.
- **Enhanced last mile delivery**: the use of AHDVs may improve the way last mile delivery is implemented by reducing delivery timings and increasing efficiency overall.
- **Decreased fuel consumption**: optimal driving behaviour which can result to less fuel consumption due to high accelerations and decelerations, thereby improving sustainability.
- **Improved truck utilization**: the truck can be driven for more hours while the driver has a maximum driving time and needs to rest.
- **Better road utilization.**
- **Better driver utilization.**
- **Customer-Centric Supply Chains:** AHDVs have the potential to reshape supply chains into customer-centric entities. By mitigating factors such as driver rest periods and human-caused accidents, AHDVs enable more streamlined material flow and efficient service delivery. This can lead to improved customer satisfaction, reduced delays, and enhanced overall supply chain performance (Neuweiler & Riedel, 2017).
- **Collaborative logistics ecosystem:** In order to optimize the entire logistics process, this concept proposes an extensive and interconnected network where AHDVs can easily engage with other stakeholders, such as suppliers, distributors, manufacturers, and customers. This cooperative ecosystem seeks to improve coordination, information sharing, and resource allocation across the supply chain by utilizing the capabilities of AHDVs. Smoother material flows, precise delivery timeliness, and effective resource use can all be facilitated by AHDVs outfitted with cutting-edge sensors, real-time tracking, and route optimization algorithms. This opportunity fits in with the broader trend of Industry 4.0 and the digital transformation of supply chains in addition to the objectives of optimizing logistics operations. AHDVs can support real-time data interchange, enabling stakeholders to make swift decisions via navigating routes, delivering items, and interacting with various supply chain nodes. This cooperative strategy may help to lessen bottlenecks, shorten delays, and improve supply chain efficiency. The collaborative logistics ecosystem can usher in a new era of efficiency,

[47] Berger, Roland. "Automated Trucks-The next big disruptor in the automotive industry." Roland Berger, 2016.

transparency, and customer happiness in the logistics sector by supporting a networked environment where AHDVs operate in harmony with other logistical components.

DHL, 2014[48] includes Environment & Emission as an opportunity from automation of HDVs.
One of the major benefits of using autonomous forklifts is **increased efficiency**. These vehicles can operate continuously without the need for breaks or rest, which can lead to significant gains in productivity. This is especially important in confined indoor or outdoor spaces, where human-operated vehicles may face difficulties navigating tight spaces or require frequent stops.
Autonomous vehicles can also be equipped with sensors and software that enable real-time **tracking of traffic** conditions and route optimization, improving the flow of vehicles and people

The AWARD partners ranked the potential cost reduction – efficiency gains as the most important opportunity from automation. Restructuring of employment and road safety followed.

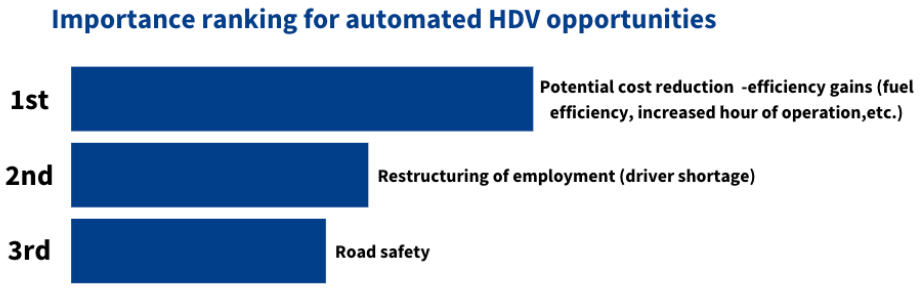

Figure 20 Opportunities of automated HDVs in logistics - ranking by importance - AWARD partners

In Figure 21 and Figure 22, the AWARD partners were asked to reply on the timeline of safety and employment structuring to be opportunities instead of barriers. In both cases, most of the respondents indicated that in 10 years, technology will make it possible for automated HDVs to become safer than the current ones and that automation can benefit operators on employment issues such as driver shortage.

[48] LOGISTICS, OMNI-CHANNEL. "A DHL perspective on implications and use cases for the logistics industry.", 2014.

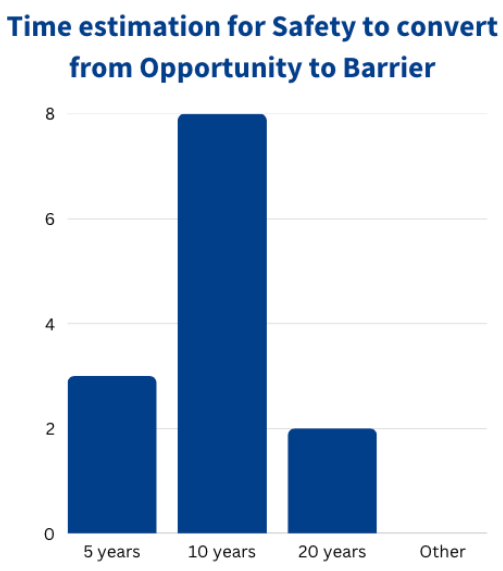

Figure 21 Safety - transition from a barrier to an opportunity

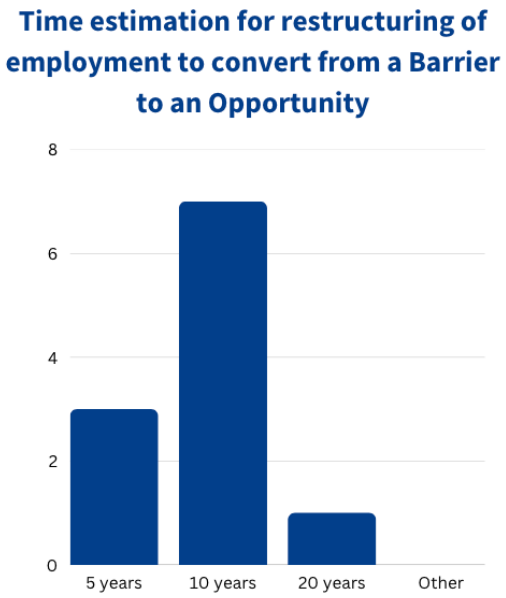

Figure 22 Restructuring of employment - transition from a barrier to an opportunity

9.2.2. Fleet management systems

Opportunities and benefits of using fleet management systems are many, since it is a system that efficiently improves operations and fleet movements, because it helps in database management, scheduling, tracking, and customer feedback.

During interviews, benefits from using a fleet management system were identified. Different experts pointed out that achieving **higher efficiency** in their operations will be one of the most important benefits from this solution. The advantages of automating processes will bring value to the whole operations process because vehicles can take over manual chores while workers oversee higher level tasks, resulting in an efficient workflow. Interviewees commented that optimizing processes is one of the biggest advantages of having an FMS.

Following, desktop research shows that the **demand for effective and secure operation** of big fleets of autonomous vehicles represents one big market opportunity. Fleet managers may optimize routes, cut down on downtime, and boost safety by using fleet management systems to track, monitor, and analyse vehicle performance in real-time.

On the other hand, solutions like AWARD can bring **improvements in the working environment and flow of operations** because of the added value that provides to logistics operations. For instance, interviewees see that applying a fleet management system could improve communication between all parties and could enhance vehicle tracking, which will result in a streamlined process and consistent performance. Additionally, polls show that professionals believe that bringing more automation will improve work conditions for some use cases like ports.

Furthermore, **cost reductions** are an important benefit of using FMS, since it optimizes processes, offering the most efficient solution, for instance, by optimizing routes to reduce costly fuel. Also, it reduces risks and insurance costs since it ensures an optimal and structured workflow avoiding accidents that could have occurred because of human errors. Following, polls pointed out that another benefit could be reductions of human-personnel costs, since specific tasks could be carried out by the system (hub-to-hub use case). Also, fleet management systems make it possible to optimize vehicle use, which results in costs are reduction; hence FMS for autonomous vehicles make it feasible to conduct operations 24/7, boosting production and lowering the demand for staff. By offering insights into idle hours, maintenance requirements, and energy use, fleet management systems can help operators' lower expenses and increase productivity.

Also, **safe operations** are another opportunity that participants saw in automated systems according to polls, creating an opportunity for solutions such as FMS. It is interesting to notice that in the short term, safety is considered as a barrier to adopt an FMS because of all factor explained in the barriers section, but in the long term, once technology is more mature, safety of the operations will indeed be a great benefit. The reason is that by lowering accidents brought on by human error, the deployment of autonomous vehicles in logistical operations might increase safety. By providing real-time monitoring of vehicle speed, direction, and other data and warning operators of any possible safety hazards, fleet management systems can play a critical role in this respect.

In addition, fleet management solutions for autonomous vehicles might provide logistics operators chances for **innovation and differentiation in their business models**. Operators can use the data produced by these systems, for instance, to create new services and business models like pay-per-use pricing schemes and predictive maintenance schemes.
Finally, **compilation of important data** is possible with the use of FMS, since it has access to the vehicle and its routes. The visualization of data and the ability of seeing all the operation on one platform was identified as a big opportunity for some interviewees.

