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AI, Sustainability and Digital Transformation: Shaping the Future of Business and Society

Societal and Industrial Expectations for the Future of Road Freight Transport Vehicles

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Abstract: Road freight transport continues to play a key role in the functioning of global and regional supply chains, but both industry and society are placing increasingly high demands on future vehicle technologies. In addition to increasing economic efficiency, there is an increasingly urgent need to reduce environmental impact, improve safety, and integrate digitalization and automation into road freight transport. The aim of this study is to map and systematize the expectations of industrial and social actors regarding future road freight vehicles, with a particular focus on sustainability, technological development, and regulatory trends. This study identifies and models the fundamental tensions between societal expectations and industrial realities as one of the main obstacles to the sustainable transition of road freight transport.
The thesis is based on a review of the literature and an analysis of current policy documents, and provides a structured discussion of the expected impacts of technological trends such as electric and hydrogen-powered vehicles, autonomous systems, and smart logistics networks. The study also looks at how social preferences are changing and what responses are required from decision-makers, manufacturers, and logistics providers. The findings of the research can provide guidance for both industrial developments and transport policy measures aimed at creating sustainable and competitive road freight transport.

Keywords: Alternative Fuels, Industrial Needs, Road Freight Transport, Societal Expectations, Sustainability, Automation, Transport Innovation

JEL Classification: Q55, L92, L22

1. Introduction

Road freight transport has been a key element of global, regional, and local logistics systems for decades. The ability to move goods quickly, flexibly, and reliably has made road transport crucial to the functioning of national economies and maintaining their competitiveness. At the same time, in the 21st century, this sector faces complex challenges that require new approaches and innovative solutions. Industry players, society, and government and regulatory bodies are all setting increasingly stringent requirements for road freight vehicles. These expectations go beyond mere economic performance and increasingly take into account environmental sustainability, transport safety, and technological and social integration.

The aim of this study is to explore and systematize the industrial and social expectations that are being formulated for the road freight vehicles of the future. To achieve this goal, the research is primarily based on an analysis of literature and policy documents, while also taking into account the directions indicated by technological innovations and regulatory trends. One of the starting points of the study is that the road freight transport sector does not operate as an isolated entity, but is part of a complex ecosystem that is closely linked to industrial production, supply chains, urban planning, and various segments of social life.

From an industry perspective, key requirements include increasing the efficiency and reliability of transport processes, reducing costs, and integrating digital technologies such as data analytics, artificial intelligence, and automation into freight and logistics systems. In addition, there is a growing focus on environmentally friendly technologies such as electric and hydrogen-powered vehicles, which enable the sector to contribute to reducing greenhouse gas emissions.

At the societal level, expectations are also diverse. The public and civil society organizations are increasingly sensitive to the environmental and health impacts of road transport, such as noise and air pollution, traffic congestion, and the risk of accidents. In addition, people expect road freight transport to fit into the concept of sustainable urban mobility and not to compromise the livability of public spaces.

At the same time, there is a strange contradiction: people support green, smart transport in theory – less pollution, safer roads, etc. – but when it comes to actually implementing it, suddenly everyone protests. For example, they don't want solar charging stations in their neighborhood, they don't trust self-driving cars, and they don't like that everything will become more expensive. People are afraid of the risks, they don't want to pay more, and many say, "Okay, let there be change, just not in my backyard."

The freight vehicles of the future must therefore meet not only economic and technological requirements, but also social and environmental expectations.

The complexity outlined in the introduction justifies the multidisciplinary approach of the study, taking into account the intertwining of technological development, economic rationality, environmental policy guidelines, and social demands. The following chapters discuss in detail the expectations of industrial and social actors, presenting current trends, future directions, and the challenges the sector may face in the coming decades.

The original contributions of the study are:

(a) technological development,

(b) environmental sustainability,

(c) regulatory trends, and

(d) social acceptance.

