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The Introduction of Self-driving / Full-automation Trucks – will we live among these modern dinosaurs?

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ABSTRACT:

Road transportation accounts for most of the freight transportation in the EU, with trucks responsible for 71.3 percent of all inland EU freight movements. The trucking industry in the EU is facing several challenges and Self-driving Trucks (SDTs) seem to be a promising solution to its problems. This study explores the current state of self-driving technologies and the benefits and drawbacks associated with SDTs. Furthermore, the study tries to examine how the European public perceives the use of SDTs.

This study utilized a mixed method, integrating qualitative and quantitative: Qualitative data were collected by means of a thorough literature review. The public's perception was assessed through a survey, from which quantitative data were extracted. There were 256 participants who answered the survey.

Key findings are that the EU public is aware of Self-driving Vehicles (SDVs) but less aware of SDTs. Most people perceive self-driving technology positively and believe that the implementation of SDTs will have profound effects on both the logistics as well as the trucking industry in particular. Even though most participants perceived SDVs to drive better than humans, thus increasing road safety, 67.2 percent did not want to share the road with them. This raises severe challenges for policy makers towards public acceptance of their wide-scale introduction.

KEYWORDS:

automation, automated driving, self-driving truck, public perception, freight transport

JEL classification:

M10, M19, R41

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List of Abbreviations

ACC	Adaptive Cruise Control
ACEA	Automobile Manufacturers Association
ADAS	Advance Driver Assistance System
ADS	Automated Driving System
AEB	Autonomous Emergency Braking
AGV	Autonomous Ground Vehicle
AHS	Autonomous Haulage System
ALKS	Automated Lane Keeping Systems
ATA	American Trucking Association
ATS	Autonomous Trucking System
AV	Autonomous Vehicle
DARPA	Defense Advanced Research Projects Agency
DL	Deep Learning
DRL	Deep Reinforcement Learning
ECOSOC	United Nations Economic and Social Council
ECU	Engine Control Unit
EU	European Union
FIS	Forschungs Informations System
GHG	Greenhouse Gases
GPS	Global Positioning System
ITS	Intelligent Transportation System
LCA	Lane Centering Assistance
LDWS	Lane Departure Warning System
LIDAR	Light Detection and Ranging
LKA	Lane-Keeping Assistance
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
RADAR	Radio Detecting and Ranging
RL	Reinforcement Learning
SAE	Society of Automotive Engineers
SDT	Self-driving Truck
TCO	Total Cost of Ownership
ToF	Time-of-Flight
UNECE	United Nations Economic Commission for Europe
UTS	United Technical Services
V2V	Vehicle-To-Vehicle

Introduction

Worldwide, road transportation is the most widely utilized mode of transportation. Road transportation is also the most prominent mode of freight transport in the EU. The European road freight market was valued at 324.5 billion euros in 2020 (Statista Research Department, 2022). Further indicated by Eurostat (2022d), road transport in 2020 accounted for 54.7 percent of all transport performance in the European Union, measured in ton-kilometers, followed by sea transport (29 percent) and rail transport (11.9 percent). Additionally, Statista (2022) revealed that in 2020, 77.4 percent of all inland freight in the European Union was transported by road, with trucks responsible for 71.3 percent of all inland freight (ACEA, 2021). In 2021, over two-thirds of the road freight transported across the EU was transported by haulers from Germany, France, Spain, Poland, and Italy (Eurostat, 2021b). As part of a logistics chain that encompasses inland waterways, road, air, and rail transport, trucks play a very crucial role. Global supply chain and logistic markets rely heavily on trucks as these are also vital for other modes of transportation for carrying freight between ports, depots, airfields, and rail terminals. Moreover, for most goods and freight, trucks are the most economical, responsive, and flexible form of transportation. There are currently about 6.2 million trucks on the roads across the EU (ACEA, 2021).

There have been several trends and challenges that have significant impacts on the trucking industry. One of the most pressing problems is the shortage of truck drivers, which is predicted to get more serious over time (McKinnon et al., 2017, p. 25; IRU, 2021; White Paper, 2021, p. 6). The introduction of innovative technologies like self-driving technology represents a promising and appealing solution for the trucking industry's problems. Self-driving technology can be beneficial for road freight transport in terms of safety, efficiency, and economics eventually (Van Meldert & De Boeck, 2016; Engström et al., 2018; Müller & Voigtländer, 2019). This technology is evolving rapidly and is foreseen to impact future transportation and mobility significantly. It is possible that automated driving will commence to take off in the freight transportation sector as a large-scale application, Self-driving Trucks (SDTs). This paper will take a further step toward a better understanding of SDTs and their potential benefits and drawbacks of their adoption. The paper focuses primarily on long-haul road freight transportation, in which SDTs are most likely to play a significant role, as will be discussed later.

Public perception has a great deal of influence on the acceptance and adoption of any new technology. Consequently, a favorable public opinion is crucial to SDTs widespread adoption. The public's perception in the EU of SDTs was another focal point analyzed in this study. Through it, the authors hope that relevant stakeholders will gain a greater understanding of the public's perspective and be able to consider certain steps such as improving technologies and implementing suitable communication and implementation strategies based on feedback from the public.

National and International Regulation of SDTs is a complex field in itself and several initiatives towards formulating and testing the rules that will govern production and operation of SDTs in the public sphere are under way. Due to the scope limitations of this study, these initiatives have been omitted from the current study.

Aims and Objectives

Studying how Self-driving Trucks (SDTs) are being developed and implemented in the trucking industry is the primary purpose of this study. The study will begin by examining the current trends and challenges faced by the trucking industry. The study will determine how SDTs could improve the field of logistics, especially in the transportation of goods on roads. At the same time, the study will investigate the possible challenges and barriers that SDTs may encounter along the way. An evaluation of the literature will be conducted on several studies that address different aspects and topics regarding SDVs and SDTs. Also included in this study are regulations and policies regarding automated/autonomous driving in the EU. A questionnaire survey is being conducted to gather primary data to determine public perception about SDTs for logistic purposes. The following is a comprehensive list of what the study aims to accomplish:

1. To understand Self-driving Vehicles, different levels of automation and their technology.
2. To understand SDTs and Truck Platooning and how SDTs are being tested
3. To discover the benefits of SDTs.
4. To explore the challenges associated with SDTs.
5. To find out and understand how the EU public perceives SDTs.

A Few Words on Research Design

The research questions and aims of this study relate to real-life scenarios that have emerged in recent years. Therefore, pragmatism is the philosophy underlying this study (Saunders et al., 2016, pp. 136-137). Further, the nature of this study is exploratory. In the absence of theoretical frameworks, this study was done with inductive reasoning, in which generalizations are made from specific observations (Saunders et al., 2016, pp. 145-147). For the purpose of finding answers to the research questions, qualitative and quantitative data were synthesized, the research method selected in this case can be characterized as a mixed method (Tashakkori & Teddlie, 1998, pp. 22-28; Saunders et al., 2016, pp. 163-165). For this study, literature from reports, journals, and interviews were gathered as secondary data from carefully selected sources and yielded valuable qualitative data. At the same time, the results of the survey conducted for this thesis served as primary data, enabling the extraction of quantitative data for a cross-sectional analysis. Google Forms was used to collect responses to our survey, allowing a broader audience to participate and convenience of use.

A total of 256 responses have been recorded for the survey. The survey took place from 18 August 2022 to 9 September 2022. Social media platforms such as Facebook, WhatsApp, Instagram, and LinkedIn were used to distribute a survey questionnaire containing 16 questions. The survey is designed to investigate how the overall EU citizens view the adoption of Self-driving Trucks, with age and geographic segmentation being the only demographic parameters covered in the survey. Participants in the survey can be anyone from any EU country, regardless of education, income, occupation, race, or gender. The first question was used to exclude participants who do not live in the EU. A qualified participant was required to answer all 16 questions, which took approximately four minutes. In order to reach broader participants, the survey is available in both English and German, two of the most commonly used languages in the EU.

Research Gap

The topic of Self-driving Vehicles has gained significant popularity in recent years. However, Self-driving Truck is still a relatively new topic, and only a few academic studies have addressed how these vehicles may affect logistics. The time for SDTs to join the public road is fast approaching. A few studies can be found regarding the development and application of SDTs, but there are no studies on how people in the EU would perceive if SDTs entered road traffic for logistics purposes. The growth of SDTs could be hindered if unfavorable perceptions toward them exist. Further, regulatory bodies and industry would address public concerns better if they were aware of and understood the public views. Public perception for SDTs should be assessed and it is the purpose of this thesis to fill the research gap.

Value and Target Audience

The primary target audience for this study is logistics companies that are seeking innovative solutions to current challenges in road transportation, as well as fellow researchers in the field of logistics. Additionally, the study could potentially provide valuable information that regulatory bodies, the logistics industry, trucking companies, and automobile manufacturers could use when it comes to implementing SDTs. The study will help them to assess and better understand how the public in the EU perceives SDTs. The public, who might be unaware of the discussed topics, can also gain some understanding of the development of SDVs and the deployment of SDTs in the trucking industry.

Current Trends and Challenges in The Trucking Industry

This chapter of the thesis explores the trends and challenges that the trucking industry is currently encountering. Moreover, the statistics in this chapter will focus primarily on the European market, with Germany's figure serving as a primary reference as German logistics holds the largest share of the European market. The annual logistics revenue of Germany is more significant than both France (195.5 billion), and Italy (157.1 billion) put together (Placek, 2022). According to Statista reports, the German logistics market reached a volume of 314 billion euros in 2020 (Placek, 2022). Also reflected in the World Bank's bi-annual Logistics Performance Index (LPI), which rating 160 countries, Germany has consistently ranked first three times in a row (The World Bank, 2018). As located geographically in the middle of Europe and has its size to its advantage, Germany is well-suited for serving as a logistics hub. Among the top exporting countries and importers of goods, Germany comes in third place globally (Germany Trade & Invest, 2022). According to Eurostat (2021b), more than two-thirds of the road freight transported across the EU was transported by haulers from Germany, France, Spain, Poland, and Italy, with 23.8 percent of freight moving within Germany and unloading/loading in Germany. Additionally, it is evident that Germany is a significant player in the EU trade flows, as in 2021, the nation is either the entry point or the endpoint of nearly half of cross-border trade flows. Overall, German technology and infrastructure are also recognized internationally as among the best in the world (Germany Trade & Invest, 2022). Combining all factors left Germany in an advantageous position in Europe's logistics market, making the German logistics market the most influential in Europe. This study will incorporate eight major ongoing trends and challenges, divided into five categories below that were identified in the extensive literature review. We will not elaborate on them to contain the volume of this paper, but details can be provided by the authors.

1. External Trends
   (1) Technology Revolution (Industry 4.0, Logistics 4.0, Alternative Power Sources)
   (2) Freight Volume Growth and E-commerce Boom
2. Economic Factor
   (3) Sharp Rise of Energy Prices and International Competition
3. Social Factors
   (4) Conscious Consumerism

(5) Labor Shortage
(6) Trucking Accidents and Human Errors
4. Legislation Factor
(7) Limited Driving Time and Health Concerns
5. Environment Factor
(8) Environmental Footprint of The Industry

An Introduction to Self-driving Vehicles, Their Growth and Significance

The purpose of the following part is to define Self-driving Vehicles, explain the different levels of autonomy and give a few examples of current advancements and applications of self-driving technology in diverse industries. Readers very familiar with the matter may consider skipping ahead.

Definition of Self-driving Vehicles

A Self-driving Vehicle is also known as an Autonomous Vehicle (AV), driverless, or robotic vehicle. A vehicle of this type is controlled by an intelligent machine, one that is able to detect its surroundings and operate independently in a safe manner without human intervention. The NHTSA describes SDVs as those vehicles that function without requiring their driver to perform direct inputs to maneuver driving functions, including "steering, acceleration, and braking" (NHTSA, 2022b). Furthermore, the driver of these vehicles is not obligated to maintain constant attention to the road during self-driving operations (NHTSA, 2022b). Ideally, SDVs do not even require a human passenger to be aboard and are capable of traveling anywhere as a traditional vehicle can and these vehicles can perform any task that an experienced human driver can (B & Vijayaramachandran, 2020; SAE, 2022). *Self-driving* or *autonomous* are terms that are generally used in literature to refer to autonomy Levels 4 and 5 (Heutger & Kückelhaus, 2014; Wevolver, 2020; White Paper, 2021). Since the 1920s, various technical experiments and advertisements have been conducted (The Milwaukee Sentinel, 1926). Tsukuba Mechanical Engineering, a Japanese laboratory, designed the first semi-autonomous vehicle in 1977, which was capable of reaching speeds of 20 km/h by detecting white road markings with the help of two vehicle-mounted cameras (Bhat, 2017, p. 1185). Nevertheless, it was only in the 1980s that Carnegie Mellon University developed a working SDV known as the NAVLAB (Shafer & Whittaker, 2018). In recent years, many world-leading technology companies and automotive manufacturers have developed innovative technologies for driverless cars and put them to the test.

Levels of Autonomy

The Society of Automotive Engineers (SAE International) was founded in 1904, based in the US, and its mission is to bring together a wide range of stakeholders to formulate guidelines and standards related to motor vehicle components (SAE International, 2022). The association is active on a global scale and has over 128,000 members who are technicians and engineers specializing in aerospace, automobile, and commercial vehicles (SAE International, 2022). The association has a long history behind it and is known as a highly reputed association that defined some highly regarded standards widely used today, such as horsepower ratings, aerospace industry standards, and levels of autonomy (SAE International, 2022). The levels of autonomy established by SAE classify a vehicle's autonomous functionality into six levels, ranging from Level 0 to Level 5

(SAE, 2022). This scale is now universally utilized by authorities and manufacturers across the globe as the standard for grading SDVs (National Highway Traffic Safety Administration, 2022a).

Level 0 (No Automation)

This level is referred to as a fully manual level. A vehicle that is manually controlled and does not have autonomous functions. The driver is entirely in charge of handling the motion of the vehicle, including steering, accelerating, braking, parking, and any other maneuvers required (SAE, 2022). Currently, this level remains the most common level of vehicles on the road.

Level 1 (Driver Assistance)

As the first level of autonomy, the vehicle is equipped with only one driver assistance feature that provides either steering assistance or speed assistance (SAE, 2022). A few examples of Level 1 driver assistance features can be adaptive cruise control (ACC), lane-keeping assistance (LKA), lane centering assistance (LCA), lane departure warning system (LDWS), and autonomous emergency braking (AEB) (SAE, 2022). These assistance features are designed to assist the driver and make driving more convenient and safer. However, these features should not be entirely depended upon, control and driving of the vehicle remain in the hands of the driver. These assistance features cannot replace the drivers' skills. Drivers still have complete control over the steering and must stay vigilant at all times. Today, it is rare to find a new car without any assistance systems.

Level 2 (Partial Automation)

The critical feature of Level 2 is advanced driver assistance systems (ADAS). Technology-wise, there is not much distinction between Level 1 and Level 2 of autonomy (SAE, 2022). The difference is that these Level 2 vehicles are capable of both automatic speed controlling and steering (SAE, 2022). The use of Level 2 driver support allows these primary driving tasks to be taken care of. Still, the driver must remain attentive and constantly monitor technology and traffic. As required, the driver has to keep their hands on the wheel, maintain full attention to the traffic and road, and assume control at any given moment (SAE, 2022).

Level 3 (Conditional Automation)

Conditional automation is when a vehicle functions independently for a limited period without human intervention (SAE, 2022). At Level 3, the vehicle is able to drive by itself, but only when certain conditions are met. Typically, Level 3 vehicles can detect their surroundings, construct intelligent decisions, and handle most situations. GPS maps enable the vehicle to navigate safely, and they can assess the speed and distance of other vehicles in neighboring lanes to make helpful lane changes (SAE, 2022). With Level 3, drivers can temporarily flip their focus and turn their attention away from the wheel to focus on something else within a known and limited environment. At this level, control has to be taken over by the driver whenever a task cannot be accomplished by the system or in overly complex situations (SAE, 2022).

Level 4 (High Automation)

Level 4 vehicles are highly automated and able to run in self-driving mode, requiring no human intervention, in almost all conditions, except in extreme weather (SAE, 2022). These Level 4 vehicles are programmed to make logical decisions. Additionally, as part of highly automated systems, 5G connectivity enables these vehicles to share information in real-time with other vehicles on the road, with traffic lights and pedestrians (SAE, 2022). With these vehicles, drivers can focus on other activities for more extended periods while on the road, such as reading, eating, working, or even sleeping. Nevertheless, it is still possible for the driver to override or regain control of the vehicle manually at any time they want (SAE, 2022).

Level 5 (Full Automation)

A fully automated vehicle has the ability to perform all driving tasks independently in any situation (SAE, 2022). As Level 5 vehicles require no human attention, steering wheels and acceleration pedals will no longer be available (SAE, 2022). The "dynamic driving task" is eliminated (SAE, 2022). In the same way as an experienced human driver, these vehicles will be able to go anywhere and perform any action. The driver becomes a pure passenger, and neither a license nor the ability to drive will be required to operate this vehicle (SAE, 2022). In order for Level 5 vehicles to perform properly and safely, these vehicles must have constant access to 5G Internet and intelligent transportation systems (SAE, 2022).