9.2.3. Quadrant analysis of opportunities

As was done in section 9.1.3, Quadrant Analysis (QA) was used in order to have a more in-depth dynamic of the opportunities and to be able to priorities them. The average **importance** score was plotted on the x-axis while average **feasibility** scores were plotted on the y-axis for each opportunity measured.

Similar to barriers, an opportunity's importance reflects the possible influence it may have on the project's success. High-importance opportunities are those that have the potential to significantly benefit or advance the project.

In this context, feasibility refers to how feasible an opportunity is in terms of the available resources, time, and effort. Low feasibility says that the opportunity may require significant ingenuity or resources to be successfully explored, while high feasibility shows that an opportunity can be achieved fairly quickly and with existing resources.

The interpretation of the QA is summarized in Figure 23 and 24.

Quadrant I (High Importance and High Feasibility): in this quadrant go the opportunities that are both important and feasible. These opportunities are typically the highest priority, as they represent areas where it is possible to achieve significant gains with relatively little effort.
Quadrant II (High Importance and Low Feasibility): in this quadrant go the opportunities that are important but less feasible. These opportunities are typically longer-term goals that require more resources, innovation, or time to achieve.
Quadrant III (Low Importance and Low Feasibility): in this quadrant go opportunities that are low in importance and low in feasibility. These opportunities are typically not worth pursuing in the short run, as they are unlikely to have a significant impact on the project.
Quadrant IV (Low Importance and High Feasibility): opportunities that are low in importance but feasible go in this quadrant. These opportunities may still be worth pursuing if they can be achieved easily or at a low cost, but they are unlikely to have a significant impact on the project.

The reason behind choosing importance and feasibility as prospects is because it aids in determining the most strategic areas to invest in. The highest priority opportunities (Quadrant I) provide significant gains with manageable effort and are both extremely significant and achievable. Opportunities in the second quadrant (Quadrant II) may be long-term objectives requiring extra funding or innovative solutions. Opportunities with low importance and feasibility (Quadrant III) may not be worthwhile to pursue at least in the short-term, whereas opportunities with low importance but high feasibility (Quadrant IV) may be taken into consideration if they are feasible to implement without taking priority away from other important areas.

The opportunities landscape aligns with the transformative potential of new technologies like AHDVs and FMS, highlighting avenues for enhanced efficiency, reduced costs, and increased sustainability. Technological advancements in connectivity, sensors, and AI drive the expansion of AHDVs' and FMS' applications. Collaboration among stakeholders, regulatory adjustments, and safety measures create opportunities to establish those innovations as a safe and reliable logistical solution.

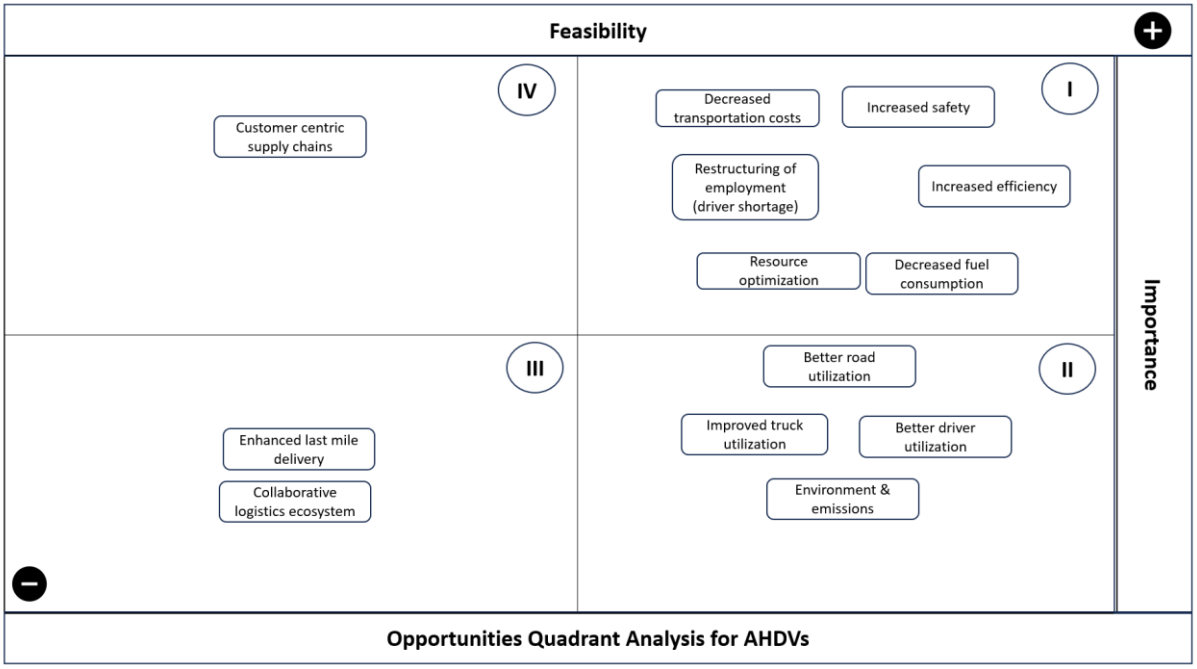

Figure 23 QA of the opportunities HDVs

Quadrant I (High Importance and High Feasibility): The reason behind choosing importance and feasibility as prospects is because it aids in determining the most strategic areas to invest in. The highest priority opportunities (Quadrant I) provide significant gains with manageable effort and are both extremely significant and achievable. For instance, using automation to get rid of errors and mishaps brought on by people might improve safety, decreased transportation costs, the restructuring of employment due to driver shortages, resource optimization by decreasing fuel consumption and enhancement of efficiency by automating processes along the logistics chain.

Quadrant II (High Importance and Low Feasibility): Opportunities in the second quadrant (Quadrant II) may be long-term objectives requiring extra funding or innovative solutions. Opportunities identified in this quadrant refer to improved truck utilization, better road utilization and better driver utilization. Moreover, by implementing AHDVs, the impact on the environment will be less harmful by reducing emissions. These are significant opportunities for the evolution of AHDVs; however, these represent a change in the existing infrastructure, operational protocols, and demand technology advancements not available yet.

Quadrant III (Low Importance and Low Feasibility): Opportunities with low importance and feasibility (Quadrant III) may not be worthwhile to pursue in the short-term given that are not urgent for the success of AHDVs and also, these opportunities may be available in the long-run once external factors like regulation and technology readiness are more available; hence, the opportunities that arise in this quadrant might not need a significant investment of time or focused attention compared with other opportunities. For example, last mile delivery might be enhanced using AHDVs in the future; however, in the present, pilots are being tested but massive adoption of this technology is expected to arrive in the coming years. Also, the use of AHDVs may induce a collaborative logistics ecosystem where stakeholders are seamlessly interconnected; nevertheless, this may happen in the future where there are all participants in the logistics chain have access to more advanced technologies.

Quadrant IV (Low Importance and High Feasibility): Finally, opportunities with low importance but high feasibility (Quadrant IV) may be taken into consideration if they are feasible to implement without taking priority away from other important areas. One example is the use of AHDVs to reshape supply chains into customer- centric systems, where client satisfaction is increased due to higher efficiency along the logistic chain. Of course, this opportunity is a consequence of the ones identified in Quadrant I; therefore, it is considered as a secondary factor pushing the adoption of AHDVs.

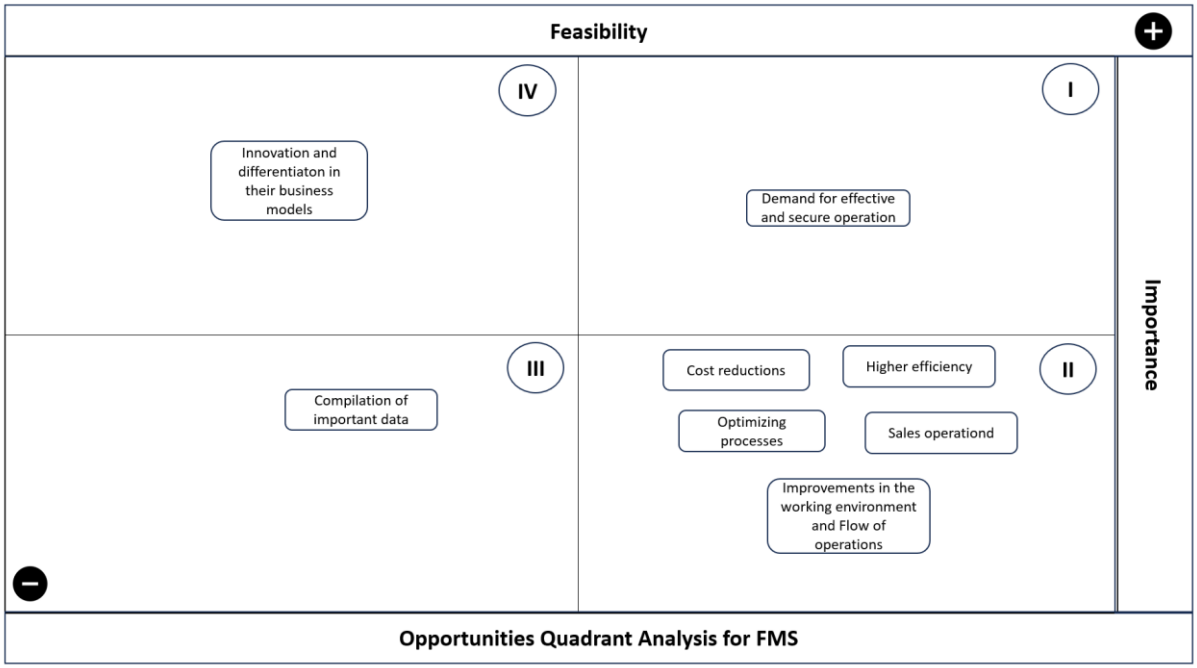

Figure 24 QA of the opportunities FMS

Quadrant I (High Importance and High Feasibility): Similarly, opportunities for fleet management system placed in the first quadrant are the ones with high importance and high feasibility of being reached. The demand for effective and secure operation is identified in this quadrant which emphasizes the growing demand for secure and effective management of autonomous heavy-duty vehicle fleets. Through real-time tracking and performance analysis, fleet management systems have the potential to improve safety, decrease downtime, and optimize routes. Since the technology is already available to create such systems, it is crucial to address the requirement for trustworthy and safe management of autonomous vehicle fleets.