2. Literature review: Practical examples and policy developments

This chapter reviews key international developments that shape the evolution of autonomous road freight transport. It summarizes relevant literature while highlighting concrete market deployments and policy actions that demonstrate how technological progress is translated into practice. By presenting both operational examples and regulatory trends, the chapter delineates the conditions under which autonomous driving technologies are currently emerging.

2.1. Autonomous driving in practice – technologies and market introduction

This section examines the practical implementation of autonomous driving in the heavy-duty vehicle sector. Through selected industry cases, it outlines the leading actors, the technological solutions they deploy, and the environments in which early commercial operations are taking place. These examples provide a concise overview of the technology's current maturity and the factors influencing its market introduction.

2.1.1. Aurora Innovation (USA, Texas)

Aurora launched its first fully autonomous trucks on the Dallas–Houston route in 2025, without human drivers, although some vehicles initially still had safety drivers on board.

According to a Wall Street Journal report, the Lidar-based system, which can detect objects up to three football fields away, reacts nearly 11 seconds faster than a human.

Aurora plans to expand its operations to include nighttime and inclement weather driving in the second half of 2025 and to open new routes, such as to El Paso and Phoenix (*Aurora*, n.d.).

2.1.2. Waymo Via (USA)

Waymo's robot test plans include Class 8 autonomous trucks, currently being tested in Texas, Arizona, New Mexico, and California; their partner is Daimler Freightliner Cascadia vehicles.

2.1.3. Plus (international)

Plus.ai, which develops Level 4 self-driving technology, is partnering with Scania/MAN/Navistar, with testing underway in Texas and Sweden. A hydrogen-powered Level 4 autonomous truck was also unveiled (*Plus and NVIDIA Collaborate to Advance AI for Level 4 Autonomous Trucks With Large-Scale World Models*, n.d.).

2.1.4. Kodiak Robotics (USA)

At the end of 2024, Kodiak Robotics pioneered the launch of its first commercial driverless truck routes along leased roads in West Texas (*Kodiak Catalyst*, n.d.).

2.1.5. Gatik (USA, Canada)

Operates in the middle-mile transport sector: in 2019, they launched pilot projects with Walmart and Loblaw in Canada, and in 2025, they will also operate driverless vehicles in partnership with Kroger and Tyson Foods.

The above-mentioned projects clearly indicate that the technology is ripe for commercial application under limited conditions (highway driving, specified routes). The main obstacle at present is not technology, but regulation, trust building, and economic scaling.

2.2. Green innovations and infrastructure development

This chapter reviews key green innovations and related infrastructure developments that support the decarbonisation of road freight transport. By examining recent industry initiatives, it highlights how alternative energy solutions, energy-efficient vehicle technologies, and dedicated charging or refuelling networks are beginning to shape more sustainable freight operations.

2.2.1. TIP Group – solar-powered refrigerated trucks

SolarEdge and Mitsubishi Heavy Industries have collaborated to develop electric trailers powered by solar panels and energy storage systems.

2.2.2. Scania – Sweden's longest electric truck route

Scania, SKU, and LOTS Group have formed a consortium to create a 430 km electric route with three fast charging stations to demonstrate long-term operation.

2.2.3. Hyundai XCIENT – hydrogen trucks in Germany

They operate a hydrogen fuel cell truck that can save up to 69,000 kg of CO_2 emissions per year compared to diesel.

2.2.4. Austria – electric vehicle transport truck

In early 2025, Hödlmayr began using the first electric vehicle transport vehicle (Mercedes-Benz eActros 300) between the Magna Steyr factory (Graz) and the vehicle depot, a distance of approximately 4 km.

2.3. Regulatory and policy frameworks

This chapter provides an overview of the policy and regulatory measures that influence the decarbonisation and modernisation of road freight transport. It highlights the most relevant EU-level and national frameworks that affect technology adoption, cost structures, and market dynamics, thereby defining the conditions for the sector's ongoing transition.