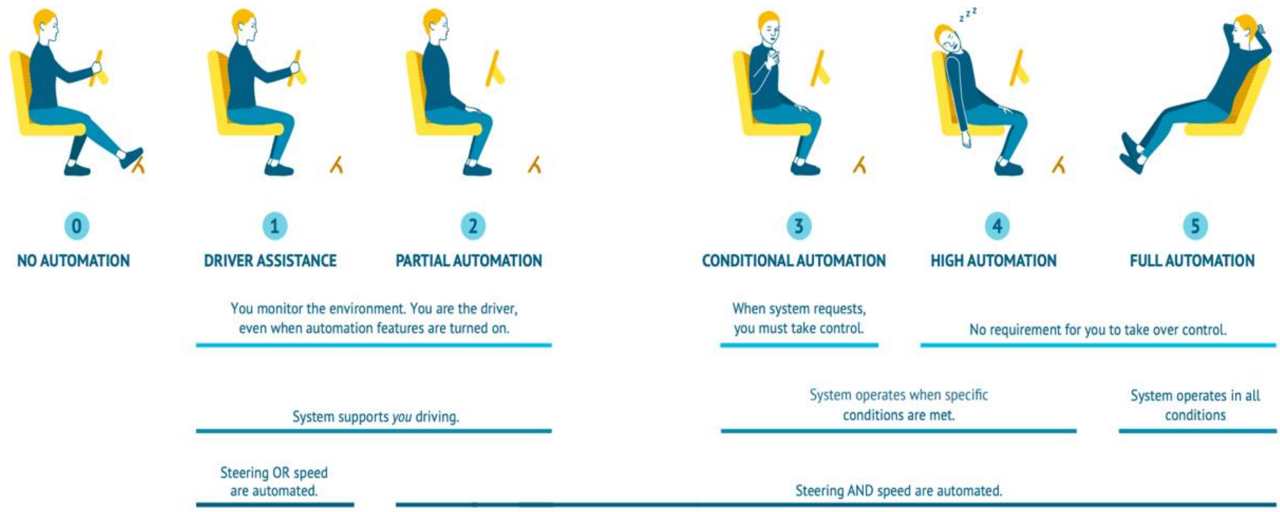

Figure 1: Autonomy Levels

Source: (Wevolver, 2020, pp. 22-23)

Technology Overview

Research suggest that it is vital to have four fundamental interdependent functions to construct a vehicle capable of driving itself: navigation, situational analysis, motion planning, and trajectory control (Heutger & Kückelhaus, 2014, p. 5; Wevolver, 2020, pp. 17-33).

Navigation

Navigation plays a crucial role in route planning (Heutger & Kückelhaus, 2014, p. 5; Wevolver, 2020, pp. 17-33). It uses weather forecasts, terrain, and road information to create a digital map that contains the most suitable route based on locations, road types, and settings (Heutger & Kückelhaus, 2014, p. 5; Wevolver, 2020, pp. 17-33). Today, vehicle route planning is performed through a Global Positioning System (GPS). The future SDVs' navigation function will be improved with vehicle-to-vehicle (V2V) communication. Vehicles can share information wirelessly through V2V communication, concerning their speed, location, and heading, which allows the self-driving system to detect hazardous events at an early stage and take action immediately (Heutger & Kückelhaus, 2014, p. 6; NHTSA, 2022c). The V2V communication technology enables vehicles to communicate omnidirectionally, allowing vehicles to send and receive information from all directions (NHTSA, 2022c). With the help of V2V communications, hazardous situations can be detected from a distance of more than 300 meters, even when they are partially obscured (NHTSA, 2022c). Allowing the vehicle to be aware of its surroundings from every angle.

Situational analysis

Situational analysis entails keeping track of the movement of all relevant objects in the vehicle's surrounding environment by utilizing several types of sensors: RADAR, LIDAR (light detection and ranging), Visual image recognition techniques, ultrasonic sensors etc. A vehicle can monitor its surroundings and decide how to proceed by interpreting the information it obtains (Heutger & Kückelhaus, 2014, p. 6).

Motion planning

This function monitors the vehicle's movements with the help of sensors that calculate the exact path of a vehicle, including direction and speed, which the vehicle will follow within a given time frame (Heutger & Kückelhaus, 2014, p. 7). To avoid colliding with stationery or moving objects, which is detected by the situational analysis, it is vital for the moving vehicle to remain within its lane and follow the correct preset direction indicated by the navigation system. As part of motion planning, the vehicle is programmed on how to interpret the collected information and respond appropriately to changing circumstances. (Heutger & Kückelhaus, 2014, p. 7)

Trajectory control

The trajectory control procedure handles the implementation of speed or direction changes. In cases where the direction and speed of a vehicle change unexpectedly, the trajectory control is responsible for stabilizing the moving vehicle. When trajectory control detects a sudden change in speed or direction, it analyzes the predicted and actual changes to determine whether to make adjustments by accelerating, braking, or steering the vehicle to make it stable again (Heutger & Kückelhaus, 2014, p. 8)

Object detection and sensors

It is essential that a Level 4+ SDV has all four of these functions in order to function autonomously. A range of sensors is required for a Level 4+ SDV to detect the vehicle's condition and the condition of the traffic around them (Yurtsever et al., 2020, pp. 3-5). There are two sets of sensors: passive and active. Light or radiation reflected from objects in the environment is detected by passive sensors (Wevolver, 2020, pp. 22-23). As opposed to active sensors, which generate their own electromagnetic signal and monitor the reflection (Wevolver, 2020, pp. 22-23). There are several sensors necessary to ensure that the system operates properly, for instance:

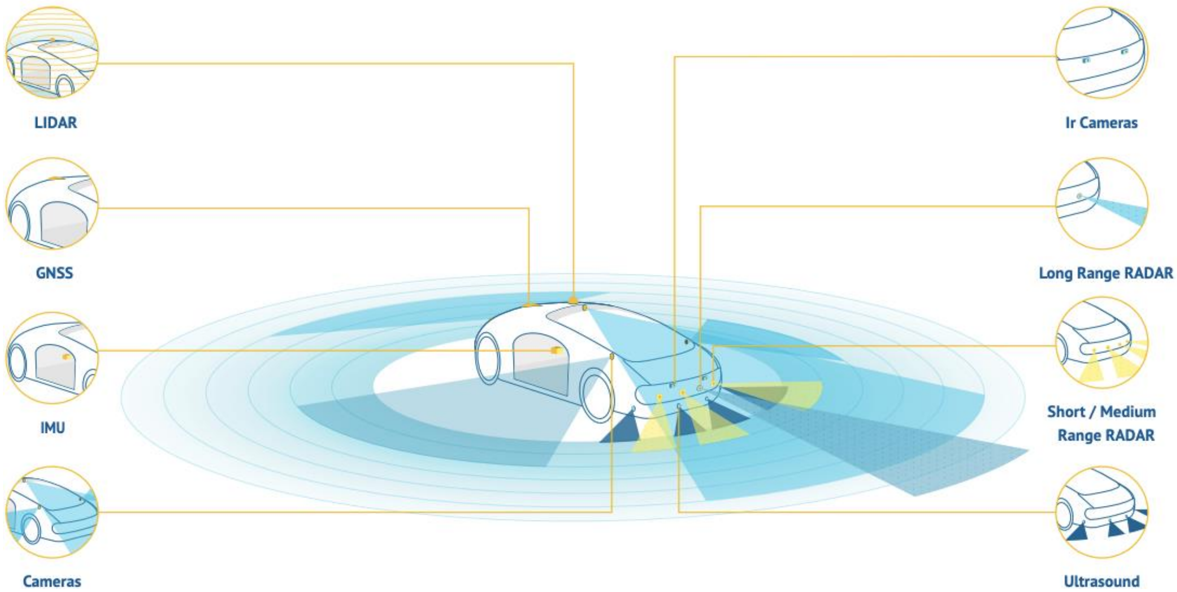

Figure 2: Sensors Used for Situation Analysis

Source: (Wevolver, 2020, pp. 22-23)

Passive sensors

Camera technology was among the first passive sensors to be applied to SDVs since it was extensively utilized in digital images and videos to determine which objects were present (Wevolver, 2020, pp. 22-23).

Video cameras

The input for machine vision in SDVs comes from camera systems that provide visual image recognition. Among the types of sensors, cameras are the only ones capable of decoding color, making them essential for monitoring traffic signs and lights (Heutger & Kückelhaus, 2014, p. 6).

Active Sensors

Time-of-flight (ToF) is a fundamental principle that active sensors can use to detect their environment (Wevolver, 2020, pp. 22-23). In ToF, the travel times of signals are measured by watching for their reflections to return after they have left their source (Wevolver, 2020, pp. 22-23).

RADAR (Radio Detection and Ranging)

This system uses electromagnetic waves to detect objects by detecting reflected waves that bounce off any surface, then transmit back to the RADAR receiver (Wevolver, 2020, pp. 22-23; Heutger & Kückelhaus, 2014, p. 6). The system determines the object's size, range, angle, and velocity (Wevolver, 2020, pp. 22-23). However, for RADAR to detect an object, its reflection strength must be strong. In assessing the strength of the reflection, many factors are taken into consideration, including the reflection size, distance from the RADAR, absorption characteristics of the radio waves, and reflection angle (Wevolver, 2020, pp. 22-23).

LIDAR (Light Detection and Ranging)

In a comparable way to RADAR, LIDAR systems help monitor the surrounding area and visualize the road in three dimensions. Instead of using electromagnetic energy, LIDAR uses laser pulses. The light emitted by LIDAR is ultraviolet, visible, and near infrared (Bergvall & Gustavson, 2017, pp. 9-10). The narrow light beam of a LIDAR system increases accuracy over a RADAR system. When LIDAR is paired with RADAR, the systems are capable of recognizing road signs, other vehicles, lanes, traffic lights, pedestrians, and any obstacles in front of the vehicle with a range of up to 200 meters (Waldrop, 2015). A significant advantage of LIDAR is its comparatively wide field of visibility, and it can also provide 360-degree 3D coverage. Nevertheless, the outcome is determined by the type of LIDAR employed. Additionally, LIDAR has a more extended range, a more accurate measure of distance, and lower computing costs than passive sensors.

Ultrasound

An ultrasound sensor works similarly to RADAR and LIDAR by releasing sound waves and capturing the echoes from objects within range. The ultrasound sensor is primarily intended for automated parking due to its narrow range and slow response time (Wevolver, 2020, pp. 22-23).

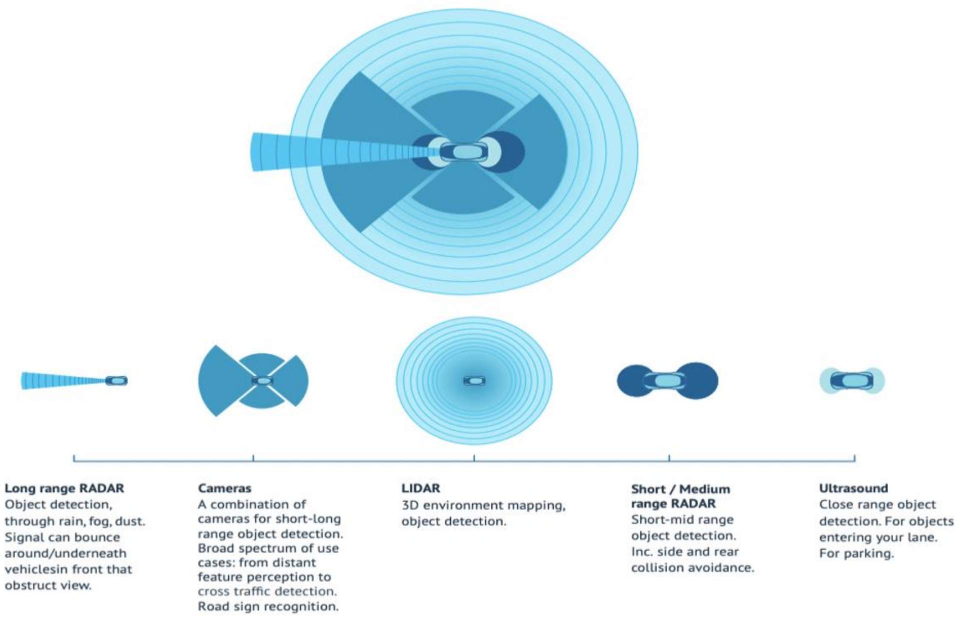

Figure 3: The Different Capabilities and Ranges of Various Object Detection and Mapping Sensors

Source: (Wevolver, 2020, pp. 22-23)

Artificial Intelligence

Equipped with all those devices, the vehicle can collect substantial amounts of data in real time about its operation, status, and surrounding environment. Accordingly, the vehicle needs to 'think' and 'act', similarly to the way human drivers do, in order to maneuver accurately and smartly. This is where AI comes into play. AI has gone a long way back, and AI is the branch of computer science that specializes in empowering machines with intelligence so these machines can resolve issues by themselves (Sadiku et al., 2021, pp. 715-716). The field of AI is composed of many computational models and algorithms, for instance, Expert Systems, Neural Networks, Machine learning, Deep learning etc. (Sadiku et al., 2021, pp. 715-716). Recent research in AI algorithms and concepts enabled breakthrough results and implementation, making AI widely adopted in many industries, including the automotive industry. Here, AI is employed to substitute human abilities in cognitive processing and driving (Sadiku et al., 2021, pp. 715-716). The central processing unit of the SDV is driven by AI and can take total control of the vehicle by making smart decisions capable of maneuvering the vehicle autonomously, making AI the key element to the success of SDV development.

Current Developments

Over the years, Self-driving Vehicles have slowly been implemented and have proven helpful across many different industries. A number of examples are provided below that illustrate the effectiveness of self-driving technology across different industries.

In terms of self-driving technologies, autopilot is one of the most well-known and notable features, which has become a standard for the aviation sector (Heutger & Kückelhaus, 2014, p. 11). The aerospace industry is another early adopter of automated driving. NASA designed a car-sized autonomous roving vehicle, Curiosity, to explore the Gale crater on Mars, as shown in Figure 22. Curiosity was launched in 2011 (NASA Science, 2022). The autonomous navigation mode allows Curiosity to move independently. Every few meters, Curiosity must use its navigation cameras and hazard detection to capture visual images of the terrain in front of it (NASA Science, 2022). Curiosity's drive software stereoscopically records these images, creating a three-dimensional impression (NASA Science, 2022). These recordings are then evaluated autonomously. According to the data collected, the Curiosity software calculates and selects the route that appears most suitable.

A minesweeping truck is also an early example of SDVs being used by the military sector. This device is designed to prevent soldiers from coming into contact with improvised explosive devices (Heutger & Kückelhaus, 2014, p. 11). SDVs are still being tested by the US military, as the industry is working toward developing unmanned vehicles that can deliver food, fuel, and supplies in conflict zones for the purpose of ensuring personnel's safety. Among the most recent tests was conducted in Fort Hood, Texas, by the contractor Lockheed Martin, where driverless convoys of off-road trucks drove through challenging terrain and uninhabited areas, as shown in Figure 23 (Heutger & Kückelhaus, 2014, p. 11). To stay connected with each other, these vehicles are equipped with laser and GPS sensors that capture the terrain and keep track of their locations (Heutger & Kückelhaus, 2014, p. 11). It is still unclear when these SDVs will start carrying out real-world tasks (Suba, 2014).

Figure 4: Curiosity (rover)
Source: (NASA Science, 2022)

Figure 5: Driverless Convoys Moving through Terrain
Source: (Woody, 2018)

The use of SDVs has also led to transformation and growth in industries such as agriculture, mining, and construction. These vehicles are especially beneficial when performing repetitive tasks. For instance, SDVs can be utilized in mining to transport materials back and forth between mines and extraction plants. Agricultural activities such as watering, fertilizing, and harvesting can also be done using SDVs (Tarantola, 2013). A German tractor manufacturer, Fendt, has introduced a system that links two tractors by satellite navigation and radio communication (Heutger & Kückelhaus, 2014, p. 12). The system is called Fendt Guide Connect. One of the two vehicles is automated, performing the exact same work as the human-driven vehicle (Heutger & Kückelhaus, 2014, p. 12).

Figure 6: Autonomous Haul Trucks in The Mining Industry

Source: (Moore, 2021)

Figure 7: Fendt GuideConnect – Two Tractors, One Driver

Source: (Interempresas, 2022)

Another given sample for the mining industry is the Australian mining giant Rio Tinto has used SDTs to transport more than a billion tons of ore and waste material across their mining sites in Pilbara. It was determined that SDVs had not caused any injuries to the mine workers. Their report estimates that each SDT operated 700 hours more than a conventional haul truck in 2017 (Rio Tinto, 2018). That has saved them charges for load and haul by about 15 percent (Rio Tinto, 2018).

Figure 8: Robotic Vacuum Cleaner

Source: (The Economic Times, 2021)

As self-driving technology is becoming more common and integrated into daily consumer life, resulting in a growing number of consumer appliances equipped with the technology. One of the most used examples could be robotic vacuum cleaners. Vacuum cleaners like these rotate autonomously throughout the house and vacuum dust and dirt into built-in containers. The robot drives itself back to a charging station when its batteries run low; upon recharging, it starts cleaning again. It is considered a labor-saving and timesaving device for everyday use. There are also robotic mops, lawnmowers, window cleaners, and other related devices.

Also widely known as an application of self-driving technology is public transportation. Ligier EZ10 is one of the most recognizable achievements of Easymile, the most prominent French manufacturer of SDVs (Schaft, 2018). The vehicle is driverless and powered by an electric motor. Ligier EZ10 has six seats and can accommodate four standing passengers or a wheelchair (Schaft, 2018). The vehicle can run up to 50 km/h, and the vehicle can travel approximately 400 kilometers (Schaft, 2018). GPS, 3D imaging, and RADAR systems are used to steer vehicles. Unlike traditional vehicles, this vehicle does not have a front or back (Schaft, 2018). This feature allows the vehicle to travel in any direction without turning around.

Figure 9: Easymile's Ligier EZ10
Source: (Wikipedia, n.d.)

Figure 10: The Ultra Pod at Heathrow Airport
Source: (Ultraglobalport, n.d.)

Navya, another French company, has constructed and operates smaller SDVs comparable to a robo-taxis (Schaft, 2018). Company officials have stated that 150,000 passengers have been safely transported using their vehicles in Europe, Asia, and the US (Schaft, 2018). United Technical Services (UTS), in partnership with 2getthere, has built three distinct types of rapid transit automated people mover - vehicles for individuals, groups, and freight (Heutger & Kückelhaus, 2014, p. 16). Each is designed to operate as an on-demand, nonstop system between any two points in a network at a maximum speed of 40 km/h (Heutger & Kückelhaus, 2014, p. 16). Both personal and freight vehicles have been in use since 2010 in Masdar City in Abu Dhabi, UAE, while the group vehicle is operated at Amsterdam's Schiphol Airport in the Netherlands. Additionally, in another project, 2getthere implemented one of the first self-driving people-mover systems in the Netherlands and named it ParkShuttle (Heutger & Kückelhaus, 2014, p. 17). Short-distance public transportation is the most suitable application for this vehicle. There has been another self-driving passenger-transportation system available at Heathrow Airport in the UK since 2011 called the Ultra Pod (Heutger & Kückelhaus, 2014, p. 17). The technology belongs to the Ultra Global PRT. While waiting for passengers, the electric vehicle recharges itself at battery points. Additionally, passengers can book these Ultra Pods via smartphone (Heutger & Kückelhaus, 2014, p. 17).