Quadrant II (High Importance and Low Feasibility): Following, those opportunities for the fleet management system that are considered important but may require more resources and innovation to reach are placed; hence, being less feasible, are placed in Quadrant II. Fleet management systems are emerging as promising solutions to optimize routes, fuel consumption, and vehicle maintenance, resulting in significant cost savings. Reducing transportation costs is still a key goal for logistics operations. However, the pursuit of significant cost savings might call for significant resources and innovative methods, placing it in Quadrant II. Furthermore, fleet management systems that automate jobs, improve workflows, and streamline operations can support the pursuit of increased operational efficiency, an important goal. Achieving maximum efficiency is important, but doing so could be difficult due to procedure changes and adaptations, making it a crucial but difficult opportunity to put into practice. Similarly, ensuring operational safety, especially in the realm of autonomous vehicles, holds paramount importance, and fleet management systems contribute through real-time monitoring and hazard alerts. Although safety's importance is high, its feasibility might be constrained by the evolving nature of autonomous vehicle technology. Additionally, optimizing various logistical processes to elevate workflow and resource utilization is of great importance, yet comprehensive optimization might necessitate intricate process reengineering and adjustments, impacting its feasibility. Lastly, introducing improvements in the working environment and workflow through enhanced communication and vehicle tracking via fleet

management systems is vital, but the feasibility may vary based on integration and implementation complexities.

Quadrant III (Low Importance and Low Feasibility): Compilation of important data is an opportunity that is placed in Quadrant III. In this quadrant, opportunities that are considered less important and less feasible, not because they are not significant but because they have less impact on the project's results. Although it is possible to obtain data utilizing fleet management systems, the significance of this opportunity may be somewhat less significant when compared to other factors. Data collection alone might not have a substantial impact on the project's overall success, classifying it in this quadrant.

Quadrant IV (Low Importance and High Feasibility): Finally, in Quadrant IV we can find the opportunities that are more feasible but may be less significant for the project success, in the short run. For instance, implementing innovative business models by using fleet management systems can enhance the project's offering and differentiate it from the competition, although this may not be paramount.

10. SWOT analysis

A SWOT analysis has been performed by project partner CARA and included in T10.3: Innovation management and impact monitoring, specifically in D10.4 due to confidentiality reasons. The methodology for T10.3 is in close relationship with T8.4. Together with WP8, we conduct desktop search, market analysis and competitive analysis to understand better the new opportunities and risks related to the project and its impact on the project results. Further, we conduct interviews to get feedback from external stakeholders regarding the future of autonomous heavy-duty vehicles in logistics and will also engage the external expert advisory board to assess the maturity and innovativeness of the solutions. Based on the results that we get from internal and external assessment, we performed a SWOT analysis to find out the project´s Weaknesses, Strengths, Opportunities and Threats.

11. Conclusions

The main conclusions and significant learnings from the analysis presented in the preceding chapters are condensed in this chapter. The market study of autonomous heavy-duty vehicles in fleet management systems and logistical operations was the focus of the paper. In the area of mobility and logistics, it intended to offer useful insights to a variety of stakeholders, including policymakers, researchers, private businesses, and the general public.

The investigation of the market for autonomous heavy-duty vehicles used in logistics operations provided valuable insights into market segmentation. To give a thorough insight of the market environment, it looked at the degree of vehicle autonomy, vehicle type, region, and application. Significant market factors, such as trends and drivers, which help to shape the sector, were also found by the investigation. The evaluation of the market's size on a worldwide and regional level, with a focus on Europe specifically, provided useful insights into the market's potential.

Similar market segmentation and dynamics were examined in the examination of fleet management systems. It revealed the elements affecting the development of the sector by identifying market trends and drivers. The TAM, SAM, and SOM analyses, coupled with the evaluation of the market's size both worldwide and in Europe, gave a thorough grasp of the market's potential. The investigation of Porter's five forces and the competitive environment added to our grasp of market dynamics.

The project's key differentiators were highlighted in the benchmarking research by comparing AWARD with other market solutions. The last-mile logistics under a variety of operational circumstances and AWARD's operations in adverse weather were cited as important strengths. To gain important knowledge for future improvement, the performance of the AWARD solution in all-weather situations was compared to traditional ADS performance. The investigation gained a worldwide perspective through the evaluation of all-weather autonomous operations conducted across the world, particularly in the United States, Asia Pacific, and Europe.

This study also examined the challenges and possibilities in the fields of fleet management systems and autonomous heavy-duty vehicles. Additionally, to identifying broad possibilities and obstacles, it carried out a quadrant analysis to determine their relative importance. The project's strengths, weaknesses, opportunities, and threats were all assessed as part of CARA's SWOT analysis, which offered a thorough assessment of the project's present situation and potential outcomes.

In conclusion, this report offers thorough insights into the market for autonomous heavy-duty vehicles in fleet management systems and logistical operations. The report emphasizes market segmentation, dynamics, and competitive environments and compares AWARD to already available solutions. For stakeholders in the transportation and logistics sector, the SWOT analysis, the identification of hurdles, and the SWOT analysis provide helpful direction.

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13. ANNEX.

13.1. Porter's five forces analysis explanation

"*The essence of strategy formulation is coping with competition. Yet it is easy to view competition too narrowly and too pessimistically. While one sometimes hears executives complaining to the contrary, intense competition in an industry is neither coincidence nor bad luck.*

Moreover, in the fight for market share, competition is not manifested only in the other players. Rather, competition in an industry is rooted in its underlying economics, and competitive forces exist that go well beyond the established combatants in a particular industry. Customers, suppliers, potential entrants, and substitute products are all competitors that may be more or less prominent or active depending on the industry.

The state of competition in an industry depends on five basic forces, which are diagrammed in the Exhibit. The collective strength of these forces determines the ultimate profit potential of an industry. It ranges from intense in industries like tires, metal cans, and steel, where no company earns spectacular returns on investment, toward mild in industries like oil field services and equipment, soft drinks, and toiletries, where there is room for quite high returns."

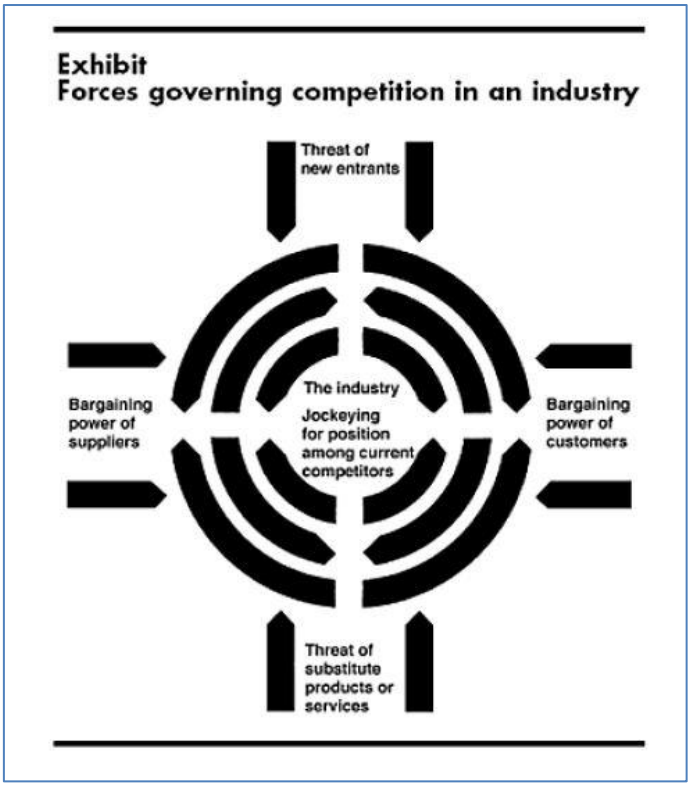


Figure 25 Porter's five forces (1979)[49]

[49] Porter, M. E. "How Competitive Forces Shape Strategy." Harvard Business Review 57, no. 2 (March–April 1979): 137–145.