For the last decade, many leading car manufacturers have endeavored to create SDVs. Across the US, more than 80 companies have been testing more than 1,400 self-driving cars, trucks, and other vehicles by 2018 (Etherington, 2019). A total of 48 automobile and tech companies provided testing reports to the California Department of Motor Vehicles (DMV) in 2019 (Waters & Burn-Murdoch, 2019). These manufacturers are taking steps to incorporate technological advancements into their most current vehicles. This technology includes automatic emergency braking, parking assist, accident warning, and semi-automated pilot driving (Hussain & Zeadally, 2018). The parking assistant system has become a widely recognizable feature found, and it is now offered as an optional accessory in several new cars. This feature allows the vehicle to park itself slowly in tight spots, and it is only applicable to parking lots (Heutger & Kückelhaus, 2014, p. 13).

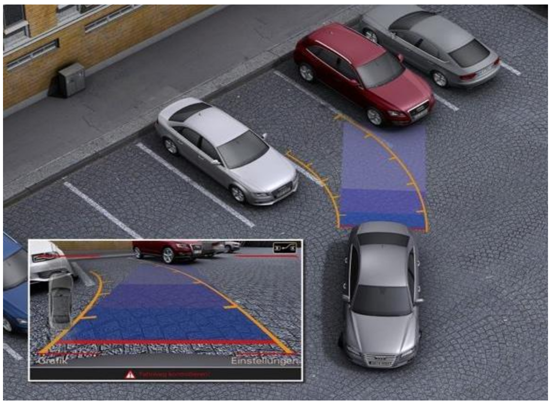

Figure 11: Parking Assistant System
Source: (Audi Technology Portal, n.d.)

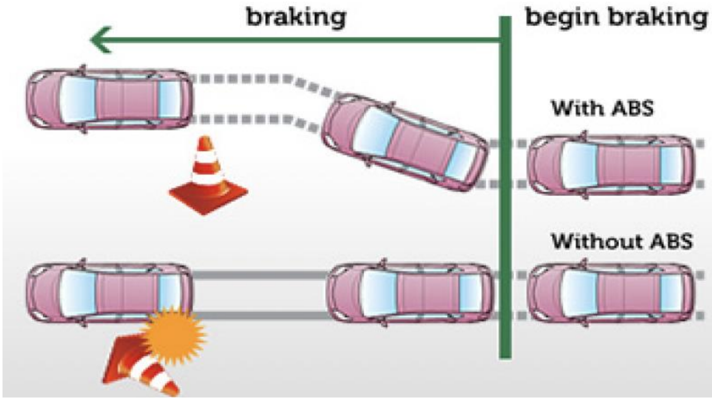

Figure 12: Anti-lock Braking System (ABS)
Source: (TOYOTA, n.d.)

More vehicles are now advanced with driver assistance features to make travel safer. Some features allow hands-free driving on pre-mapped highways, such as Cadillac's Super Cruise and Ford's Blue Cruise (Singh & Saini, 2021). Besides, many other vehicles are fitted with hands-free assistance driving but have specific restrictions, such as driving within certain speed limits or operating only on properly marked roads. For driverless cars to become a reality, car manufacturers are now collaborating with technology companies. Microsoft has teamed up with Toyota and Volvo, and Apple is working with Uber to develop SDVs (Singh & Saini, 2021).

With the full autonomous package, Tesla came the closest to launching a self-driving car on the market in 2021 (CBS News, 2022). The vehicle enabled autonomous hands-free highway and freeway driving. However, it does not meet all the criteria to be considered an SDV. Currently, Honda's 2022 Civic is one of the latest technological advances; the car can drive itself down the road and automatically slow down behind stopped vehicles (CBS News, 2022). However, this car is not yet considered an SDV since the system is not yet regarded as hands-free technology, indicating the driver remains fully responsible for controlling the vehicle (CBS News, 2022). It appears that automakers and technology companies are so close to realizing their goal in the near future as they are making breakthroughs in innovation.

Self-driving Trucks in The Trucking Industry

Self-driving trucks could be a promising solution to the trucking industry's ongoing problems and challenges. This chapter of the thesis covers the introduction of SDTs and one of the first commercially viable applications of SDTs, Truck Platooning. After that, there will be some examples of how SDTs are being experimented with and integrated into the real world. This chapter will also explore how SDTs could benefit the industry and what obstacles they might encounter.

Introduction of Self-driving Trucks to The Industry

There is a real possibility that self-driving technology could change the face of logistics in the near future (Möller, 2022). Self-driving Trucks and Self-driving Cars contain similar artificial intelligence systems that allow them to operate autonomously (Future Bridge, 2020). However, SDTs still need a longer time than Self-driving Cars to be in the market and become viable (Future Bridge, 2020). Due to its heavier weight and larger size, a truck takes much longer to stop than a car, making trucks less effective at avoiding accidents (Truck Smart, 2022). SDTs, therefore, face unique technological challenges compared to Self-driving Cars. Furthermore, compared to a passenger car, truck dynamics are much more complex due to the low power/mass ratio, the delays in internal engine control and air brake, noticeable disturbances when shifting gears, wind, and slight gradient (Lu et al., 2004). Since trucks have complex movements and challenging dynamics, it is hard to directly migrate the existing decision-making and planning system from cars to trucks (Wang et al., 2022, pp. 2-3). Nevertheless, when a simple use case within operational design domains (ODD), for example, highway transportation, is focused, it may require lower requirements for perception and prediction in a Self-driving Truck than in a Self-driving Car (Wang et al., 2022, p. 2).

An example of some essential technologies and sensors that would be essential in a SDT, as illustrated in Figure 31:

- Engine control unit (ECU) is the brain of the vehicle and is responsible for controlling the engine's driver assistance systems.
- Sensors - typically Cameras, Ultrasonic, Lidars, and Radars
- Global Navigation Satellite System (GNSS)

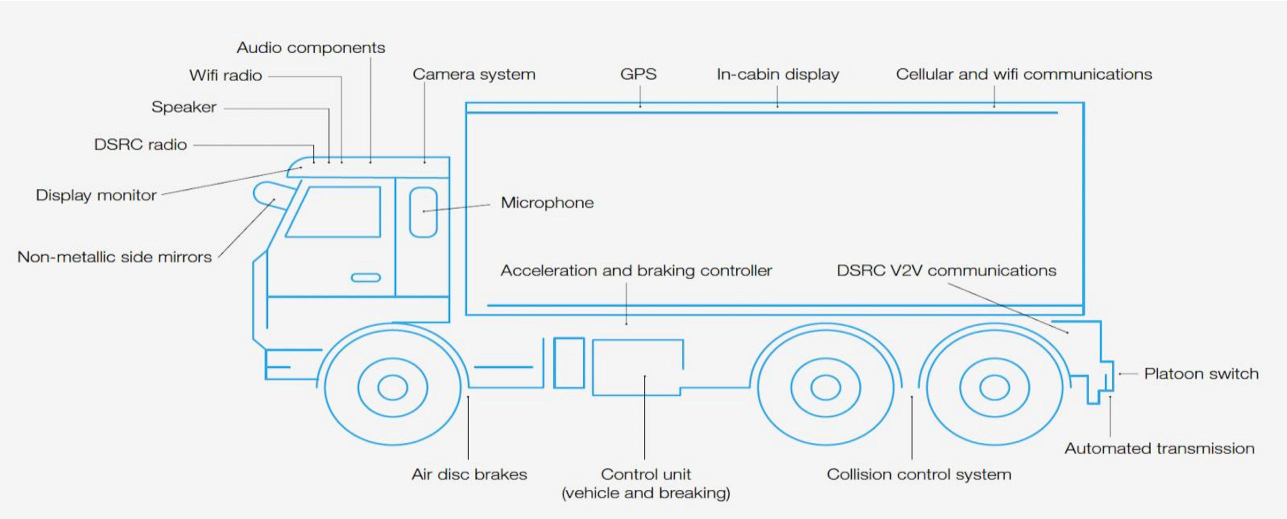

Figure 13: Example of The Elements Required to Automate a Truck

Source: (White Paper, 2021)

Figure 32 presents a timeline of major breakthroughs in technologies for SDTs. It was in the 1980s that SDT development fully took off, and the challenge grew with each breakthrough. As a result of current market assessments and technological development tracks, SDTs are expected to be developed and deployed in design domains instead of "all at once" approaches (D'Orazio et al., 2020, p.6; Rahimi & He, 2020, p.2). Accordingly, the first SDTs will likely be designed for highway setting only, making them ideal for long-haul routes over complex geographical settings (D'Orazio et al., 2020, p.6). Availability of these trucks is expected in the mid-2020s. Eventually, with further testing and development, SDTs in semi-urban areas will be possible by the early 2030s.

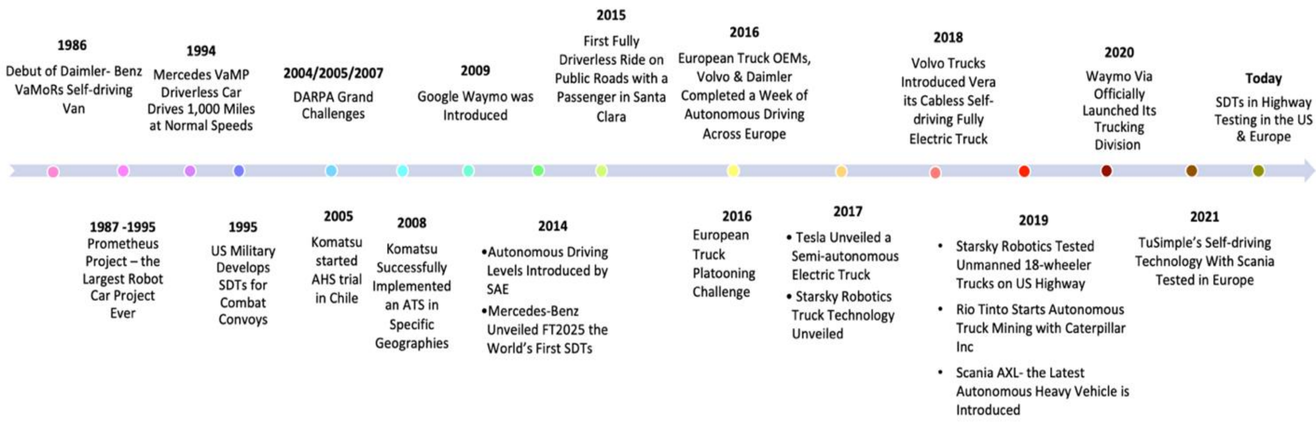

Figure 14: Timeline of Development of Self-driving Truck (SDT)

Reproduced from: (Future Bridge, 2020; Rahimi & He, 2020, p.2; D'Orazio et al., 2020, p. 6)

Autonomous or *Self-driving* are terms that are generally used in literature to refer to autonomy Levels 4 and 5 (Heutger & Kückelhaus, 2014; Wevolver, 2020; White Paper, 2021). These levels of technologies are still undergoing testing and development.

Introduction of Truck Platooning

Vehicle platooning is not a new concept, it dates back decades and has been pursued for many years (Khan, 2019; Lee et al., 2021; Li et al., 2021). A vehicle platoon means a group of vehicles traveling in a close formation with a minimum safety distance between them, similar to a train (Khan, 2019; Lee et al., 2021). The use of these techniques improves safety, mobility, and energy efficiency (Lee et al., 2021).
Recent waves of automated driving have finally given Truck Platooning a vital boost, making it the first viable self-driving technology for Heavy Good Vehicles (HGVs) (Mendes et al., 2017). In the words of the European Automobile Manufacturers Association (ACEA, 2017), Truck Platooning is described as

> ... the linking of two or more trucks in convoy, using connectivity technology and automated driving support systems. These vehicles automatically maintain a set, close distance between each other when they are connected for certain parts of a journey, for instance on motorways.
>
> In this system, the truck in the front leads the platoon, with the vehicles behind reacting and adapting to changes in its movement – requiring little to no action from drivers. In the first instance, drivers will remain in control at all times, so they can also decide to leave the platoon and drive independently (p.1).

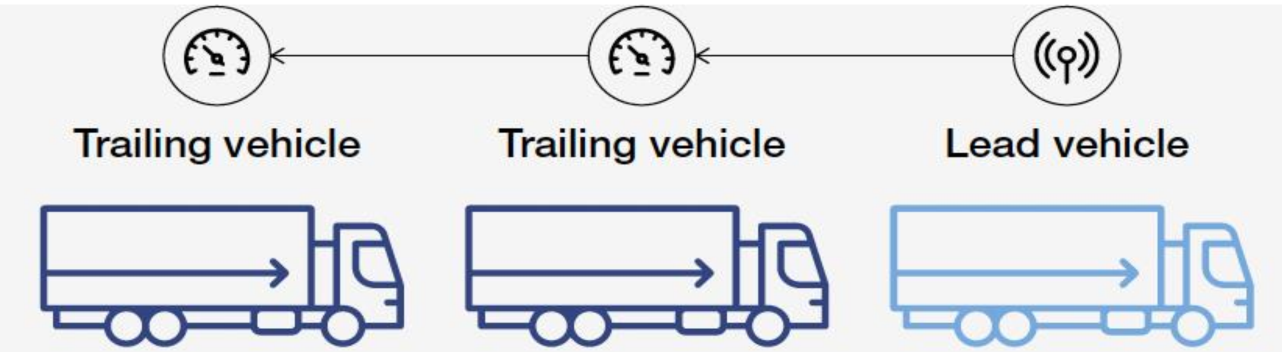

Figure 15: Truck Platooning Process

Source: (White Paper, 2021)

The platoon's trucks are equipped with radar, cameras, and GPS technology to respond quickly to situations, and by using vehicle-to-vehicle communication (V2V), trucks are enabled to communicate wirelessly and alert drivers of potential hazards enabling platooning to connect multiple trucks (White Paper, 2021). In the first platooning phase, one driver manually maneuvers a lead truck with the assistance of active safety systems. Platooning regulates the speeds of all trailing vehicles in a manner that precisely matches the lead truck's pace, while the drivers of trailing vehicles are responsible for keeping a close eye on the road regulating speed, steering, and dealing with other traffic (Khan, 2019; Lee et al., 2021; White Paper, 2021; Atasayar et al., 2022). Based on SAE's classifications of vehicle autonomy, introduced in Section 3.2, Truck Platooning falls under Level 1 since it solely controls the truck's speed (Khan, 2019; Lee et al., 2021; White Paper, 2021; Atasayar et al., 2022).

In recent years, the EU, governments around the world, and the trucking industry have launched numerous projects and research activities on Truck Platooning. Promote Chauffeur, a European Commission-sponsored project and cost-shared with the industry, initiated the first Truck Platooning research in Europe in 1996 (Atasayar et al., 2022). One of the first uses of towbar technology for platooning two trucks was in the Promote Chauffeur I trial (Atasayar et al., 2022). A fully operational truck platoon consisting of three trucks was demonstrated under actual conditions as part of Promote Chauffeur II (European Union, 2009). It was in the 2000s that Japan and the USA began investigating Truck Platooning in order to assess its technical feasibility and fuel efficiency (ATA, 2015, p.5). Several other projects have also been conducted, for instance, the KONVOI from Germany (Hoffmann, 2009), PATH from the US (2017), and the Energy ITS program from Japan (Flämig, 2016), and many more. In the German project called KONVOI, truck platoons were analyzed in mixed traffic scenarios on motorways (Hoffmann, 2009). As part of the European Safe Road Trains for the Environment (SARTRE) project, self-driving passenger cars are trailed by manually controlled trucks on the highway, creating a platoon of both cars and trucks (Chan, 2016). In another project called COMPANION, which took place in 2016, six convoys of multi-brand trucks traveled from Sweden and Germany to Rotterdam (Paddeu & Jozef, 2020). Among the latest European projects, ENSEMBLE explores the possibility of multi-brand platooning (Schmeitz, 2022). A European Truck Platooning roadmap was introduced by ACEA in 2017 (ACEA, 2017). The initial stages of platooning development focused on a mono-brand platoon system, where trucks are identical in model and brand can platoon together. The ACEA roadmap states that this stage of Truck Platooning is already feasible (ACEA, 2017). There is considerable competition among truck manufacturers not only over their trucks but also their platooning services. There is a projected timeline that, with Level 2 autonomy, three multi-brand trucks are capable of platooning by 2023 (ACEA, 2017). The next step, according to the roadmap in the development of SDTs, lies when trailing drivers are able to sleep, and then both leading and trailing drivers sleep at the same time (ACEA, 2017).

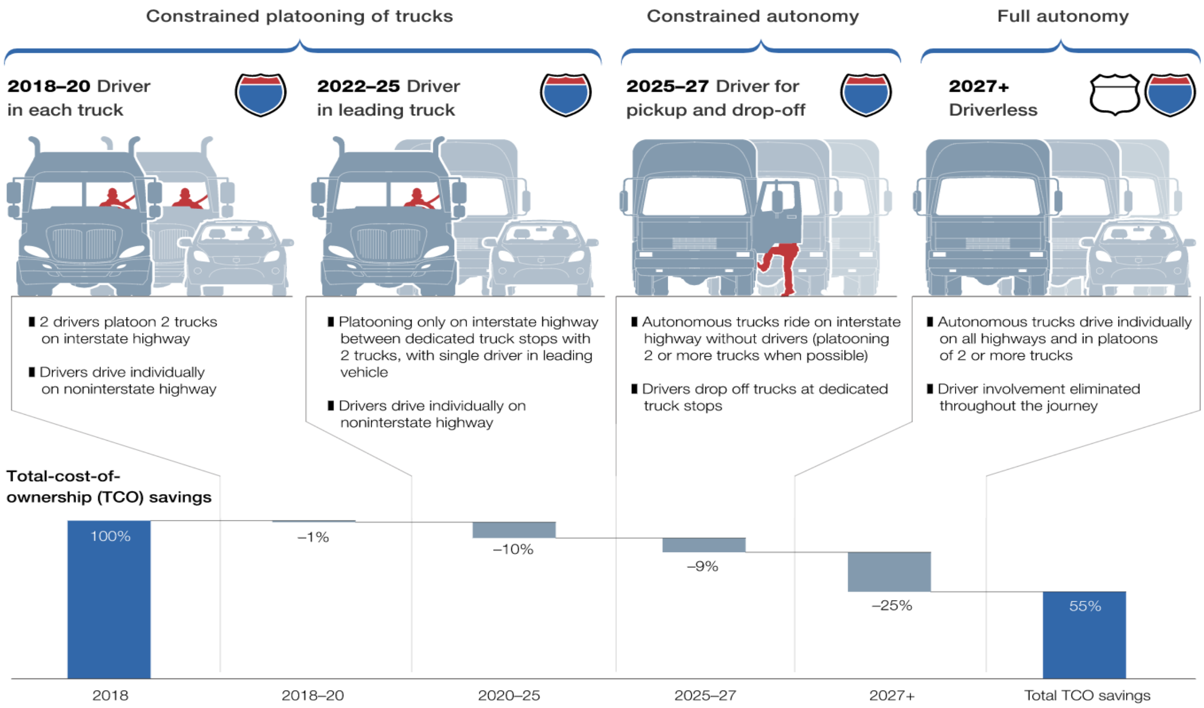

Figure 16: Future of Self- driving Trucks

Source: (McKinsey, 2018)

At the same time, research done by McKinsey Center for Future Mobility suggests that SDT development would progress in four phases, as shown in Figure 34 (2018). The full autonomy of Truck Platooning is expected by the year 2027. Platooning of trucks will mark the beginning of greater automation of trucks, followed by trucks that are fully self-driven. Through the deployment of each phase, operators' total cost of ownership (TCO) will become lower (McKinsey, 2018). In the future phase of platooning, the lead truck will be manually maneuvered by a driver, whereas the following vehicles will operate fully autonomously in response to the actions of the lead truck (ACEA, 2017). It has been demonstrated through numerous studies, and research projects that Truck Platooning can significantly improve road transport in the future by making it more efficient, safer, and cleaner (ACEA, 2017; Khan, 2019; Lee et al., 2021; White Paper, 2021; Atasayar et al., 2022). Since trucks can drive closer together, air resistance is minimized between trucks. Therefore, the trucks consume less fuel and emit fewer greenhouse gases (ACEA, 2017; European Commission, 2017; Khan, 2019; Lee et al., 2021; White Paper, 2021; Atasayar et al., 2022). The ITS4CV report by Ertico indicates that by forming a platoon, the emissions from trailing vehicles can be lower by up to 16 percent, whereas leading vehicles can reduce emissions by 8 percent (Winder, 2016). Efforts are being made throughout the world to encourage the use of Truck Platooning technology, which has been proven to have beneficial effects on the environment, in an endeavor to lower logistics-related emissions (ACEA, 2017; European Commission, 2017; Khan, 2019; Lee et al., 2021; White Paper, 2021; Atasayar et al., 2022). A relatively early development stage is being reached in platooning technology adoption, and through the progressive advancement of self-driving systems, platooning technology will develop further in the near future.

Self-driving Trucks: Using and Testing in The Real World

Connectivity, collaboration, and digitalization condition new possibilities for the trucking industry. On the road to a better trucking industry, worldwide companies are trying to develop self-driving technology with different strategies. These are some examples of what some leading companies aim to accomplish as well as their testing process.

In October 2016, 2,000 cases of Budweiser were delivered by a SDT operated by Otto, an Uber-owned startup, covering a 120 miles journey (roughly 193 km) (Isaac, 2016; Ohnsman, 2016). It took the SDT two hours to complete the journey. Without the driver's assistance, the SDT could drive by itself on the highway, adjust its speed and acceleration, and keep its position in the lane of travel (Isaac, 2016; Ohnsman, 2016). Another example is Volvo, a Swedish multinational automobile manufacturer. Volvo is in the process of developing Vera, a Level 5 autonomy self-driving electric trucking vehicle without a driver's cabin (Volvo, 2019). Vera is designed to transport large quantities of goods along a predefined, short-distance route. Tests are underway in Gothenburg, Sweden, to evaluate Vera's capability to transport goods between the terminals and the supply chain center (Volvo, 2019).

Figure 17: Vera Truck
Source: (Volvo,2022)

Figure 18: Einride Pod
Source: (Einride, 2022b)

Another Swedish company called Einride is also working on a self-driving Pod, which is also powered by electricity (Einride, 2022a). In the Einride test truck, there is no driver's compartment, just like the Vera. Einride is different from Vera primarily because it still requires human assistance through remote control, making it suitable for various transport types (Garsten, 2022). Einride Pod is Level 4 autonomy. At the moment, Einride has its Pod on Swedish public roads and operated on customer premises, and Einride recently, in June 2022, became the first company granted authorization to run its Pod on US roads (Einride, 2022a). It was announced on September 15, 2022, that Einride would enter the German market (Einride, 2022b).

While most developers continue to work on developing the technology for SDT, TuSimple and Plus.ai focus on safety enhancements by developing 360-degree awareness that provides visibility in all weather conditions and can detect hazards up to 1,600 meters away (Thuis, 2020). A network of 50 autonomous freight vehicles is being run by TuSimple between hubs in Arizona, Dallas, and Texas (Stumpp, 2021). TuSimple tested its self-driving technology in Europe in 2021 together with Scania, the Swedish truck manufacturer (Stumpp, 2021). The same year, a test of the delivery of fresh watermelons from Nogales to Oklahoma, US, was conducted by the company. As a result, the transportation time was reduced by 42 percent from 24 hours to 14 hours, making it more efficient than transportation with human-drivers. Continuing testing is being carried out to enhance the safety and productivity of self-driving technology. At the same time, several companies, including Waymo, AutoX, Aurora Innovation, Hyundai, and Ike, are pursuing software, hardware, and data services relevant to unmanned vehicles (Thuis, 2020).

Moreover, in Germany, Hamburg TruckPilot, an autonomous prototype truck collaborative developed by the Hamburger Hafen und Logistik (HHLA) and the vehicle manufacturer MAN Truck & Bus, was successfully completed in May 2021 (Donnelly, 2021; Traton, 2022). This three-year project marked a significant milestone for the use of SDT at port terminals. Its results were presented in Hamburg at the ITS World Congress 2021 on 13 October (Donnelly, 2021; Traton, 2022). The project results highlighted new German laws relating to automated driving that define future hub-to-hub applications (Donnelly, 2021; Traton, 2022).

Benefits of SDTs

An analysis of the benefits associated with adopting innovative technology is of utmost importance before any innovative technology is implemented. In this case, studies and research have shown that Self-driving Trucks can offer benefits in the following ways:

- **Safer Road Transportation**

As demonstrated in chapter 2.3.3, human error is the cause for roughly 90 percent of road accidents, which human errors in recognition, decision-making, and performance are the three leading causes of traffic accidents (US Department of Transport, 2015). An analysis is discussed in this chapter on how self-driving technology is believed to improve safety. It is the advanced technology that SDVs are equipped with, which is supposed to enhance road safety by performing more driving tasks and prevent errors like these or minimize the severity of any errors that do take place. The SDV is often promoted to improve road safety (Van Meldert & De Boeck, 2016; Engström et al., 2018; Müller & Voigtländer, 2019), but at this point, the impact of higher levels of autonomy on road safety has not yet been determined in the real world, which means more real-world evidence is needed to support this claim. Theoretically, enhancing road safety in terms of reducing accidents is anticipated as one of the most promising advantages of adopting SDVs, including SDTs.

In the future, SDTs will be capable of setting new standards for truck safety (Zarif et al., 2021). When compared to human senses of sight and hearing, SDTs are capable of detecting more of what is going on around the vehicle with better range and greater precision by using a combination of diverse kinds of sensors, refer to chapter 3.3. Just a second's distraction and loss of concentration, a driver could highly result in an accident. While with machine vision, the chance of distraction and divided attention can be eliminated, as it constantly monitors everything around the moving vehicle without distractions or feeling fatigued. When RADAR, LIDAR, Ultrasound, and Cameras work together, the vehicle can have a 360 degrees field of view vertically at all times of its surroundings, as illustrated in Figures 20 and 21. According to Sardegna and Shelly (2002, p. 253), a person's field of attention is usually only limited to around 60 degrees. Having 360-degree vision also helps eliminate the blind spot problem, a common cause of truck accidents. In general, blind spot problems refer to a truck driver's inability or difficulty seeing vulnerable road users in front or to the right of its cabin (Share The Road Safely, 2022). Below is a figure illustrating the four most significant blind spots of a semi-truck.

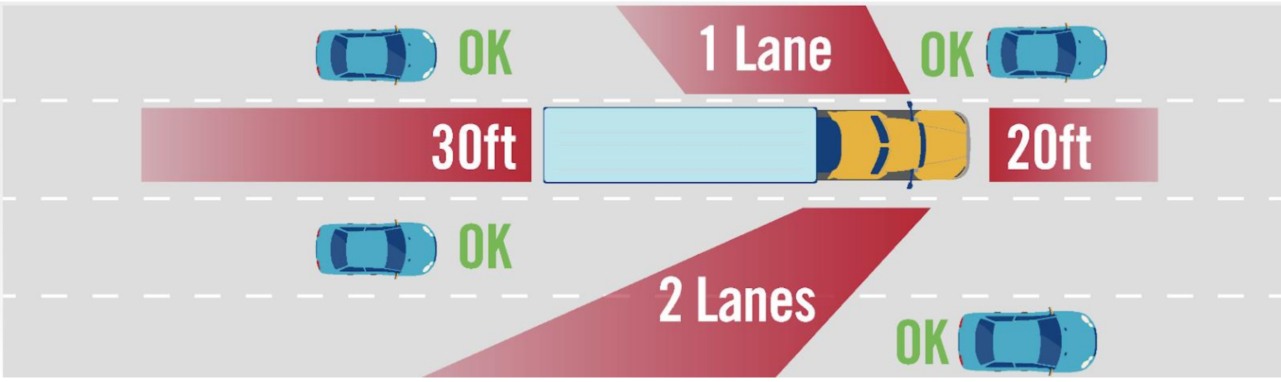

Figure 19: Semi-Trucks Blind Spots

Source: (Share The Road Safely, 2022)

The driver's decision errors result when the driver fails to choose the right action, whether it relates to speeding or steering, at specific points in time. When operating an SDT, the computer controls the truck, so if it has been programmed to handle every possible scenario, it should always make the right decision. It is theoretically possible that a vehicle control system can figure out ways to respond to all traffic situations over time through the use of AI. Vehicle control systems are expected to perform perfectly once they have received sufficient programming and learning. Realistically, the situation is more complicated, as other road users might be human-driven vehicles, and often human behavior cannot be predicted with absolute accuracy. The vehicle control system, at the same time, lacks the common sense of humans, therefore, the system will not know how to respond if an un-preprogrammed incident occurs. Hence, ensuring that SDTs are capable of adapting to all types of accidents on the road remains a substantial challenge for the technology developers.

Besides, self-driving technology has the potential to eliminate human input in the case of performance errors. In theory, control systems in SDTs will be able to calculate more accurately than a human, enable them to make better decisions and judgements on time and enhance performance efficiency (Davenport et al., 2020). With the capability to observe its surroundings continuously, the vehicle control system will, therefore, be able to execute any action more smoothly and respond faster in comparison to a human driver. Therefore, sudden stops and turns will be less likely to occur, resulting in fewer accidents. Furthermore, as explained in chapter 3.3, with Vehicle-to-Vehicle communications (V2V), SDTs can detect hazardous events at an early stage, even before a human driver is aware of those risks. A vehicle can determine potential hazards by analyzing messages from surrounding vehicles, enabling the control system to take action that prevents an accident from occurring. Unlike human drivers, who can recognize objects only within their eyesight, V2V communications allow vehicles to determine potential hazards by analyzing messages from all surrounding vehicles (NHTSA,2022c). The use of V2V communication would offer the vehicle controller more time to react to a situation, whether it be a human driver or a computer system (Heutger & Kückelhaus, 2014, p. 6). According to NHTSA (2022c), there is an excellent promise in V2V communication in enhancing environmental safety, diminishing collisions, and alleviating traffic congestion. Nevertheless, only when all vehicles on the road are capable of communicating with each other can the optimal benefits be reached (NHTSA, 2022c). Having the ability to see a wider range, monitor their surrounding environment at all times, gather more information, at the same time analyze it more thoroughly, and respond quicker than humans, it is believed that SDVs in general, and SDTs, can have a considerable impact on improving road safety.

The removal of human drivers has the potential to reduce human errors in driving, which are responsible for 90 percent of today's accidents. Taking the US as an example, reducing road safety incidents by one percent would result in cost savings of more than $8 billion (Klaver, 2020). In other words, SDTs' value can significantly benefit a wide range of stakeholder groups, including the vehicle's users. The use of SDTs could save substantial societal costs related to traffic accidents, which include both the vehicles and the infrastructure wear and tear (Klaver, 2020).

- **Cleaner and Greener**

Improving transportation by transforming it into a cleaner mode of transportation is also expected to be an advantage that SDTs can bring. This chapter will explore ways in which SDTs can help diminish the negative environmental impacts of the transportation industry and make logistics greener. As illustrated in Figures 16 and 17, the transportation sector produces 20.27 percent of the total CO2 emissions, of which 22 percent are from heavy and medium trucks. The use of machine control vehicle speed will enable trucks to have the most efficient driving speeds, efficient steering, transitions, and rapid response to traffic conditions. These factors contribute to lower fuel consumption (Ma et al., 2015, pp. 205-206). Therefore, over time, fuel efficiency will improve, greenhouse gas emissions will be lowered, and overall environmental impacts will be reduced.

Based on a test conducted by TuSimple (2019) with the University of California San Diego, SDTs were discovered to be 10 percent more fuel-efficient than traditional human-driven trucks. The reduction of truck fuel consumption can make a considerable impact on pollution reduction. As mentioned in chapter 4.2, Truck Platooning represents the initial stages of SDTs. It can be illustrated by Truck Platooning as an example of how Connected and Autonomous Vehicles (CAVs) can be arranged on the road. Several studies have demonstrated that Truck Platooning will make road transport far more efficient, safer, and cleaner in the future (ACEA, 2017; Khan, 2019; Lee et al., 2021; White Paper, 2021; Atasayar et al., 2022). With Truck Platooning, trucks can drive closer together, and air resistance is minimized between trucks. Therefore, the trucks consume less fuel and emit fewer greenhouse gases (ACEA, 2017; European Commission, 2017; Khan, 2019; Lee et al., 2021; White Paper, 2021; Atasayar et al., 2022). The ITS4CV report by Ertico indicates that platooning can reduce CO2 emissions from trailing vehicles by up to 16 percent, whereas leading vehicles can reduce emissions by 8 percent (Winder, 2016). By reducing carbon emissions, SDTs will improve the environmental impact of everyday transportation. Systems can be optimized to perform in accordance with the environmental targets.

Self-driving technology can be even more environmentally friendly when applied to trucks powered by electricity. At the moment, no indication has been given whether the SDTs applied to logistics will run on fuel, diesel, electricity, or hybrid power. The most notable benefit of a vehicle being electric is its ability to reduce noise, making electric trucks ideal for noise-restricted areas and nighttime operating (Department for Transport (DfT), 2010). Operators and drivers will benefit from increased productivity without needing to hire more drivers (Wrenn, 2017). The use of electric trucks would also allow the trucks to access a broader range of roads that were restricted to internal combustion engine-powered vehicles (Schöder et al., 2016). Optimal results, both environmentally and economically, will be gained from self-driving technology if the vehicles run on electric power. It is, therefore, most favorable to push forward the development of fully electric SDTs. Regardless, even if the SDT does not run-on electricity, it still consumes less fuel than a traditional truck driven by humans. Further, Berns et al. (2009) believe it would not only be beneficial for the environment to be sustainably conscious, but by doing this, the company can enhance its image and brand, giving the company a competitive advantage.

- **Operational Efficiency**

The adoption of SDTs is also expected to significantly boost the efficiency and productivity of the logistics industry (Van Meldert & De Boeck, 2016; Engström et al., 2018; Müller & Voigtländer, 2019). The use of SDTs could be a solution to the logistic problem by filling the gap between surges in logistics demands and shortages of qualified drivers. Furthermore, in the current situation, human-driven trucks are also underutilized, and lost time is incurred due to restrictions on drivers' driving time. SDTs, on the other hand, can operate at any time of day, all year round without requiring a break. Additionally, self-driving technology helps the vehicle to respond more quickly to traffic conditions and control the vehicle's speed more effectively, therefore improving travel time (Horne & Reyner, 1995, pp. 565–567; Van Meldert & De Boeck, 2016; Engström et al., 2018; Müller & Voigtländer, 2019). Unlike humans, self-driving technology does not require to be recruited, retained, or trained. Moreover, logistics and transportation are among the leading sectors that experience employee strikes (Eurofound, 2021). Strikes are triggered by many factors, including wage demand, working conditions, and safety concerns. As a result of these strikes, shipments are late in delivery and cause the customer to be dissatisfied with the company. The machine will never get sick or have a difficult day or have a strike. It is expected that a machine will always perform consistently, punctually, and predictably as it is programmed. In this way, SDTs maintain a higher level of stability than human-driven trucks. As SDTs eliminate driver breaks, SDTs can operate over longer distances and complete more deliveries in the same timeframe.

Numerous studies have concluded that the more self-driving technology on the road, the more information will be exchanged between vehicles (NHTSA,2022c). The technology will be able to plan the most optimized routes while also avoiding peak traffic times. This way, the traffic flow will be smoother, and the roads will be less congested (Neufville et al., 2022). By eliminating vehicle downtime and offering timely shipments, self-driving technology can enhance industry productivity, maximize network accessibility and operations, and enhance profitability. Improvements in driving efficiency can result in lower fuel consumption, thereby lessening environmental impacts. The use of SDTs can also open a variety of delivery options depending on a customer's needs, such as instant delivery, scheduled delivery, nighttime delivery, and weekend delivery, which were previously unattainable because of labor laws (Kassai et al., 2020, p. 16). As a result, overall productivity would increase, and bottlenecks in the workflow would decrease. In turn, this results in better performance for the company and a reduction in total transportation costs.

- **Cost Savings**

The American Transportation Research Institute breaks down the cost structure for traditional trucks as in Table 1 (Williams & Murray, 2020, p. 22). To date, there have been no studies with concrete data that quantify how much cost savings SDTs can generate over traditional human-driven trucks. It is because SDTs still being in the testing phase and are not yet being commercialized. In spite of this, there are a number of theories that suggest SDTs can save companies money by reducing fuel and driver labor costs. While fuel consumption and labor costs can be significantly reduced, additional costs will arise when self-driving technology is finally implemented, and these costs must be considered when calculating cost savings.