Following the original input from Michael Porter we could conclude that Porter's Five Forces is a business analysis model helping to explain why various industries are able to sustain different levels of profitability. Before analyzing the AWARD-related use cases and business areas we want to provide you with a short definition of the five forces itself[50]:

a. Threat of substitute products or services,
b. Bargaining power of supplier,
c. Bargaining power of buyers,
d. Threat of new entrants,
e. Rivalry among existing competitors.

Threat of substitute products or services
A substitute is another product or service that meets the same underlying need that the industry's product meets in a different way. Videoconferencing is a substitute for travel. Email is a substitute for express mail. The threat of a substitute is high if it offers an attractive price-performance trade-off versus the industry's product, especially if the buyer's cost of switching to the substitute is low.

Bargaining power of supplier
Companies in every industry purchase various inputs from suppliers, which account for differing proportions of cost. Powerful suppliers can use their negotiating leverage to charge higher prices or demand more favourable terms from industry competitors, which lowers industry profitability. If there are only one or two suppliers of an essential input product, for example, or if switching suppliers is expensive or time consuming, a supplier group wields more power.

Bargaining power of buyers
Powerful customers can use their clout to force prices down or demand more service at existing prices, thus capturing more value for themselves. Buyer power is highest when buyers are large relative to the competitors serving them, products are undifferentiated and represent a significant cost for the buyer, and there are few switching costs to shifting business from one competitor to another. They can play rivals against each other – especially if an industry's products are undifferentiated, it's inexpensive to switch loyalties, and price trumps quality. There may be multiple buyer segments in a given industry with different levels of power.

Threat of new entrants
The threat of new entrants into an industry can force current players to keep prices down and spend more to retain customers. Actually, entry brings new capacity and pressure on prices and costs. The threat of entry, therefore, puts a cap on the profit potential of an industry. This threat depends on the size of a series of barriers to entry, including economies of scale, to the cost of building brand awareness, to accessing distribution channels, to government restrictions. The threat of entry also depends on the capabilities of the likely potential entrants.

[50] The Five Forces - Institute For Strategy And Competitiveness - Harvard Business School. (n.d.). The Five Forces - Institute for Strategy and Competitiveness - Harvard Business School. https://www.isc.hbs.edu/strategy/business-strategy/Pages/the-five-forces.aspx

If there are well established companies in the industry operating in other geographic regions, for example, the threat of entry rises.

Rivalry among existing competitors
If rivalry is intense, it drives down prices or dissipates profits by raising the cost of competing. Companies compete away from the value they create. Rivalry tends to be especially fierce if:

- Competitors are numerous or are roughly equal in size and market position,
- Industry growth is slow,
- There are high fixed costs, which create incentives for price cutting,
- Exit barriers are high,
- Rivals are highly committed to the business,
- Firms have differing goals, diverse approaches to competing, or lack familiarity with one another.

13.2. Market trends sources

DHL Logistics Trend Radar

The DHL Logistics Trend Radar is based on over 13,000 DHL customers, partners, and employees who visit the DHL Innovation Centers every year, providing DHL experts with invaluable feedback to develop the DHL Logistics Trend Radar. Figure 26 shows one result focusing on 'Auto-Mobility'-related trends clustered in low, medium and high impact areas.
A further classification within this figure is done by dividing trends into social & business trends as well as technological trends. In total, the DHL Logistics Trend Radar contains 29 key trends.

The most important social & business trends are:

- Supergrid Logistics,
- Next-Generation Security,
- Sustainable Logistics,
- Logistics Marketplaces,
- Future of Work,
- Omnichannel Logistics.

The most important technology trends identified are:

- Self-Driving Vehicles,
- Artificial Intelligence,
- Robotics & Automation,
- Internet of Things,
- Cloud & APIs,
- Big Data Analytics.

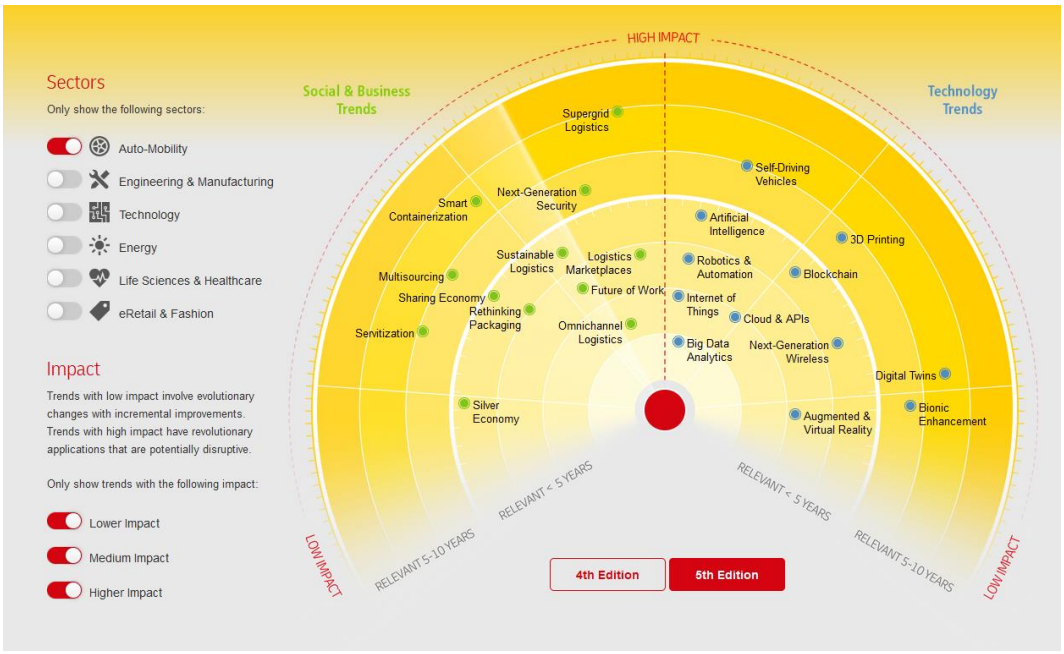


Figure 26 Auto-Mobility-related trends bases on the DHL Logistics Trend Radar

Trendmanager tool

Based on the Trendmanager tool (www.trendmanager.com) a trend analysis was performed. The online tool Trendmanager helps companies and projects, as AWARD, to identify and systematically monitor the trends that are relevant for them. Currently 50 mega-trends, 352 macro-trends and 38052 microtrends are part of the Trendmanager tool.

13.3. Market drivers

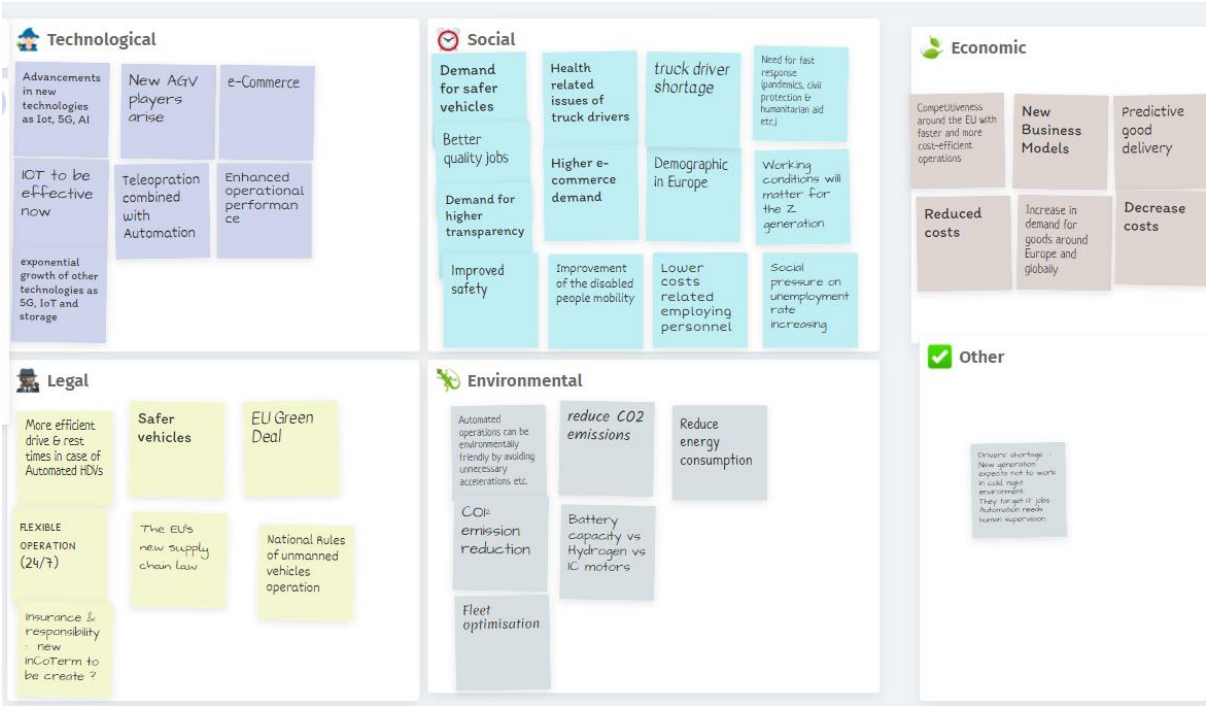


Figure 27 PESTEL concepts

Technological drivers:

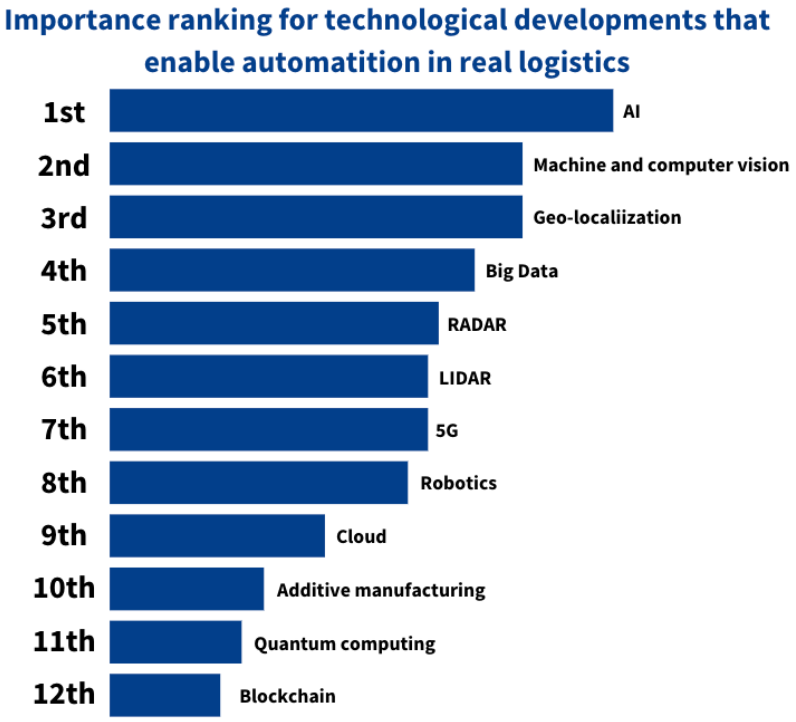


Figure 28 Importance ranking for technological developments that enable automation in real logistics

Economic drivers:

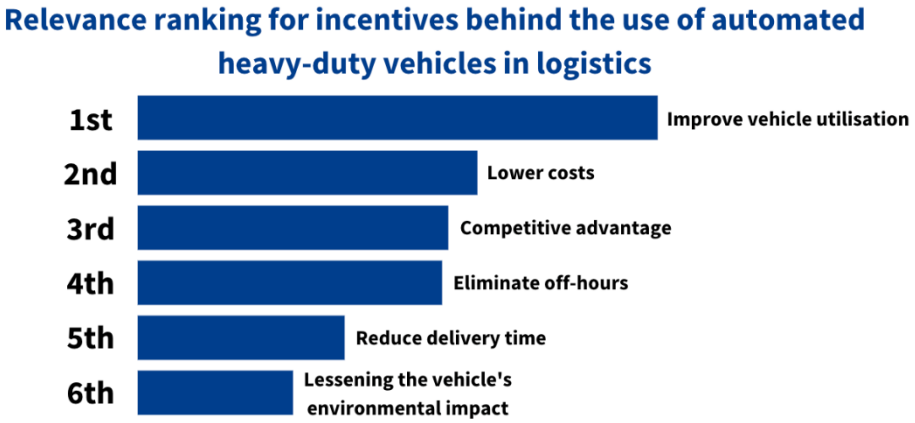


Figure 29 Relevance ranking for incentives behind the use of automated heavy-duty vehicles in logistics

Social drivers:

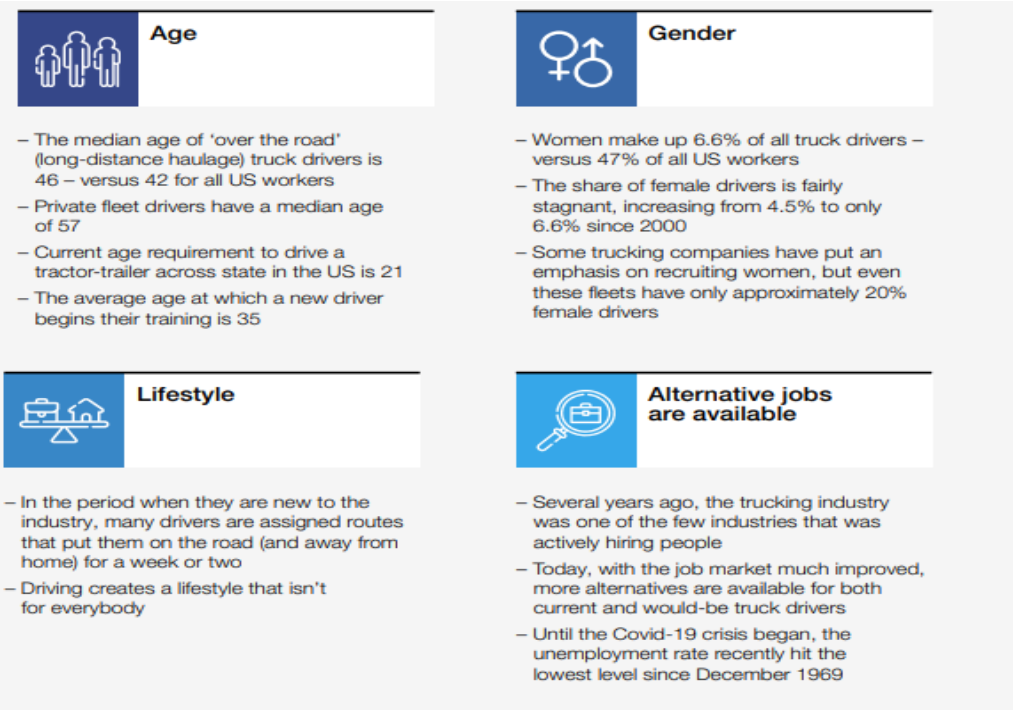


Figure 30 Social drivers overview

Environmental drivers:

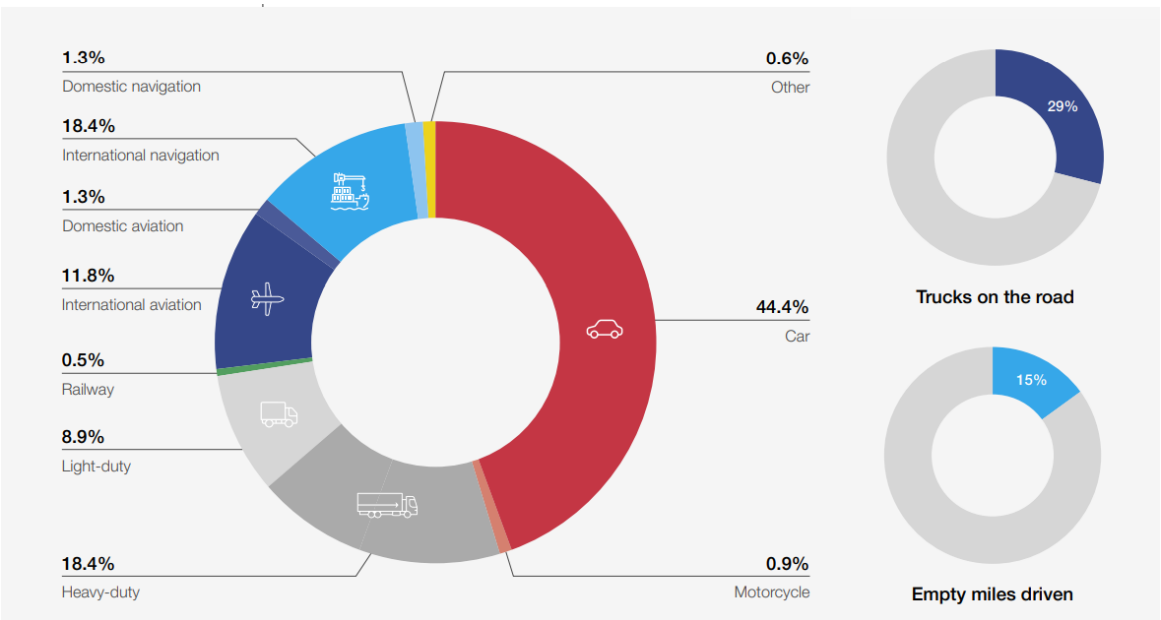


Figure 31 share of GHGs in EU transport sector

13.4. Market size

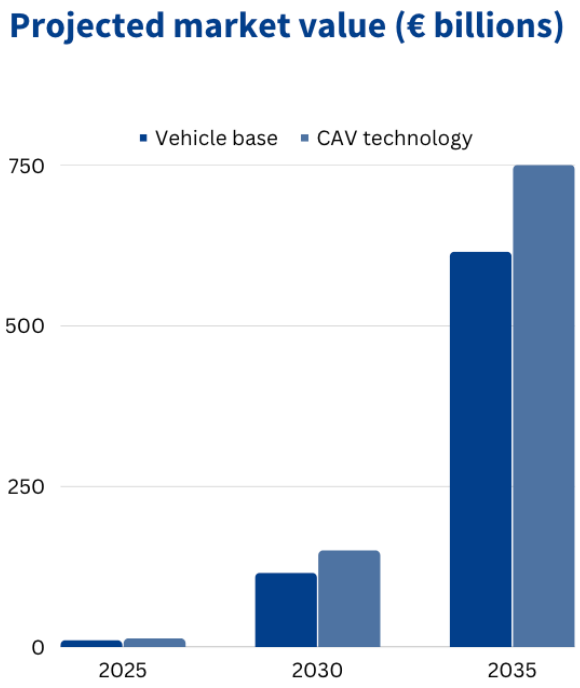


Figure 32 Projected market value

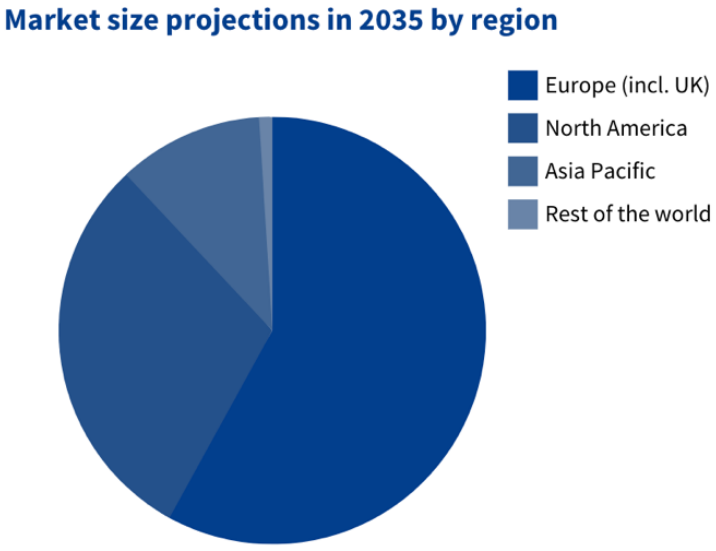


Figure 33 Market size projection in 2035 by region[51]

[51] Market Research Company offers Syndicate & Custom Market Research Reports with Consulting Services - Allied Market Research. (2023, May 1). Market Research Company Offers Syndicate & Custom Market Research Reports With Consulting Services - Allied Market Research. https://www.alliedmarketresearch.com/autonomous-vehicle-market)

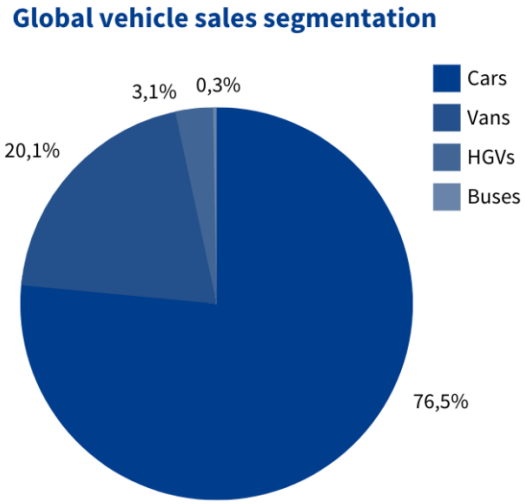


Figure 34 Global vehicle sales segmentation[52]

13.5. Competitive landscape for autonomous heavy-duty vehicles

PALFINGER	***PRODUCT***	***FACTS***
Company description: *Founding year: 1932* *Nb employees: 11,000 approx.* *Turnover: € 1.53 billion* *Group members: Palfinger Marine, Palfinger Platforms*	*Heavy Duty material handling equipment* • *Payload: Up to 2.5 T* • *Drive system: diesel* 	*Past projects:* • *Fully electric offshore cranes (2018)*

ek·robotics	***PRODUCT***	***FACTS***
Company description: *Founding year: 2006* *Nb employees: 200* *Turnover: € 27.8 Million (ek robotics, 2019)*	*Heavy Duty material handling equipment* • *Payload: Up to 20T* • *Drive system: diesel and electric*	*Past AGVs projects:* • *Outdoor AGV for Tricor in Bad Wörishofen (2014)* • *Cutom Mover for JTI, Trier (2018)*

[52] Market Research Company offers Syndicate & Custom Market Research Reports with Consulting Services - Allied Market Research. (2023, May 1). Market Research Company Offers Syndicate & Custom Market Research Reports With Consulting Services - Allied Market Research. https://www.alliedmarketresearch.com/autonomous-vehicle-market)

TII KAMAG	**PRODUCT**	**FACTS**
Company description: *Founding year: 1969* *Nb employees: 300* *Turnover: € 190 Million (TII Group, 2020)* *Parent organization: TII Group*	*Heavy Duty Logistics vehicles.* • *Payload: Up to 17T* • *Drive system: diesel and electric* 	*Past AGVs projects:* • *Demonstration at CeMAT (2018)* *Other funded projects:* • *SAFE20* • *SAFE3LY* *Partnerships:* • *Automation PoC with DB Schenker (2018)* • *Teleoperation PoC with Fernride (2021)*

KONECRANES	**PRODUCT**	**FACTS**
Company description: *Founding year: 1994* *Nb employees: 16,900* *Turnover: € 3.2 Billion (Konecranes Group, 2020)*	*Heavy Duty container port equipment* • *Payload: 70t* • *Drive system: diesel and electric* 	*Past AGVs projects:* • *AGVs Long Beach Container Terminal (2020)* *Other funded projects:* • *GAMA* • *PRODUCTIVE 4.0* • *OPTIMUM* *Partnerships:* • *Automated Terminal Tractor with Terberg (2018)* • *FRESH wit HHLA (2019)*

KALMAR	**PRODUCT**	**FACTS**
Company description: *Founding year: 1997* *Nb employees: 5.500* *Turnover: € 1.5 Billion (Kalmar, 2020)* *Parent Organization: Vehiclegotec*	*Heavy Duty yard logistics & container port equipment* • *Payload: up to 70t* • *Drive system: diesel and electric*	*Past AGVs projects:* • *PSA Singapore (2015)* • *Kalmar Fastcharge (2018)* *Partnerships:* • *Terminal Automation with Nokia (2021)* • *Strategic Cooperation with Sichuan Port & Shipping Group (2021)*

E/NRIDE	**PRODUCT**	**FACTS**
Company description: *Founding year: 2016* *Nb employees: appx. 100* *Turnover: appx. € 10 Million (annual)* *Funding: appx. $ 150 Million*	*Heavy Duty Logistics vehicles* • *Payload: up to 16t* • *Drive system: electric* 	*Past AGVs projects:* • *DB Schenker (2018)* • *Lidl, Coca Cola, Michelin (2019)* • *Oatly (2020)* *Other funded projects:* • *Tripple F (19 – 21)* *Partnerships:* • *5G with Ericsson & Telia (2018)* • *Innovation Partnership with Port of Helsingborg (2019)*

STÄUBLI WFT	**PRODUCT**	**FACTS**
Company description: *Founding year: 2018* *Nb employees: appx. 90* *Turnover: appx. € 8,4 Million (Stäubli – WFT,2019)* *Parent organization: Stäubli*	*Heavy duty logistics & special vehicles* • *Payload: up to 500t* • *Drive system: electric* 	*Partnerships:* • *Automation partnership with BMW (2018)*

TERBERG SPECIAL VEHICLES	**PRODUCT**	**FACTS**
Company description: *Founding year: 1869* *Nb employees: appx. 260* *Turnover: € 216,7 Million (Terberg, 2019)* *Parent organization: Royal Terberg Group*	*Heavy duty logistics & special vehicles* • *Payload: up to 36T* • *Drive system: diesel, electric & hydrogen*	*Past AGVs projects:* • *Terberg launches AutoTUG on TOC Europe Conference (2017)* *Other funded projects:* • *Living Lab Zeeland (2019 – 2023)* *Partnerships:*

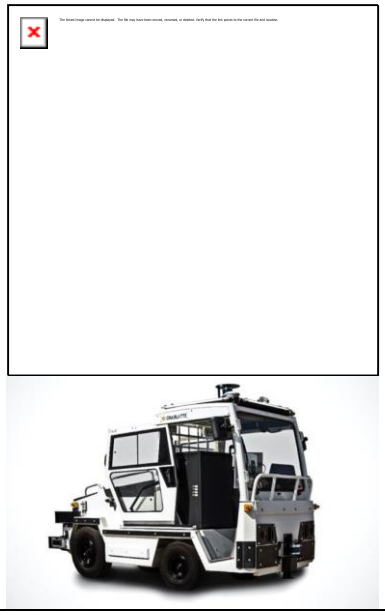
		• *Automated Terminal Tractor with KONECRANES (2018)* • *Autonomous Tractor with ZF (2019)* • *Unmanned Truck with ASI, Phantom Auto and FANUC (2020)* • *Teleoperation with Fernride (2021)*

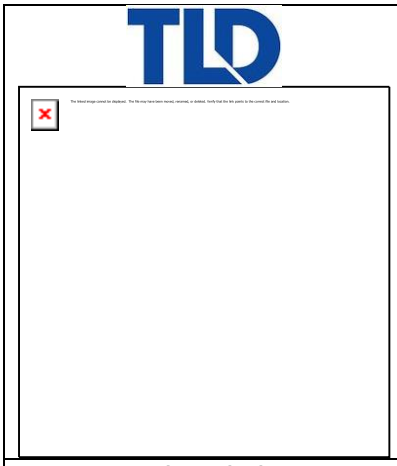
GAUSSIN Be Faster... Safer & Cleaner	***PRODUCT***	***FACTS***
Company description: *Founding year: 1880* *Nb employees: appx. 310* *Turnover: € 40,3 Million (GAUSSIN, ,2020)* *Parent organization: GAUSSIN Group*	*Heavy duty logistics & special vehicles* • *Payload: up to 65T* • *Drive system: electric & hydrogen* 	*Past AGVs projects:* • *Tuas Megaport project Singapore (2019)* *Partnerships:* • *Long term partnership with ST Engineering Land System (2019)* • *Airport logistics with SIEMENS (2019)*