As explained in chapter 2.5, the use of freight trucks contributes significantly to the overall emissions and fuel consumption of vehicles on the road. Emissions can be reduced, and economic benefits can be realized through fuel efficiency improvements in long-haul transportation. Regarding transportation costs, fuel consumption is directly correlated with distance and time of travel. This means transportation costs will get higher as the transport takes longer and travels farther. Accordingly, supply and demand are constantly being affected. A truck's fuel costs account for about one-fourth of the total operating costs, as reflected in Table 3. The results of numerous studies and research have shown that computer-driven technology is able to consume less fuel than humans (AXA UK, 2015, pp. 6-7; Manyika et al., 2013, pp- 80-82). When the vehicle is controlled by machines, its speed will be better managed, and its response to traffic conditions will be faster, resulting in better fuel efficiency. Moreover, further fuel savings can be saved through the use of platooning and vehicle-to-vehicle communications. In this way, SDTs can communicate with one another and maintain a steady distance from one another, which reduces air resistance between vehicles (Alam, 2014, pp. 63,141). It has been estimated by AXA (2015, pp. 6-7) that trucking companies will save 10-15 percent on fuel by implementing SDTs.

Motor Carrier Costs	**Share of Total Cost**
Vehicle-based	
Fuel Cost	24%
Truck/Trailer Lease or Purchase Payments	16%
Repair & Maintenance	9%
Insurance	4%
Permits and Licences	1%
Tyres	2%
Tolls	2%
Driver-based	
Driver Wages	32%
Driver Benefits	10%
TOTAL	**100%**

Table 1: Share of Total Average Marginal Cost of Truck Operation in 2019

Source: (Williams & Murray, 2020, p. 22)

Labor costs are constantly rising, making them one of primary driving forces for SDTs adoption. As SDT can drive by itself without human assistance, therefore, a truck driver is no longer required. Having no driver would save the company money on loans, sick leave, and other employee benefits (Kassai et al., 2020, p. 16). Aside from this, SDTs are not restricted to a specific working schedule like human labor is. Furthermore, without a human driver, the mandatory resting times for drivers can also be eliminated. Given that most transportation companies only earn money when goods are actually being transported, maintaining a high fill rate is critical to their profitability. Generally, transportation companies do not earn money whenever the trucks are stationary and standing still, regardless of whether the trucks are taking a break or resting at night. Consequently, to maximize profitability, the vehicle should operate 24/7 with a high fill rate. SDTs could theoretically sustain continuous driving for extended periods without stopping. As a result, SDTs will be more efficiently utilized. In this way, companies can save money and enhance their competitiveness at the same time.

Furthermore, the usage of SDTs is expected to result in a lower accident rate, as discussed in chapter 4.4, this would also lead to lower repair and maintenance costs and accident-related expenses for companies. Without considering the additional costs that would be incurred when SDTs are implemented, the overall long-term

Total Cost of Ownership (TCO) for truck owners will be lowered through improved fuel efficiency and reduced labor costs.

Challenges and Barriers of SDTs

The introduction of Self-driving Trucks may have many positive effects and benefits, nonetheless, the implementation of these vehicles may encounter several challenges and barriers along the way. Technologies play an integral part in making SDTs operate smoothly. Although critical technology has mostly been developed for SDTs to operate independently, these trucks are still in the developmental stage and are still being tested. A substantial amount of time must be invested in developing and testing the technology of SDTs in order for these vehicles to become commercially viable. The purpose is to assure that the vehicles perform reliably through all conditions, whether there is heavy rain, snow, unpaved or unmapped roads, or even unstable internet connections. The technology must show no flaws or errors before being marketed. This can be considered one of the greatest challenges for developers and manufacturers alike. Apart from the technical challenges, SDTs also raise significant concerns, which pose substantial challenges to the industry. It is unlikely that the following challenges will prevent SDTs from being introduced. It is crucial, however, for companies to pay attention to these challenges and risks and determine ways to overcome them.

- **(Cyber-) Security**

The introduction of autonomous and connected vehicles is expected to improve traffic flow and safety. However, cybercriminals might find this as an opportunity to perpetrate their crimes. There have been some suggestions that cyber security poses a major disadvantage to SDTs (Kassai et al., 2020; Ioppolo et al., 2020). An SDT is exceptionally vulnerable to hacker attacks since it relies heavily on technology and software and is controlled by computers. Numerous concerns have been expressed about hackers' possibility to access and use the systems illegally (Kassai et al., 2020; Ioppolo et al., 2020). With increased levels of vehicle autonomy, hackers may be able to hack and remotely hijack vehicles, posing a significant safety risk (Nash et al., 2022). In the event of a security breach, data privacy could be lost, the safety of the vehicle could be negatively impacted, or even an accident could occur. Taking control of the vehicles by a hacker with malicious intent could result in a catastrophic incident. The attacker might be a thief, a criminal organization, a terrorist, an activist group, a foreign hostile government, or even the vehicle owner (Dominic et al., 2016). The cyber attacker can manipulate settings, alter the code, and corrupt the system with malware and viruses (Uma & Padmavathi, 2013, p. 390; Petit et al., 2014, pp. 2-3). The imperative of strict cybersecurity safety measures is unquestionable when developing and implementing SDTs for safety purposes. These include the safety of passengers, and all those in the surrounding area. By observing videos and images from sensors mounted around the vehicle, SDTs perceive the world around them at 360 degrees, explained in chapter 3.3. It is, therefore, crucial that the self-driving system must be entirely unbreakable and uncompromised, especially the image sensor footage.

In order to gain control of or take over the vehicle, hackers could manipulate its video stream by altering the legitimate video with a false one or altering the output stream by replacing video packets (Venkat, 2019). This situation is known as tampering. In this type of attack, the vehicle can be misled into making undesirable decisions that can result in potentially fatal consequences. In the event of a denial-of-service attack, the host may be prevented from accessing image-related services (Venkat, 2019). For example, the signal could be disconnected, the lens could be blackened, or the sensors could be damaged due to an electrical attack. Self-driving technology could also be the target of many other illegal activities. Various malicious purposes can be achieved through these attacks, including data theft, social and political activism, espionage, and intellectual challenge.

Additionally, there is a possibility that cyber-attacks are used to take over SDTs to transport people illegally for purposes such as human trafficking and human smuggling. The crime of trafficking entails forcing a victim into a desperate situation of exploitation, forced labor, forced marriage, prostitution, organ extraction (Europol, 2016). Victims can be men, women, or children. Typically, human smuggling occurs when an individual seeks illegal entry into a foreign country through the use of transportation or fraudulent documents (Europol, 2016). The EU has experienced many cases of immigrants being smuggled in the back of trucks' containers and of human trafficking as well (Europol, 2016). At the moment, no studies or research have been conducted regarding the possibility of SDTs being exploited for illegal people's transportation or being hacked for such purposes.

A further possible vulnerability does not relate to the vehicle itself, but to its cargo. In classical trucking, one or more drivers accompany the load of a truck, reacting to attacks or attempts of cargo theft in unpredictable ways – in this case the human factor is protective to the cargo. Given the absence of this factor, the SDT becomes perfectly dependable in its reaction – SDT has to follow certain security protocols that are public knowledge and that can potentially be exploited to halt a moving vehicle, mainly the highest priority of not endangering human lives. This vulnerability can be used to unload the valuable cargo until help arrives in whatsoever form. No mention of this was found in literature, and we can only speculate about the reason – to avoid promoting this potential abuse or the unawareness of it?

- **Liability**

Besides concerns regarding hackability, there is also a great deal of apprehension about safety and liability regarding accidents. It is frequently asked who will be liable if the SDT causes a traffic accident. It would be necessary to examine the situation in these types of events carefully since so many questions would arise. For instance: Could a software or hardware malfunction have caused the accident (Punev, 2020, p. 98)? Could a third party have hacked the system (Dima, 2019, p. 20)? Could the vehicle's mistake have been caused by road traffic (Punev, 2020, p. 98)? When these issues are closely considered, it becomes clear that many parties could be held accountable for an accident. It could be the person in the driver's seat (if applicable, for the lower levels of autonomy), the owner of the vehicle, the manufacturer, the technology/ software provider, OEM, hacker, or other third parties (Uzair, 2021, pp. 2-3; European Transport Safety Council, 2016, p. 20).

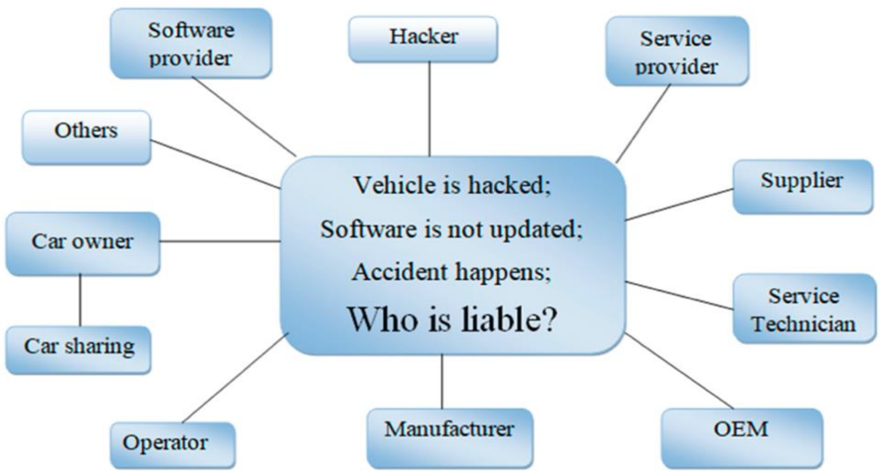

Figure 20: Who is Liable?

Source: (Uzair, 2021, p. 2)

Accident liability remains one of the most controversial topics when it comes to SDTs, as the law around AVs and liability for accidents is still evolving (Chatzipanagiotis & Leloudas, 2020, pp. 6-7; Martínez-Díaz & Soriguera, 2018, p. 281). Eventually, there will be inevitable accidents where liability issues must be addressed. The driver traditionally takes full responsibility for controlling the vehicle while driving, which is reflected in current traffic law, where the driver is generally held accountable, and manufacturers are rarely exceptional (Chatzipanagiotis & Leloudas, 2020, pp. 6-7). It is likely that the situation will change with SDVs deployment. With increasing levels of autonomy, the vehicle becomes more dependent on machines, and the driver is no longer mandatory. It is possible that liability would shift from the driver to the automated driving system, where the manufacturer should bear the responsibility (Chatzipanagiotis & Leloudas, 2020, pp. 6-7). Germany and some other countries are following a three-pillar liability model that involves the driver, owner, and manufacturer (Tanenblatt et al., 2022). It should be carefully examined the distinct levels of autonomy, which require diverse levels of driver interaction, as explained in Chapter 3.2. The driver will remain responsible as long as the driver is able to take control over the partially-/semi-automated vehicle and intervene in case of an emergency (European Transport Safety Council, 2016, p. 20; Tanenblatt et al., 2022). In the event that a driver fails to comply under his duty of care and thereby causes an accident, that driver will be held liable, as well as the owner, for the damages resulting from the accident (European Transport Safety Council, 2016, p. 20; Tanenblatt et al., 2022). Nevertheless, the question of liability must be answered if a collision occurs due to a malfunction in SDV. The malfunction of SDV may be the result of a programming error or a system failure, potentially putting several parties at risk for liability (Marchant & Lindor, 2012, p. 1328; Boeglin, 2015, p. 185). There are currently strict liability regimes in most European countries that adequately cover the vehicle holder's liability if there is an accident that is caused by SDVs (Gasser, 2012, p.64). An individual who uses a vehicle at their own expense is referred to as a vehicle holder (Bundesanzeiger I, 2021, p. 3108, s. 7). All damages resulting from operational risk could be deemed the holder's responsibility, which includes risks associated with automation, where it could be improper handling by the driver of the automated system or technical defects (Gasser, 2012, p. 1529). In this way, the owner of an SDV is therefore strictly liable for accidents caused by the vehicle, even if the owner did not commit any mistakes. The situation may be perceived as unfair by some parties. In this sense, many have argued that manufacturers should be responsible for any damages that result from a defect in their product (Reed, 2020; Tanenblatt et al., 2022).

Furthermore, as an SDT, the vehicle must make decisions when unavoidable accidents occur. Software designed for SDVs attempts to mimic the decision-making process of humans through the machine learning process, as mentioned in chapter 3.3. Nevertheless, programming guidance may entail moral dilemmas. In order to avoid the dilemma, there must be agreement on the particular dilemmas as well as a convergence of ethical guidelines and public opinions (Kallioinen et al., 2019, p. 13). However, several studies suggest that, at present, the general public is not yet fully accepting the moral decisions that machines are making (Bigman & Gray, 2018, p. 34; Kallioinen et al., 2019, p. 13). If a life-or-death situation is involved, most people would want someone else, a human, with a full mind to make the decision instead of a machine (Bigman & Gray, 2018, p. 34). It is emphasized in the German Ethical Guidelines that human life has priority over that of animals or over things and mandate that SDVs make decisions that result in less damage (BMVI, 2017, p. 11; Martínez-Díaz & Soriguera, 2018, p. 281).

In addition, in the event a vehicle is hacked, it is essential to understand who should be held responsible. With all these factors in mind, different levels of autonomy ought to be regulated differently, and new laws and regulations need to be adopted in order to clearly separate the responsibility between drivers, owners, and manufacturers. This creates an overly complex situation. It is expected that liability issues of the various parties will be significantly altered as SDVs become a part of the road transportation system. It is vital that the liability framework needs to take risks and culpability seriously in a consistent and adequate manner. Further, it is crucial to distinguish between the responsibility of the vehicle owner, the driver, and the manufacturer. This involves collaboration between insurance companies, software developers, the government, and societal stakeholders. Efforts are already underway, for instance, the EU's C-ITS Platform and EU89's ITS Action Plan, in which the need for a black box in the vehicle is deemed essential by all parties to support legal decisions in case of collision (European Transport Safety Council, 2016, p. 20; Martínez-Díaz & Soriguera, 2018, p. 281). Before moving forward, it is crucial that regulators and politicians clearly define the responsibilities and liabilities of each party to ensure that risks are distributed fairly, and victims are adequately protected.

- **Job Losses and Workforce Restructuring**

Self-driving Trucks are capable of transforming the future of the transport industry. In the beginning, the adoption of SDTs might not appear to be a problem as these trucks can be seen as an opportunity to overcome one of the industry's most significant challenges, the driver shortage problem (Short & Murray, 2016; ITF, 2017; Fitzpatrick et al., 2017; White Paper, 2021). However, considering the long-term, widespread concerns have sparked regarding the threat of job losses for drivers, especially in the long-haul sector. The exact number is unclear, but it is estimated that thousands to millions of truck drivers may be affected when the transition occurs (ITF, 2017; Wisskirchen et al., 2017; Beede et al., 2017; Heard et al., 2018). As shown in Figure 38, there were 10.8 million people employed in transport occupations in 2020, of which 35 percent were heavy truck and bus drivers, equivalent to 3.78 million workers.

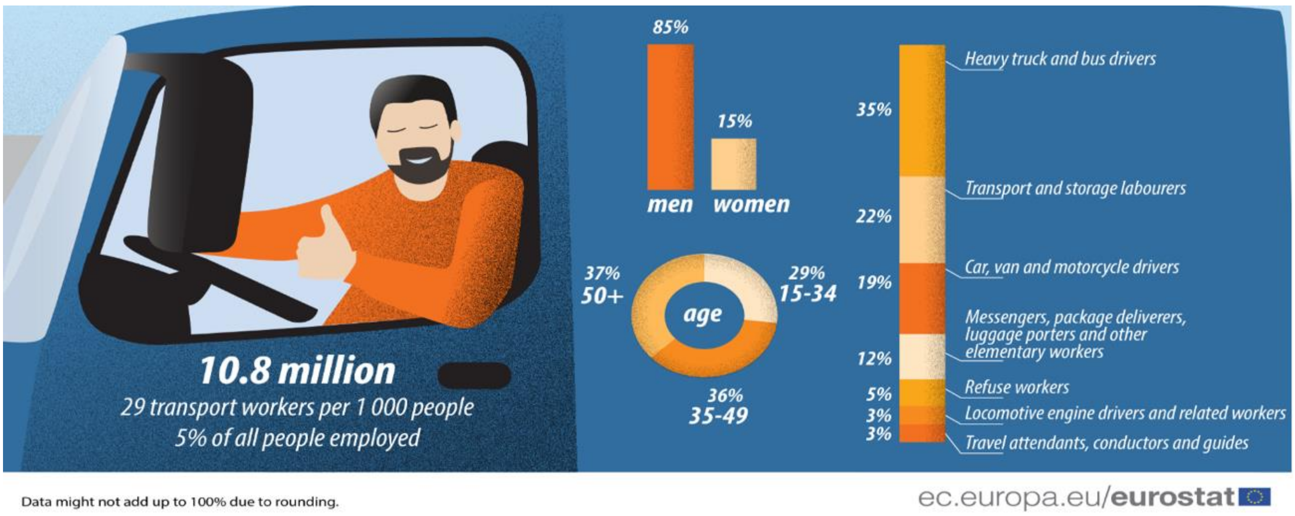

Figure 21: Transport Workers in The EU 2020

Source: (Eurostat, 2021a)

It is predicted that long-haul truck drivers may be the first to lose their jobs or have to be reallocated as the level of autonomy increases, and a truck will no longer require a driver to operate (Pettigrew et al., 2018; Slowik & Sharpe, 2018; Mohan & Vaishnav, 2022). This is regarded as a downside of this adoption. In general, the salary of professional drivers is considered to be decent, especially in comparison with other occupations that do not require tertiary education (Pedigo & Bendix, 2017). It is possible that the socioeconomic gap between those who have received higher education and those who do not will exacerbate the loss of jobs among professional drivers (Pedigo & Bendix, 2017; Slowik & Sharpe, 2018). Typically, besides driving, truck drivers are also responsible for carrying out other duties, including loading, unloading, inspecting cargo as well as inspecting the vehicle for safety (ITF, 2017). These roles may still require human-worker to be fulfilled.

It is also possible to reassign drivers, who are now replaced by technology, to focus on short-haul, last-mile delivery or warehouses where human labor is also needed. As a result, these new roles would be a way to improve their working conditions as new roles could allow drivers to work closer to home and the drivers no longer must work at night-time. Another way to look at this problem is that adopting SDTs could create many new employment opportunities that did not exist before, in logistic terminals, or other external services connected to SDTs. There will somehow be a compensatory effect for the long-haul jobs lost from creating new and short-haul positions. New types of roles will be required, such as driver safety specialists, vehicle operations specialists who support on-road testing of AVs/SDVs, autonomous transport planners, analysts, fleet supervisors and managers, and supply chain managers (Autor, 2015; ITF, 2017; Ioppolo et al., 2020). These new occupations may require higher education levels or different skill sets than those required for truck drivers. There is a possibility that all currently employed workers will be required to be reskilled or upskilled.

The elimination of truck drivers would also have many adverse effects on businesses along the highway, like hotels and restaurants at every highway rest stop. There are still significant questions regarding SDTs' deployment, the social implications, and the actual effects of these technologies on real-world driving conditions. Anyways, taking steps toward addressing this problem is essential in order to prevent the adoption of SDTs from being unwelcome.

- **High Investment**

When it comes to freight applications, return on investment (ROI) is usually a key determinant of innovative technology adoption (Slowik & Sharpe, 2018). According to many reports, studies, and research, self-driving technologies are evidently economically beneficial (Slowik & Sharpe, 2018; Manyika et al., 2013, pp- 81-83; Kassai et al., 2020, p. 16). However, there are currently no industry-wide business cases available, and therefore ROI regarding self-driving technologies remains unknown. Nevertheless, it is likely that the new technology will be expensive to get started, particularly for the first commercially available SDTs, which implies high upfront investments. The technology for SDTs is estimated to cost between $ 30,000 and $ 100,000 (Bergvall & Gustavson, 2017, pp. 42-43; Engholm et al., 2020). There is a possibility that this could be a barrier to adopt this technology, particularly for smaller and mid-sized haulers, since some may not be financially able to invest in new technology, which could lead to them being pushed out of the market by larger haulers. Most smaller haulers are concerned about upfront technology costs, in contrast to larger haulers, who often to be more motivated by savings accumulated over time from economies of scale (Bevly et al., 2017; Slowik & Sharpe, 2018). In particular, if there are no government incentives to encourage the adoption of SDTs, small haulers will be pushed farther away from implementing this technology because of the high investment.

While SDTs have not yet been deployed, the impact of SDTs on real-world driving conditions, and also how these vehicles will coexist with the public and other vehicles, remains unclear. The actual outcomes of SDTs will only be confirmed once these vehicles become feasible and practical. It is possible that more unforeseen challenges and risks could arise when SDTs are actually implemented than what were anticipated in the study. But in the meantime, considering these mentioned benefits and challenges will help the industry gain a better understanding and expectation of how technologies are adopted and their impact, as well as supporting logistics companies in managing, adapting, and integrating SDTs. It is crucial for the trucking industry and automotive manufacturers to find ways to limit and overcome the challenges it potentially encounters and achieve numerous positive outcomes with SDTs adoption to excel at the delivery of SDTs.

Summary

Status of SDTs today	- heavier weight and larger size, trucks have complex movements and challenging dynamics, making them harder to maneuver than regular cars. - SDTs need more time than Self-driving Cars to become viable. - many successful tests and developments around SDTs have been made around the world, even in Level 5. - the first SDTs implementation will likely be employed on long-haul routes.
Concept of Platooning	- first commercially viable application of SDTs technology. - allows multiple trucks to travel in close formation with a minimum safety distance between each truck. - consist of one lead vehicle and several trailing vehicles, with a driver manual controlling the lead truck. - this concept is level 1, because only the vehicle's speed is controlled. - reduce emission impacts: leading vehicles can reduce by 8 percent and up to 16 percent reduction for trailing vehicles. - the concept is still in constant development, with full autonomy expected by 2027.
Benefits of SDTs	- improve road safety, and reduce injuries and fatalities compared to trucks controlled by human drivers. - reduce fuel consumption and emissions. - solve the driver-shortage problem. - reduce labor costs. - improve overall efficiency by optimizing truck utilization.
Challenges and Drawbacks of SDTs	- relies heavily on technology. - vulnerable to cyber-attacks, and potentially exploitable for human trafficking and smuggling. - potential job losses, layoffs, and restructuring of the workforce. - high investment. - liabilities yet to be finalized by government bodies.

Public Perception of Self-driving Trucks

The chapter seeks to learn what the general public in the EU thinks about Self-driving Trucks and how they envision them being adopted. Presented in this chapter is an overview of public perception, along with a discussion on its importance. The study's objectives were fulfilled through a survey conducted, the results of which will be outlined in this chapter.

Introduction to Public Perception

As Slovic described in his work (2000), public perception is "the judgments make by people when asked to describe or estimate hazardous activities, situations or technologies". According to Rom et al. (2022), public perception represents the feelings that people have on a given topic at a given time based on the opinions of individuals. Considering that people do not always have an opinion on everything, public perception can be presented by those views expressed openly by members of the public (Rom et al., 2022). Public perception was also defined by Glynn et al. (2015) as the collective mind of a majority of the population that can influence an organization's policies, tactics, strategies, or actions. Public perception also reveals the level of public support and whether something is seen as a promising idea. Understanding the public's opinion is essential to directing a company's marketing efforts. Thus, public perception has a significant impact in the success of businesses or any innovative technology by supporting and encouraging its growth. Human beings tend to think in an individualistic way, so the general public is unlikely to hold a uniform opinion. The perception of each individual may shift for a variety of reasons and change over time. So, it is imperative to understand that a public perception survey can only provide an overview of what people thought at the time the survey was carried out (Rom et al., 2022). For businesses, industries, and regulators, it is necessary to research public perception, as this provides them with greater insight into the public and comprehends the wants, needs, motivations, emotions, and beliefs of the public. By taking a broader view, it will facilitate businesses, industries, and regulatory bodies to establish closer relationships with the public. Especially when implementing innovative technologies that have a significant effect on people's lives, engaging people in good faith is essential. The delivery of new technology or new products to the public can sometimes be challenging for manufacturers since the public has no existing knowledge and is unfamiliar with the technology or product (Shane, 2000; Capaldo et al., 2014). There is a substantial difference in how technology is perceived around the world (Funk et al., 2020). How technology is perceived and adopted is influenced by these beliefs and opinions.

Survey Questionnaire

The survey questionnaire consists of seven sections. The cover letter is presented in the first section. The second section asks if the participants live in the EU. The survey will end immediately if the participant does not live in the EU. The third section contained questions asking if the participant is familiar with SDVs in general and with logistics in particular. The fourth section examines how participants envision Self-driving Trucks being implemented. Participants' opinions about SDTs are collected in the fifth section of the questionnaire. The survey uses a 5-point semantic scale to allow participants to express their levels of opinion. The sixth section of the questionnaire requests participants' opinions on when they think SDTs will become a reality. Participants' age and geographic information are collected in the last section.

After the questions are designed, a backward translation technique was performed to translate the questionnaire into German, using two independent translators following the guidelines described by Brislin

(1970). Once the translation process was completed, native English and German speakers proofread and correct the survey wordings. Finally, the bilingual questionnaire was created online using Google Forms. The final survey design can be provided by the authors upon request.

Survey Results

This chapter aims to evaluate the data collected from participants in the survey. Results and interpretation of the survey are presented and discussed below, based on the responses of 256 survey participants.

Q1: Are you currently residing in Europe?

The first question aims to filter participants who do not live in the EU. This survey focuses only on perceptions of the public in the EU; therefore, when the participant does not live in the EU, the survey will end immediately for that participant.

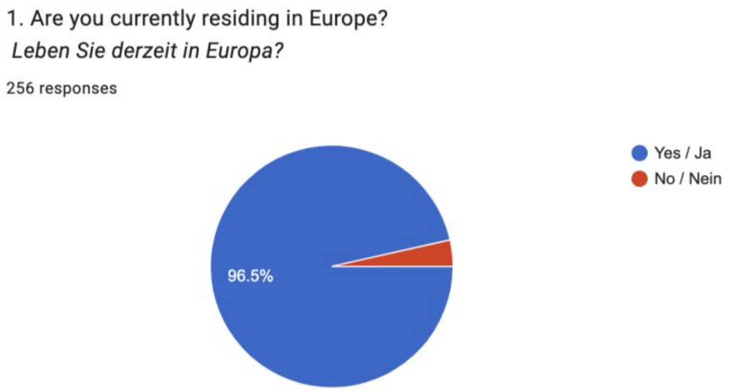

Figure 22: Participant's Responses Regarding EU Residency

Accordingly, 247 out of 265 participants (96.5 percent) currently reside in Europe, and 247 participants would be the exact number of participants counted to satisfy the survey requirement and complete the whole survey.

Q2: Are you aware of the concept of Self-Driving Vehicles?

The purpose of this question is to determine what level of awareness survey participants have about Self-driving Vehicles in general. To answer this question, participants do not require any technical knowledge but rather their awareness and knowledge about Self-driving Vehicles.

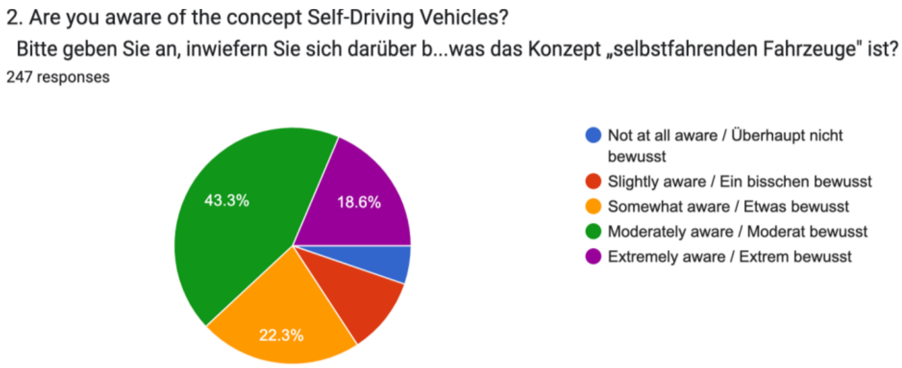

Figure 23: Participant's Awareness Regarding SDVs

18.6 percent of participants are extremely aware of SDVs, while the majority 43.3 percent have moderate awareness, followed by 22.3 percent of participants who are somewhat aware of SDVs. 10.5 percent of participants are slightly aware of SDVs. Overall, that would mean more than half of the participants (18.6 percent + 43.3 percent = 61.9 percent) seem to have a relatively good understanding of SDVs. Only a small percentage of people are still unaware of SDVs.

Q3: Which purpose do you relate Self-driving Vehicles mostly to?

Self-driving Vehicles are being adopted in many industries, so this question sought to determine how participants associate them with one or more industries. Participants were asked to choose the industries they associated with SDVs in this question.

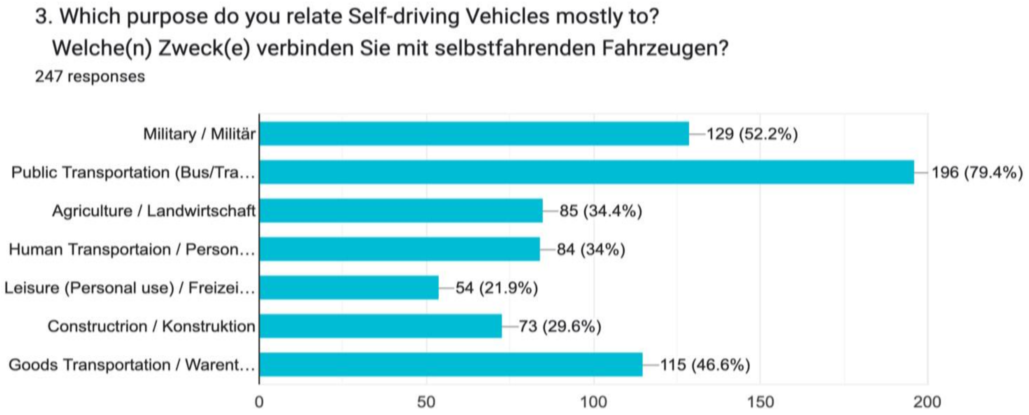

Figure 24: Participant's Association of SDVS with Respective Industries

Most participants (196, which is 79.4 percent) associate SDVs with public transportation, followed by the military (129, which is 52.2 percent). The use of SDVs for good transportation also received 115 votes or 46.6 percent. In general, it can be seen that SDVs seem to find their usage in every industry.

Q4: Are you aware of Self-Driving Trucks used in Logistics?

By asking this question, the survey is trying to determine the level of awareness participants have about the potential uses of Self-driving Trucks in logistics.

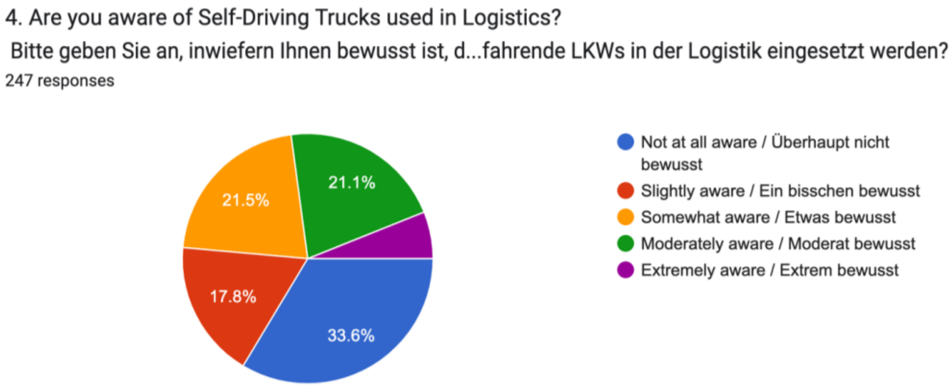

Figure 25: Participant's Awareness Regarding SDTs in Logistics

There are divided opinions among participants on this question. The SDTs for logistic purposes were utterly unknown to 33.6 percent of participants. Still, a total of 42.6 percent of participants are somewhat (21.5 percent) and moderately (21.1 percent) aware of this concept. Only 6.1 percent of participants were remarkably familiar with this concept. It looks like the use of SDTs in logistics still has less awareness than the general SDVs.

Q5: How likely or unlikely do you support the Self-driving Trucks concept for logistic purposes?

The survey is asking this question in order to determine whether participants support the use of Self-driving Trucks for logistics.

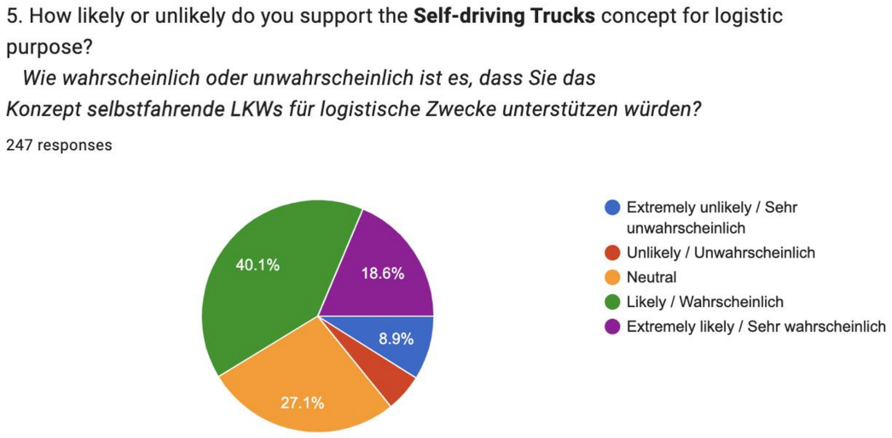

Figure 26: Participant's Level of Support Regarding SDTs Usage for logistics

Most participants are in favor of the use of SDTs in logistics, with 40.1 percent considering it likely, and 18.6 percent considering it extremely likely. Meanwhile, 27.1 percent of participants feel neutral in supporting the use of SDTs for logistics. However, 5.3 percent of people do not like this idea and 8.9 percent are strongly against it. This results in 14.2 percent being dissenters, which is a notable number that must be taken into consideration.

Q6: Which route is more likely to have Self-driving Trucks for goods delivery purpose first?

The purpose of this question is to understand which routes participants anticipate will be the first to be served by Self-driving Trucks for the delivery of goods.

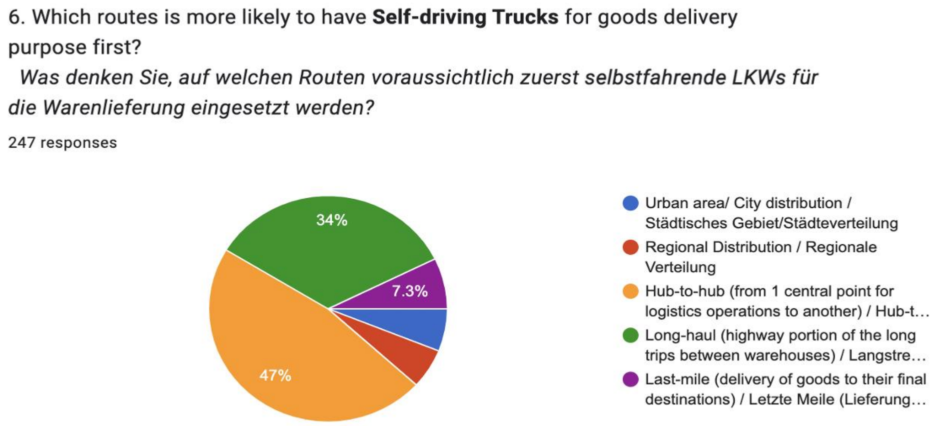

Figure 27: Participant's Responses Regarding First SDTs Route

Hub-to-hub is the most suitable delivery route for SDTs, selected by 47 percent of participants, followed by long-haul routes with 34 percent. Last-mile, regional and urban distribution seem to not be favored by the participants.

Q7: Which concept do you expect that companies aim to execute when Self-driving Trucks are viable?

This question tries to put participants in the role of logistic companies and ask for their opinion on what type of route they would first implement for SDTs.