VDL	***PRODUCT***	***FACTS***
Company description: *Founding year: 2016 (VDL Automated Vehicles)* *Nb employees: 15,464 (VDL Group)* *Turnover: € 4.7 Billion (VDL Group, ,2020)* *Parent organization: VDL Group*	*Heavy duty public transport & special vehicles* • *Payload: up to 70T* • *Drive system: electric & diesel* 	*Past AGVs projects:* • *Automated Yard TractorKatoen Natie Singapore Pte. Ltd (2017)* • *Heavy Duty AGVs for BASF (2017)* *80 AGVs Singapore Port (2019)*

VOLVO	***PRODUCT***	***FACTS***
Company description: *Founding year: 1928 (Volvo Trucks)* *Nb employees: 96,194 (Volvo Group)* *Turnover: € 20,6 Billion (Volvo Trucks, ,2020)* *Parent organization: Volvo Group*	*Heavy duty vehicles (Trucks)* • *Payload: up to 36T* • *Drive system: electric & diesel* 	*Past AGVs projects:* • *Bronnoy Kalk AS in Norway (2018)* • *DFDS Göteborg (2019)* *Partnerships:* • *AI platform for autonomous trucks with NVIDIA (2019)* • *Autonomous transport solutions with Aurora (2021)*

CHARLATTE MANUTENTION FAYAT GROUP	***PRODUCT***	***FACTS***

Company description: *Founding year: 1961* *Nb employees: 97 (France)* *Turnover: € 70 Million (Charlatte, Annual)* *Parent organization: FAYAT Group*	*Heavy duty vehicles (Trucks)* • *Towing capacity: up to 30T* • *Drive system: electric* 	*Past AGVs projects:* • *Toulouse-Blagnac Airport (2019)* • *GEODIS logistics company (2021)* *Partnerships:* • *Autonomous tractor for industrial sites and airports with Navya (2018)*

	***PRODUCT***	***FACTS***
Company description: *Founding year: 1987* *Nb employees: 1900 (TLD Group)* *Turnover: € 700 Million (Alvest Group, 2019)* *Parent organization: Alvest Group*	*Heavy duty vehicles (Trucks)* • *Towing capacity: up to 25T* • *Drive system: electric*	*Past AGVs projects:* • *Japan Airlines (2019)* • *Shiphol Airport (2021)* • *PSA Sochaux (2021)* *Partnerships:* • *Autonomous tractor for industrial sites and airports with EasyMile (2017)*

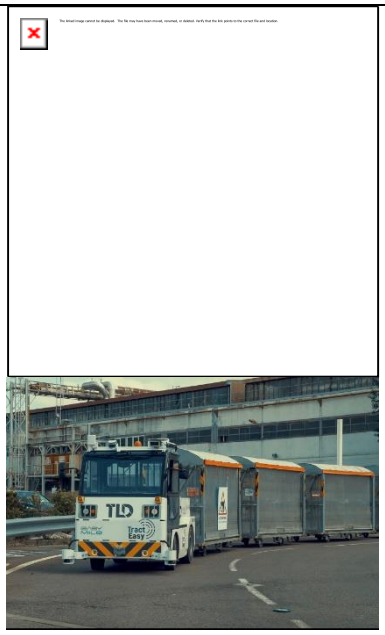
		
WESTWELL	***PRODUCT***	***FACTS***
Company description: *Founding year: 2015* *Nb employees: 80* *Turnover: Unknown*	*Heavy duty vehicles (Trucks)* • Towing capacity: up to 90T 	*Past AGVs projects:* • Hutchinson Ports Thailand (HPT) with 6 vhc (12 months trial in 2020-2021) • In Xinjiang, the Q-Truck fleet operates at the International Land Port of Urumqi • Tests at the Port of Felixstowe
SANY	***PRODUCT***	***FACTS***
Company description: *Founding year: 1989* *Nb employees: 90 000* *Turnover: 16 billion USD*	*Heavy duty vehicles (Trucks)* 	*Multiple partnerships announced:* • JV with Pony.ai & NVIDIA
Weisheit	**PRODUCT**	**FACTS**
Company description: Unknown	Heavy duty vehicles (Trucks)	• Unknown

Table 3 Heavy Duty Vehicle OEMs

Company	Retrofit vs. Integrated	OEM Partners	Safety approach	Autonomous navigation technology	Funding	Footprint
aidrivers	Retrofit		Unknown	Free (LiDAR SLAM)	Private equity	Global, port industry focus
easymile	Integrated	TLD, KAM AG, Terberg, AIT(Palfinger)	Inhouse hardware and software developments	Free (LiDAR SLAM)	Private equity	Global
GOTTING	Retrofit		Safety sensors based	Guided (transponders)	Family owned	Germany centred & EU
navya	Integrated	Charlatte	Safety sensors based	Free (LiDAR SLAM)	Public & private equity	Global

Table 4 Main European companies with autonomous outdoor logistics solutions

13.6. Competitive landscape for fleet management

Fleet operator/OEM	Description	Selling FMS	Vehicle agnostic	Data integration	Data analytics	Partnerships and customers	Market
Daimler Trucks	Manufacturer of commercial trucks and buses part of Daimler AG	Yes: Fleetboard	Agnostic	Yes	Yes	Trimble, Zonar	Globally
PACCAR	Manufacturer of commercial trucks and buses under brands like Kenworth, Peterbilt, DAF	Yes: Peterbult SmartLINQ	Agnostic	Yes	Yes	Trible, Omnitracs, Verizon Connect	Globally
SCANIA	Manufacturer of commercial trucks and buses	Yes: Scania Fleet Management	Agnostic	Yes	Yes	Trimble, TomTom, Vehco	Globally
ZOOX	Autonomous vehicle company acquired by Amazon (2020)	Not for external sources	No (only for Zoox vehicles)	Yes	Yes	Amazon, Luminar	United States
Cruise	Autonomous vehicle company	Not for external sources	No (only for Cruise vehicles)	Yes	Yes	GM, Honda	United States
Gaussin	Technology company that designs, assembles, and manufactures heavy-duty logistics (i.e.,	Yes: G-Track	Agnostic	Yes	Yes	Port of Los Angeles, the Port of Rotterdam, and the French logistics company FM Logistic.	Globally

	electric, and autonomous vehicles, transportation systems, and fleet management)						
STILL	Supplier of electric and diesel-powered forklift trucks, warehouse equipment, and intralogistics solutions.	Yes: STILL FleetManager	Agnostic	Yes	Yes	BMW, and Lufthansa Cargo.	Globally
Mack Trucks	Manufacturer of commercial trucks and buses (subsidiary of Volvo Group)	Yes: GuardDog Connect	Agnostic	Yes	Yes	Geotab, Omnitracs	Globally
Navistar	Manufacturer of commercial trucks and buses	Yes: OnCommand Connection	Agnostic	Yes	Yes	Geotab, Verizon	North America

Table 5 Fleet operators/OEMs developing FMS

ADAS provider	Description	Selling FMS	Vehicle agnostic	Data integration	Data analytics	Partnership and customers	Market

Robert Bosch GmbH	OEM specialized in automotive and industrial technology	Yes: Connected Transport	Yes	Yes	Yes	TomTom, Here Technologies, Trimble Transportation, DB Schenker, Lidl, UPS, FedEX, DHL	Globally
Continental AG	OEM specialized in tires, brake systems, automotive safety and powertrain components	Yes: VDO FleetVisor	Yes	Yes	Yes	Zonar Systems, Geotab, Verizon Connect, UPS, FedEx, Deutsche Post	Globally
ZF Friedrichshafen	OEM specialized in driveline, chassis and passive safety technology	Yes: Openmatics and ZF Scalar	Yes	Yes	Yes	MAN, Volvo, Daimler	Globally
WABCO	Supplier of braking system and safety technology	Yes: TX-FUELCOMPASS	Yes	Yes	Yes	DHL, Volvo Trucks, Hino Motors, UPS, FedEX	Globally
SIEMENS	Multinational specialized in energy, transportation and healthcare	Yes: Synalytics	Yes	Yes	Yes	London Bus Services, Singapore's Land Transport Authority, and the Regional Transportation Commission of Southern Nevada. Deutsche Bahn, Lufthansa, UPS	Globally
EasyMile	Technology company focused on ADAS solutions for autonomous transportation	Yes: Easymile fleet management	Yes	Yes	Yes	RATP Group, Keolis, First Transit Cities: Columbus, Ohio, and the Dubai Roads and Transport Authority.	Europe and United States

Table 6: ADAS providers developing FMS

ADAS provider	Description	Vehicle agnostic	Data integration	Data analytics	Established partnerships and customers	Market