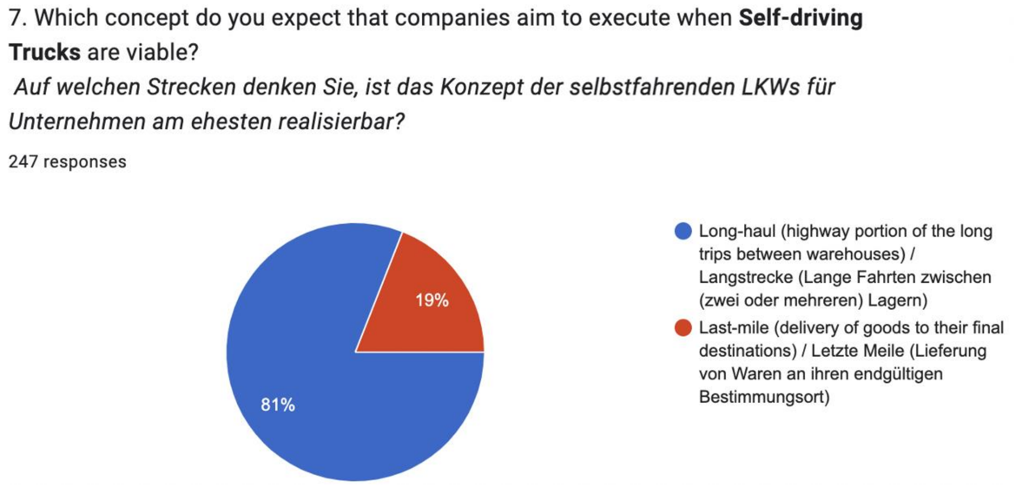

Figure 28: Participant’s Responses Regarding the Route Companies Plan to Execute SDTs First

It is believed by most participants (81 percent) that companies will operate SDTs on long-haul routes.

Q8: Where should the Self-driving Vehicles operate?

This question asks participants for their opinion on which lanes or areas participants would prefer Self-driving Vehicles to operate. Indirectly, this question tries to find out whether people are comfortable sharing the road with or driving next to this type of vehicle.

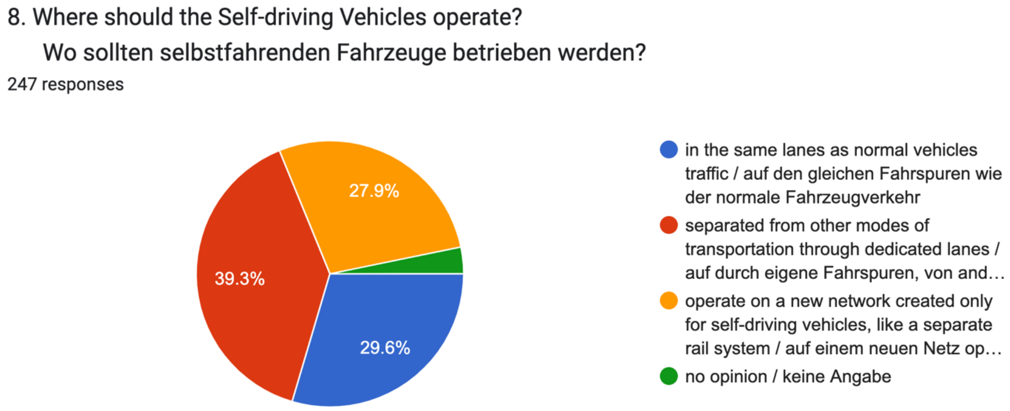

Figure 29: Participants' Responses Regarding Where SDVs Should Operate

The opinions of participants on this question were divided. 39.3 percent of participants would like SDVs to operate separately in dedicated lanes. 29.6 percent of participants feel comfortable sharing the same lane with these types of vehicles. Interestingly, another 27.9 percent prefer SDVs to operate on a new network designed exclusively for these vehicles. These results suggest that 67.2 percent (39.3 percent + 27.9 percent) of participants are unwilling to drive next to a SDV or share the same road with one.

Q9: Who should be liable when a Self-driving Truck causes an accident?

Participants were asked this question to collect their opinion about liability in accidents involving Self-driving Truck.

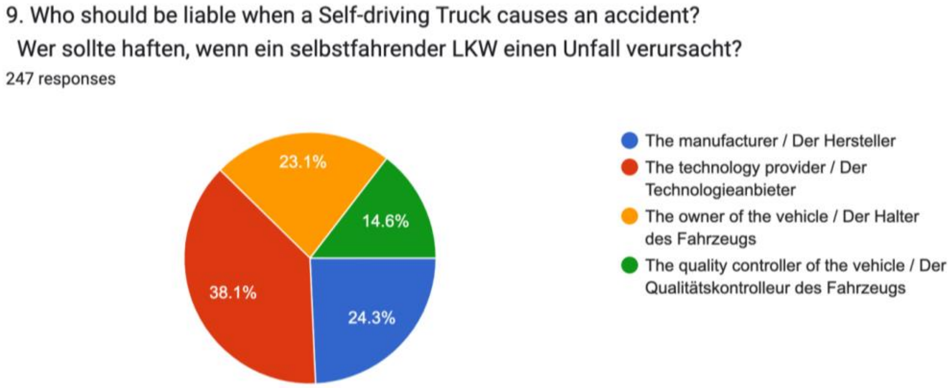

Figure 30: Participant's Responses Regarding SDTs' Liability in Case of Accident

The question of responsibility for driverless vehicles remains a controversial topic for the public, as reflected in the responses. Many participants (38.1 percent) believe that the technology provider should take responsibility when a SDT causes an accident. 24.3 percent of participants believe that the manufacturer should be responsible, while the other 23.1 percent believe it should be the owner who takes responsibility. Furthermore, among participants, 14.6 percent feel that the vehicle's quality controller should be responsible in the event of accidents.

Q10: Do you think that technological systems could make better decisions and drive better than human drivers?

This question is intended to determine whether participants trust technology to make better decisions and thus drive better than humans.

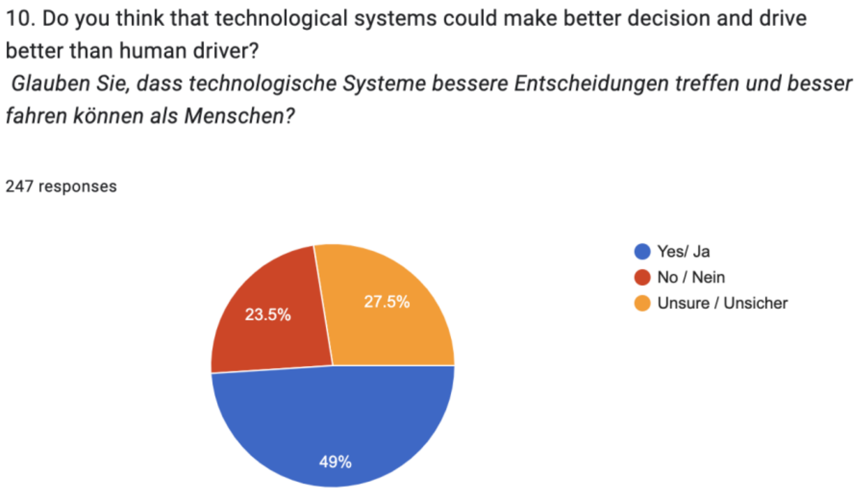

Figure 31: Participant's Responses Regarding the Safety of Self-driving Technology

Nearly half of the participants (49 percent) believe that intelligent machines can make better decisions and drive better than human drivers. 23.5 percent of participants disagreed, followed by 27.5 percent who could not make up their minds.

Q11: How concerned would you feel when participating in road traffic with Self-driving Trucks?

This question aims to determine the concern level of people sharing roads with Self-driving Trucks.

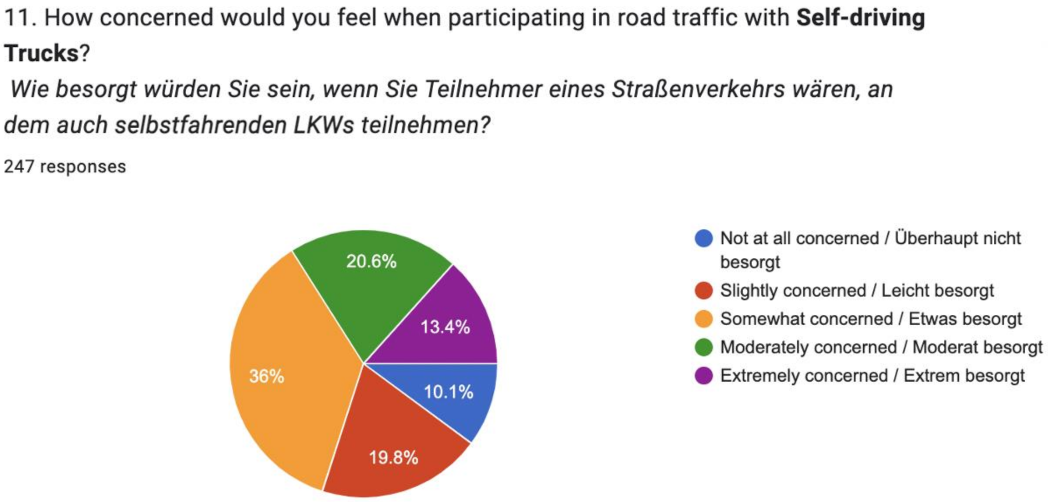

Figure 32: Participant's Level of Concern When Sharing the Road with SDTs

In the survey, only 10.1 percent of participants were not concerned at all about sharing road traffic with SDTs. There is 13.4 percent of participants who indicate they are extremely concerned, followed by 20.6 percent who are moderately concerned, and 36 percent who are somewhat concerned. That results in a total close to 70% of people with concern when sharing road with SDTs.

Q12: To what extent do you agree or disagree with these following statements:

This question tries to gain insight into how the public views the use of Self-driving Trucks for long-haul deliveries.

- **The usage of Self-driving Trucks for Long-haul delivery will lead to faster delivery**

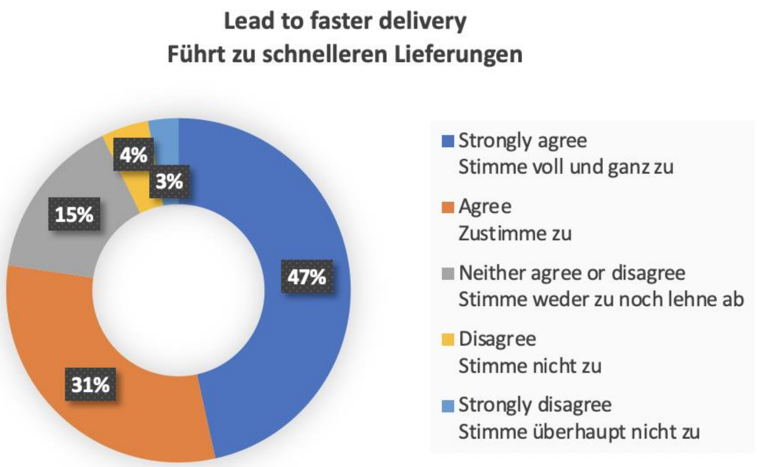

Figure 33: Participant's Level of Agreement/Disagreement on SDTs Lead to Faster Delivery

Faster delivery is one important expectation of customers and an ultimate goal of logistics companies nowadays, and SDTs could play a role in achieving this. There was 78 percent of participants who either strongly agreed or agreed with it. The statement was disagreed with by a total of 7 percent of participants.

- **The usage of SDTs for Long-haul delivery will lead to more frequent delivery**

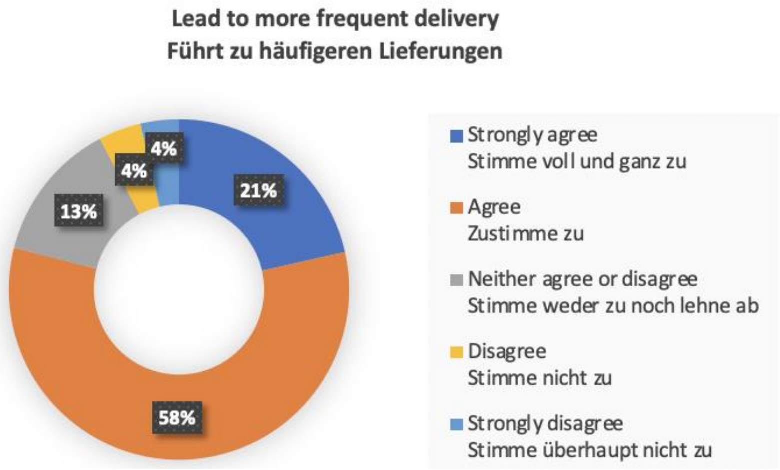

Figure 34: Participant's Level of Agreement/Disagreement on SDTs Lead to more Frequent Delivery

79 percent of participants "agreed" (58 percent) or "strongly agreed" (21 percent) with this statement. While only 8 percent of participants "disagreed" (4 percent) or "strongly disagreed" (4 percent). The remaining 13 percent of participants had a neutral view of it.

- **The usage of Self-driving Trucks for Long-haul delivery will lead to lower shipping prices**

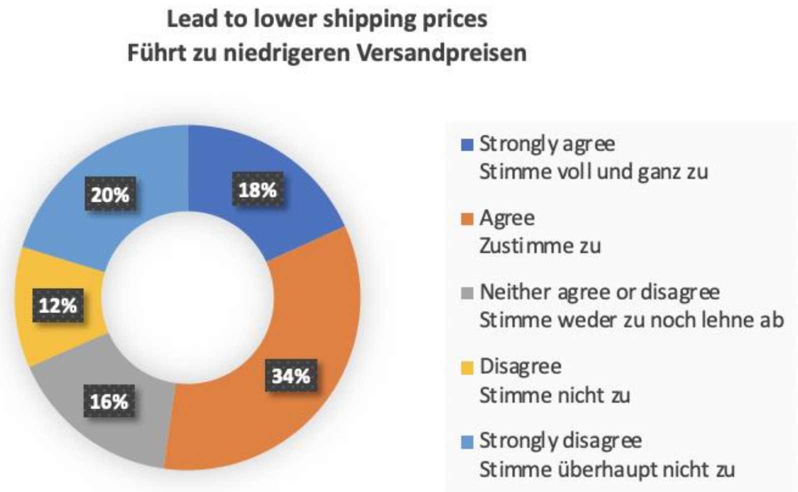

Figure 35: Participant's Level of Agreement/Disagreement on SDTs Lead to Lower Shipping Prices

There was a mixed response to the above statement among the survey participants. In total, 52 percent of participants agreed with this statement, of which 34 percent agreed, and 18 percent strongly agreed. The percentage of participants with neutral opinions was 16 percent, while the percentage of those with disagreements was 32 percent, "strongly disagreed" (20 percent), and "disagreed" (12 percent). There is a slight tendency toward disagreement with the statement in the responses.

- **The usage of Self-driving Trucks for Long-haul delivery will lead to safer road traffic**

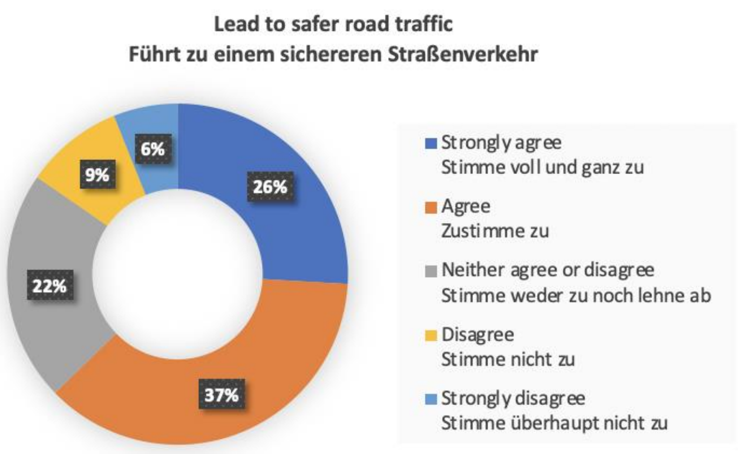

Figure 36: Participant's Level of Agreement/Disagreement on SDTs Lead to Safer Road Traffic

This statement was agreed upon by 37 percent of participants and strongly agreed upon by 26 percent. There were only nine percent of participants who disagreed with the statement and six percent who strongly disagreed, this means that 15 percent of participants do not believe that SDTs could make roads safer. The neutral opinion was expressed by 22 percent of participants.

- **The usage of Self-driving Trucks for Long-haul delivery will lead to fuel-consumption efficiency**

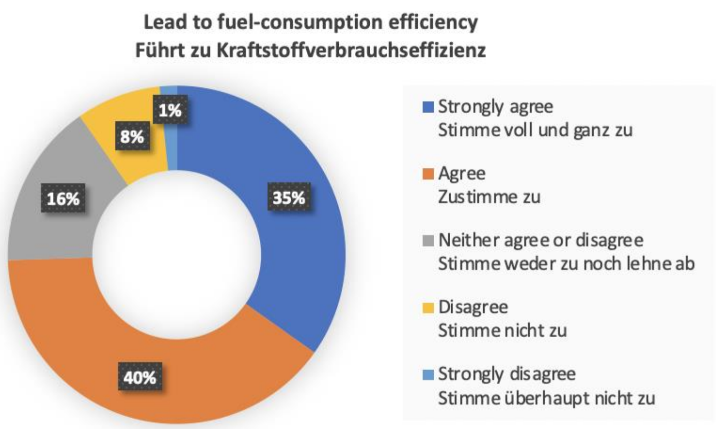

Figure 37: Participant's Level of Agreement/Disagreement on SDTs Lead to Fuel-consumption Efficiency

The statement is supported by 40 percent of participants and strongly supported by 35 percent of participants. The statement was disagreed with by only 8 percent of participants, and 1 percent strongly disagreed with it. The neutral opinion was shared by 16 percent of participants.

- **The usage of Self-driving Trucks for Long-haul delivery will be environmentally friendly**

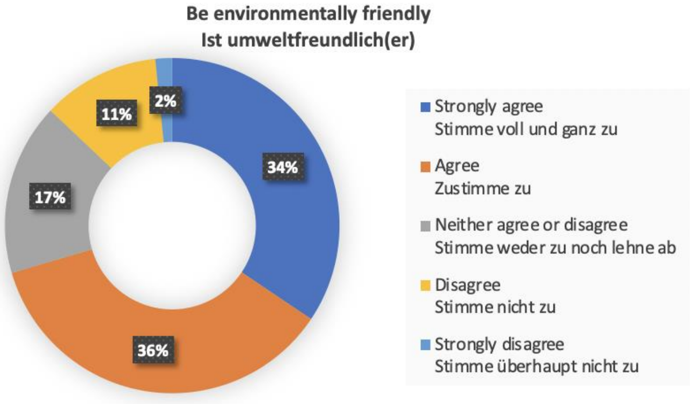

Figure 38: Participant's Level of Agreement/Disagreement on SDTs Will Be Environmentally Friendly

The opinions of participants regarding the environmental benefits of SDTs were similar. In total, 70 percent of participants agreed with this statement, of which 36 percent agreed and 34 percent strongly agreed. Responses with neutral opinions accounted for 17 percent of participants, while the percentage of those with disagreements was 13 percent, "strongly disagreed" (2 percent), and "disagreed" (11 percent).

- **The usage of Self-driving Trucks for Long-haul delivery will lead to an improvement in drivers' working conditions**

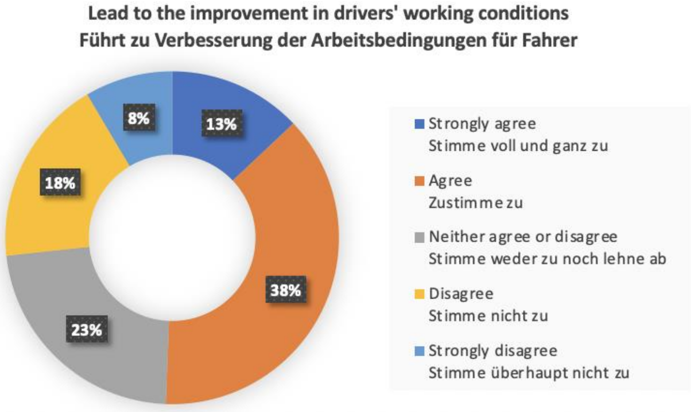

Figure 39: Participant's Level of Agreement/Disagreement on SDTs Lead to Better Working Conditions

The results of this question indicate mixed opinions regarding the improvement of drivers' working conditions through the use of SDTs. 38 percent of participants agreed with the statement, and 13 percent strongly agreed with it. There is a slight tendency towards disagreement in the responses. According to the survey, 18 percent and 8 percent of participants disagree with the statement and strongly disagree with it, respectively.

- **The usage of Self-driving Trucks for Long-haul delivery will lead to layoff to current drivers**

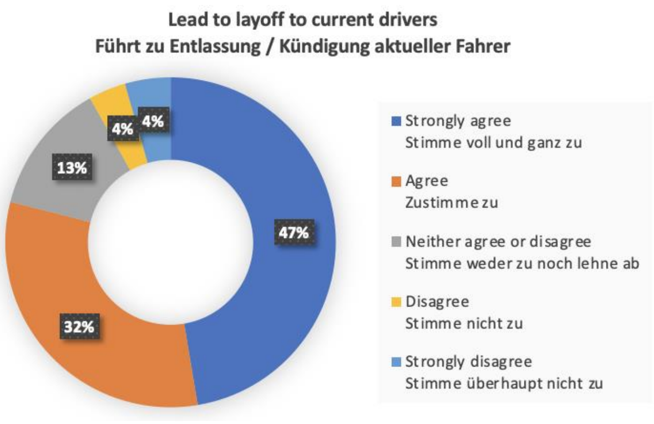

Figure 40: Participant's Level of Agreement/Disagreement on SDTs Lead to Layoff

The majority of participants "agreed" (32 percent) or "strongly agreed" (47 percent) that SDTs will result in layoffs of current drivers in long-haul deliveries. There were only eight percent of participants who disagreed (4 percent) or strongly disagreed (4 percent). This statement is neutral to 13 percent of participants.

The usage of Self-driving Trucks for Long-haul delivery can be hacked

Figure 41: Participant's Level of Agreement/Disagreement on SDTs Can Be Hacked

This statement received consensus from participants. In most responses, participants either "agreed" (32 percent) or "strongly agreed" (51 percent) that SDTs can be hacked. Overall, only five percent of participants disagreed (3 percent) or strongly disagreed (2 percent).

Q13: Which one for you is the most important benefit of Self-driving Trucks?

Self-driving Trucks offer several benefits to society, and this question aims to determine which benefits the public value most. The answer to this question may provide insight into the motivation behind the public's support for SDTs.

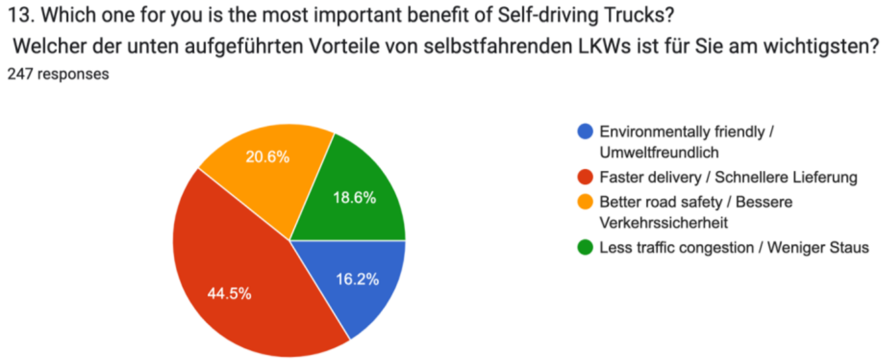

Figure 42: Participant's Responses Regarding the Most Important Benefit of SDTs

The result shows motivation behind faster delivery (44.5%) has highest expectation, followed by higher road safety (20.6%) and lower traffic congestion (18.6%).

Q14: When do you expect Self-driving Trucks to be practical?

This question aims to assess when people expect Self-driving Trucks to be a reality.

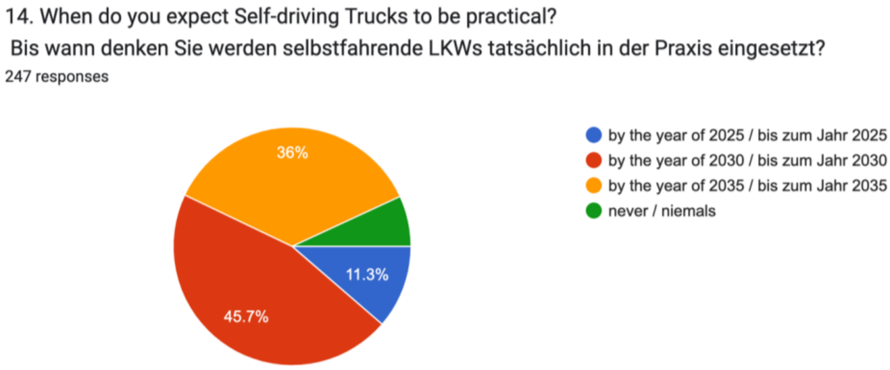

Figure 43: Participant's Responses Regarding When SDTs are Expected to Be Practical

- SDTs are expected by almost half of the participants (45.7 percent) to be practical by 2030, followed by 36 percent to be practical by the year 2035. Interestingly, 6.9 percent of participants still have doubts about viable SDTs and think this technology will never be implemented.

Q15: Which generation are you?

The participants were asked to select their age group.

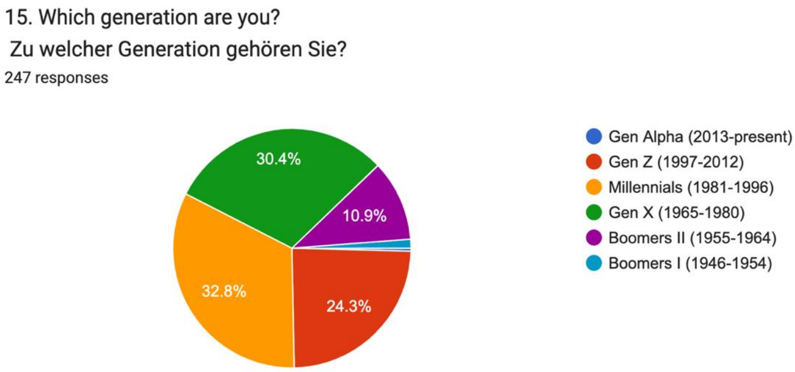

Figure 44: Participant's Age Range

The online nature of the survey enabled the survey to capture responses from individuals across all age groups. 32.8 percent of participants were a part of the Millennials group. At the same time, Gen X contributed 30.4 percent of the participants to the survey. A total of 24.3 percent of participants were from Gen Z and 10.9 percent from Boomers II. Among the participants, there is also a tiny percentage of Boomers I and Gen Alpha joined the survey.

Q16: Which of the following best describes the area where you live?

The question asked the participants to select where they currently reside.

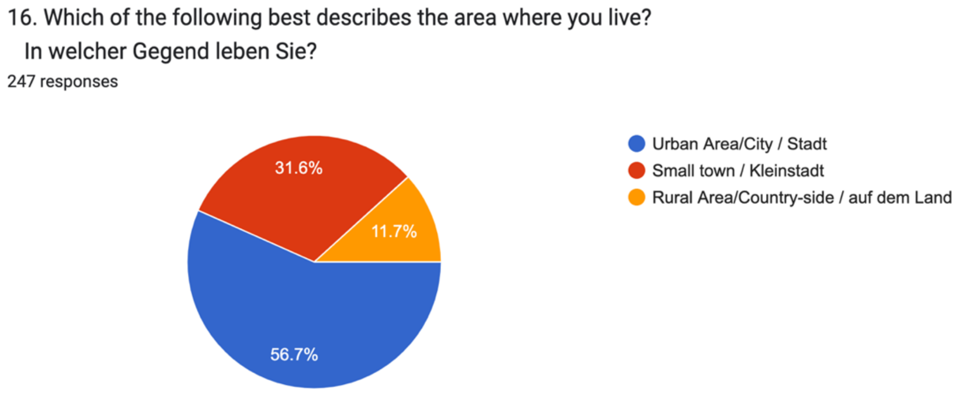

Figure 45: Participant's Living Area

56.7 percent of participants lived in the city, and the percentage of participants living in small towns was 31.6 percent. The remainder, 11.7 percent, live in the countryside.

Key Findings

The key findings are outlined below based on the survey results:

- The participants were highly aware of the existence of SDVs (94.7 percent) and can associate SDVs with many industries, especially public, military, and good transportation. The use of SDTs in logistics appeared to have lower awareness than SDVs in general.
- Most participants believed that intelligent machines would perform better in decision-making and could drive better than humans.
- The majority of participants (85.5 percent) accepted the use of SDTs in logistics, but still a considerable number (14.2 percent of the participants) was against it.
- The participants found Hub-to-hub and long-haul to be the most suitable routes for the first implementation of SDTs.
- SDTs were generally viewed as beneficial for long-haul deliveries, with numerous advantages being acknowledged by the participants. SDTs would lead to faster delivery, higher productivity, with improvement in road safety. There was an overall agreement among the participants that SDTs in long-haul delivery would help reduce fuel consumption and contribute positively to the environment. From the

participants' perspective, the primary motivation for implementing SDTs were faster delivery and a safer driving experience.

- Most of the participants were aware of the challenges associated with SDTs' implementation, such as the possibility of workforce layoffs and the vulnerability to cyber-attacks. Also, not everyone agreed that using SDTs could lower the shipping costs for consumers.
- The majority (70 percent) of participants were concerned about sharing the same road with SDTs and the majority (67.2 percent) of participants suggested having SDVs in general, operating on dedicated lanes or an explicitly dedicated network.
- There was a controversy among participants' opinion regarding the liability for accidents caused by SDTs.
- Most participants anticipated the SDTs in real life by the year 2030-2035.

Discussion and Conclusion

As a way to further understand SDTs operations and their potential contributions to logistics, five research questions were outlined. After reviewing a wide range of literature and conducting a survey, the following summarized answers can be provided to the research questions:

Question 1. Self-Driving Vehicles: what they are, their levels of automation, and their technology.

The study examines what Self-driving Vehicles are, and reviews six standardized levels of autonomy that the Society of Automotive Engineers (SAE) has established. An SDV is one that is driven by an intelligent machine which operates independently without human intervention. The study highlights some real-world applications of SDVs across various industries, including consumer, public transport, and automotive sectors.

Question 2. Self-driving Trucks: what they are, their growth, and their significance

As a special form of Self-Driving Vehicle, a Self-driving Truck is one operated by an intelligent machine and can do so independently without human intervention. Due to the heavier weight and larger size of the truck, the technology and sensors used in SDTs are much more complex compared to passenger vehicles. Hence, SDTs require further development and more thorough testing. However, there have recently been several breakthrough developments in regard to SDTs, promising a realistic implementation in the near future. Truck Platooning is one of the first commercially viable applications of SDTs technology which allows multiple trucks to travel in close formation with a minimum safety distance between each truck. The use of Truck Platooning has been proven to enhance traffic safety and mobility while lowering fuel consumption. A few examples have also been described in the study to illustrate how SDTs are being tested and implemented in practice.

Question 3. In what ways do Self-driving Trucks create opportunities for the trucking industry?

The study points out four significant benefits of SDT for the trucking industry:

(1) improved road safety through innovative technologies and elimination of human error

(2) enhanced fuel efficiency and reduced emissions of trucks, thereby making the trucking industry cleaner and more environmentally friendly

(3) reduced operational costs in terms of fuel efficiency and accident-related costs (maintenance expenses, medical treatment, delays expenses, damage costs, vehicle downtime etc.). Over time, Self-driving Trucks might significantly reduce labor costs in the trucking industry by reducing the need of human drivers.

(4) improved operational efficiency – SDT can operate longer, travel farther distances with minimum break, allowing trucks to be more fully utilized.

Question 4. What are the challenges and barriers Self-driving Trucks may encounter?

There are four substantial drawbacks that Self-driving Trucks potentially encounter:

(1) security risks - since SDTs are operated by an intelligent machine that does not require human intervention, which makes it susceptible to cyber- (and potentially other) attacks.

(2) yet to be finalized regulation over the liability for accidents involving SDTs.

(3) job losses and workforce restructuring - while SDT could help reduce labor costs, it causes downsizing of the driver workforce thereby putting millions of truck drivers at risk of being transferred or losing their jobs or being transferred.

(4) high upfront investment - It is expected that the investment for self-driving technology will be high in the early adoption phases, which prevents many hauler companies from affording this innovative technology.

Moreover, there is the possibility that unknown or uanticipated risks could be introduced when the first commercial SDTs become available.

Question 5. What is the EU public perception toward adopting Self-driving Trucks in the transportation of goods on public roads?

The survey results indicated that public awareness of SDTs was lower than the awareness of general SDVs. The majority of the participants viewed faster delivery as the most significant benefit of SDTs, followed by improvement in road safety, less traffic congestion, and less impact on the environment. They looked forward to the implementation of SDTs in logistics; however, they were uncomfortable and concerned about sharing the road with those machines. Most of the participants suggested having these vehicles operate on dedicated lanes or an explicitly dedicated network. Also, there were different options about who should be held accountable for accidents caused by SDTs. The results revealed that there were a considerable number of participants who are still against the use of SDTs.

For some concluding thoughts: Like many other industries, the logistics industry is experiencing a technological revolution, which offers both opportunities and poses challenges at the same time. The transportation industry in logistics has been facing recurrent and increasing problems related to human truck drivers. There are not enough truck drivers to accommodate market demands, and the shortage is expected to worsen in the future, making a convincing case for the rapid introduction of SDT. In addition, the regulations pertaining to the restriction of driving time, which set the utilization limit of human drivers, make this problem more challenging to resolve. Self-driving Trucks can be a potential solution to replace human drivers and are anticipated to have a major impact on future logistics and transportation. In recent years, several breakthroughs in technologies and adjustments in laws and regulations related to SDVs and SDTs (which were excluded from the scope of this study) have been made, which promise a realistic implementation of SDTs in the near future. In the study, the use of Self-driving Trucks is demonstrated to enhance future logistics and mobility by making them safer, cleaner, and more efficient. The combination of several innovative technologies now allows Self-driving Trucks to maneuver the vehicle autonomously, respond quicker and more accurately to traffic conditions, and be more consistent. By making fewer “human errors”, such as those resulting from fatigue, distraction, or sickness, road traffic safety will be enhanced. In the long term, fuel efficiency is also improved, and externalities are reduced, which are beneficial to both society and the environment. Self-driving Trucks can achieve higher utilization and productivity, unlocking new opportunities for suppliers and bringing benefits to consumers. While Self-driving Trucks have several advantages to offer, there are some drawbacks and concerns which need to be addressed, such as cybersecurity concerns, liability debates, and high up-front investments. The side impact of a successful SDT implementation on the existence of the truck driver workforce cannot be neglected.

According to the survey results, the EU public seems to show a positive attitude toward this innovative technology and expects its implementation in the near future, but there are still expressed concerns about safety, security, and its social impacts. In particular, the expressed reluctance to share the roads with SDT’s must be seen as a wake-up call for the future producers of these vehicles as well as public policy-makers. Piloting and later releasing this technology must be in line with public acceptance, thus a broad-based information campaign must complement the process, covering the technology itself, its potential benefits to everyone, and how the potential negative impacts are dealt with. The sheer size and therefore potential dangers of these machines seems to be at least in the back of respondents’ minds and must be dealt with proactively and honestly for the benefits to be harvested. A separate infrastructure for SDTs is highly unlikely to be spatially and economically viable, therefore we must find ways to accommodate them, safely and as an integral part, into our daily mobility of the future.

Limitations and Recommendations

As a future-oriented topic, it is very intriguing to research but challenging to locate relevant literature. There is a limited amount of data that is available to study the effects of Self-driving Trucks in depth, where most existing data and studies on Self-driving Vehicles are theoretical or hypothetical.

As of the time this study was conducted, no SDTs have been commercialized. Consequently, it is difficult to accurately estimate the price or cost of operating one, so the economies of SDTs are not included in the study.

Most likely, all the participants of the conducted survey have never encountered or experienced SDTs. These participants might only become aware of these types of vehicles through newspapers or other media platforms. Consequently, it could be possible for the participants to be biased in answering some of the survey questions because the concept may be unfamiliar to them. Despite attempts to reach all EU residents, the conducted survey was only available in English and German, making it only accessible or limited to those who speak these two languages.

Finally, several recommendations can be provided for further research on SDTs in order to facilitate the technology’s successful implementation in the future:

- More detailed research on how self-driving systems can be protected from cyberattacks and other potential vulnerabilities of the technology, including theft, sabotage or terrorism.
- Further study or research should be conducted on preventing SDTs from being used for illegal transport, such as human trafficking and human smuggling.

- Laws and regulations should be further refined and extended to ensure all aspects of automated driving are covered, such as a concrete harmonized regulatory system between all European countries while being flexible enough to foster innovation and deployment without compromising the public interest.
- Further study or research should be conducted on the effects and consequences of laying off and restructuring driver workforces to society as a result of SDTs' implementation.
- Further study or research should be conducted to examine the actual costs of implementing Self-driving Trucks and their overall economic viability.
- Further study or research should be conducted to discover why people perceive SDVs to drive better than humans, increasing road safety, yet do not want to share the road with them.

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