Fleet Complete	Offering fleet management, asset tracking, and Internet of Things (IoT) solutions, Fleet Complete is a leading global supplier of connected vehicle technology. Businesses may enhance productivity, safety, compliance, and customer service thanks to their solutions. They provide a thorough fleet management solution with GPS monitoring, telematics, dispatch, and analytics.	Yes	Yes	Yes	General Motors, Ford	Globally
Fleetio	Fleetio provides a telematics and data analytics-enabled fleet management system that is independent of the type of vehicle being used. The system, known as Fleetio, operates on a global scale.	Yes	Yes	Yes	Bridgestone, FleetCore, Zipcar	Globally
Autofleet	Autofleet provides a telematics and data analytics-enabled fleet management system that is independent of the type of vehicle being used. The system, known as Autofleet, focuses on controlling autonomous cars.	Yes	Yes	Yes	Aurora, Nvidia, HERE technologies, Avis Budget Group, Zipcar, Keolis, Suzuki, Bluebird (Indonesia taxi provider), Revel (electrified transportation company)	Asia, United States
Via	Via provides a telematics and data analytics-enabled fleet management system that is independent of the type of vehicle being driven. Via is the name of the system, which manages ride-hailing and shared mobility services.	Yes	Yes	Yes	EasyMile, May, Motional, Navya, Mercedes Benz, Keolis, Berliner Verkehrsbetriebe (BVG).	Globally[53]
Synaos	Synaos provides a telematics and data analytics-enabled fleet management system that is independent of the type of vehicle being used. The system, known as Synaos, operates on a worldwide scale.	Yes	Yes	Yes	AGV/AMR OEMS: STILL, Linde, Gotting, etc	Europe (Germany, Austria, etc)

[53] United States, United Kingdom, Germany, Japan, Australia

Idealworks	Idealworks provides a telematics and data analytics-enabled fleet management system that is independent of the type of vehicle being used. Ideal Fleet is the name of the system, which focuses on managing autonomous vehicles.	No: only for AVs	Yes	Yes	BMWGroup, Schiller, WFT, Staubli, Mobileye, Baidu	Germany mainly
Onfleet	Onfleet provides a telematics and data analytics-enabled fleet management system that is independent of the type of vehicle being driven. Onfleet is the name of the system, which focuses on fleet management for last-mile deliveries.	Yes	Yes	Yes	Postmates, Instacart, Shopify	-
Samsara	Samsara provides a telematics and data analytics-enabled fleet management system that is independent of the type of vehicle being driven. The system, known as Samsara, functions on a worldwide scale.	Yes	Yes	Yes	Summit, Univar Solutions FBM (Foundation Building Materials)	Globally

Table 7: Fleet management software companies

13.7. Benchmarking by countries

Company	Category (use case)	All weather	Demonstrated project
United States			
Einride	Cabinless autonomous truck (last mile, movements of goods from manufacturing facility to warehouse)	No information reported	Public road pilot in Selmer, Tennessee Link
Daimler Truck with TORC robotics	Autonomous truck (long haul)	No information reported	Public road pilot under defined environment along major trucking routes with steady, high speed (across US states) Link
WAYMO	Autonomous truck (last mile)	Operate under heavy rain and fog	Public road pilot under defined environment along major trucking routes with steady, high speed (Dallas to Houston route) Link
Plus.AI	Semi-autonomous and fully autonomous truck (long-haul)	No information reported	Public road pilot across US states with IVECO Link
TuSimple	Autonomous truck (long-haul, last mile)	No information reported	Public road pilot covering 550 miles in Arizona Link
Kodiak Robotics	Autonomous truck (long-haul)	Operate under harsh weather	Public road pilot, +800 miles across the US Link
Embark Trucks	Autonomous truck (long-haul)	Operate under heavy snow (Montana)	Public road pilot across US Link
Thordrive	Autonomous cargo and baggage tractor (aviation ground support operations)	No information reported	Aviation ground support operations at C

			Cincinnati/Northern Kentucky International Airport Link
Outrider	Autonomous tow tractor (yard operations)	No information reported	Autonomous yard operations/from warehouse to public roads across US states Link
ASI	Autonomous tow tractor (yard operations)	No information reported	Autonomous yard operations/from warehouse to public roads across US states Link
Singapore			
AiDrivers (UK based company, deployment in Singapore)	Autonomous Truck (Yard truck, port logistic)	Operate under any weather condition	Proof of Concept project with PSA Singapore Link
Venti Technology (Singapore)	Autonomous Truck (Yard truck, port logistic) Autonomous tow tractor (Industrial Logistic)	Operate with monsoon rain	There is no official release of demonstrated project
BYD/ST Engineering (Singapore)	Autonomous tow tractor (Industrial Logistic) AMR/AGV (Port logistic)	No information reported	Only information on product release Link
Singpilot (Singapore)	Autonomous tow tractor (Industrial Logistic)	No information reported	No information reported
China			
UISEE/GoodSense	T30 tow tractor	Weather capability (winter condition, monsoon)	Logistics Vehicles Fleet in Urumqi International Airport Link
	(Industrial Logistic)		Trial project with Baiyun Airport Logistics Vehicles Link
InceptioTechnologu	Semi-autonomous and autonomous truck (long-haul)	No information reported	China's first L4 driverless heavy-duty truck test in Shandong
			China L4 public road driving license

			Link
Alibaba Damo Academy/Alibaba Holding Group	Autonomous truck (long-haul)	No information reported	Autonomous truck without a driver behind the steering wheel on open roads in Zhejiang
			Link
PonyTron	Autonomous truck (long-haul)	Operate under heavy rain	Autonomous truck test on open expressways
(Pony.ai joint venture with Sany Heavy Truck)			Link
Cyantron (Pony.ai joint venture with Sinotrans)	Autonomous truck (long-haul)	Operate under heavy rain	Autonomous truck test on public roads in Dongguan Link
Plus.AI	Autonomous truck (long-haul)	No information reported	Autonomous truck demonstration on Wufengshan highway in Jiangsu province
			Link
Westwell lab	Qomolo Q-Truck	No capabilities	Promoted the implementation of AIGT autonomous driving at Qingdao Port
	(Yard truck, port logistic)		Fully autonomous driving project at Tianjin port
			Link
Others (Thailand, Vietnam, Japan, and Taiwan)			
WestWell (China company, deployment in Thailand)	Qomolo Q-Truck	No capability	Latest project with Hutchison Ports Thailand : deployment of 6 prototype trucks for a period of testing and integration Link
	(Yard truck, port logistic)		
AIRO/ZMP (Japan/Vietnam)	CarriRo Tractor 25T	No information reported	Proof of Concept project with Narita International Airport Link
Toyota Industries (Japan)	Autonomous tow tractor	No information reported	Partnership with All Nippon Airways

	(Industrial Logistic)		(ANA) in Tokyo Haneda Airport Test of autonomous tow tractor Link
Noveltek (Taiwan)	Autonomous tow tractor (Industrial Logistic)	No information reported	No information reported
France			
Charlatte/Navya	Autonom® Tract AT135 (Industrial Logistic)	performance under wide weather conditions	Experimental project in real conditions with GEODIS Link
Gaussin	ATM & APM (Yard truck, port logistic)	moderate rain or snow	No information reported
ECA GROUP	Goods transport car (not a tow tractor) (Industrial logistic)	Operational in all weather conditions	Project with French supply chain provider IDEA. A German manufacturer will test ECA GROUP's outdoor autonomous mobile robot in real operating conditions
Spain			
Synersight	CMV25000 (Industrial Logistic)	No information reported	No information reported
DTA	Autonomous guided vehicle (industrial logistics, aerospace industry)	No information reported	AGV with a load capacity of 1.2 tons, implemented inside a fabric Link
BAMA sistemas	Autonomous guided vehicle/ autonomous mobile robots	No information reported	Link
Proyecto R3CAV (Renault, Alsa, GMV, Indra, Masmovil, etc.)	To develop an autonomous vehicle (L4) for industrial logistics in controlled environments	No capabilities	Ongoing project
Germany			
Hamburg TruckPilot (MAN truck & Bus and Hamburger Hafen und Logistik AG)	Autonomous truck (Long-haul – container handling)	No information reported	Use of autonomous trucks in port terminals for container handling at HHLA Container Terminal Altenwerder Link

ATLAS L4 (MAN Truck & Bus, Knorr – Bremse, Leoni, Bosch, Fernride)	Autonomous truck (hub to hub)	No information reported	Autonomous truck project for operation on national roads and highways Link
Gotting AGV	Tow tractor/AGVs (container handling and long haul)	No information reported	No information reported Link
Plus.AI and IVECO	Autonomous truck (long haul)	No information reported	Public road pilot across Germany with IVECO Link
United Kingdom			
AiDrivers	Autonomous Truck (Yard truck, port logistic)	Operate under any weather condition	Latest project with AD Ports Group proof of concept Link
Aurrigo	Auto dolly (container airport logistic)	operate in snow, heavy rain, direct sunlight and fog	No information reported
5G CAL (Vantec, Nissan, Terberg)	Autonomous truck (industrial logistics, hub to hub)	No information reported	Proof of concept, autonomous truck to drive between Vantec and Nissan Link

Table 8 Benchmarking by countries