2.3.1. European carbon dioxide reduction targets

Between 2024 and 2040, CO_2 emissions from heavy-duty vehicles must be gradually reduced (by 45% by 2030 and 65% by 2035, and by 90% by 2040) at the EU level – the new regulations are already in force following their adoption in May 2024.

2.3.2. Germany: CO_2-based road tolls and support for alternative drive systems

The introduction of CO_2-dependent road tolls and exemptions for zero-emission vehicles (e.g., until 2031) is encouraging the transition, although the latter support may be discontinued after 2025.

2.3.3. German climate programs and government incentives

The 2030 target is for one-third of German truck traffic to be electric. According to industry reports, up to 75% of new trucks could be zero- or low-emission by 2030. Hybrid solutions, HVO100 (hydro-treated vegetable oil), LNG (liquefied natural gas), and hydrogen will also play a role, but infrastructure and costs continue to hinder a rapid transition.

2.3.4. EU: Support for combined transport

The Combined Transport for Europe initiative aims to ensure that intermodal (rail+water+road) transport can deliver up to 90% CO_2 reductions by 2040, in line with the EU's proposed climate law.

2.3.5. EU regulatory barriers for heavy-duty vehicles

ACEA (Association des Constructeurs Européens d'Automobiles) and freight transport organizations are pushing for an update to the EU's vehicle size and weight directive so that heavier electric vehicles (e.g., those with large batteries) can be competitive. They also recommend allowing longer trailers and higher load capacities.

2.3.6. ICCT forecast: road emissions to peak in 2025

According to the ICCT (International Council on Clean Transportation), CO_2 emissions from road transport in the EU could peak as early as 2025 and fall by around 25% by 2035, thanks to recent regulations. (*Clean and Sustainable Mobility*, n.d.)

2.3.7. Impact of toll and ETS systems on logistics

From 2025, the transport sector will also be affected by the ETS (EU Emissions Trading System) emissions trading system, with companies being required to purchase quotas. According to research, this will increase operating costs while encouraging energy efficiency and alternative modes of transport.

2.4. Practical developments, examples, and policy directions

Not only technological innovations, but also concrete practical implementations and developments in the regulatory environment play a key role in shaping the future of road freight transport. In recent years, several initiatives have been launched worldwide that are not only in the testing phase but are already operating the freight vehicles of the future in real traffic environments, whether they are self-driving, electric, or alternatively powered trucks.

2.4.1. Autonomous trucks: from theory to practice

One of the most significant advances has been in the field of autonomous road freight transport. In 2025, the American company Aurora Innovation launched its first fully self-driving trucks in Texas, without any human presence (*Aurora*, n.d.). During transport between Dallas and Houston, Aurora's lidar-based sensors were able to identify obstacles three football fields away, reacting 11 seconds faster than a human driver (Kekade, n.d.). This development is a milestone in the application of Level 4 autonomous driving technology, especially on long-distance freight routes.

Similar initiatives are also underway at Waymo Via, Kodiak Robotics, and Gatik. Waymo is using Daimler Freightliner Cascadia trucks for testing in Texas and California (*Waymo Via Expands Partnership with UPS to Autonomous Freight Movement with Class 8 Trucks*, n.d.). Gatik's autonomous systems, optimized for middle-mile transportation, are already in commercial operation in the United States and Canada, with partners including Walmart and Kroger ('AI Research', n.d.).

2.4.2. Sustainable powertrains and green innovations

In the interests of environmental sustainability, the logistics sector is rapidly transitioning to alternative powertrain technologies. In 2025, Swedish companies Scania, SKU, and LOTS Group launched Sweden's longest electric truck route to date, covering 430 kilometers and supported by three fast-charging stations (Kumar et al., 2025). The aim of the demonstration was to prove the viability of long-distance electric freight transport, not only technologically but also economically.

Hyundai's XCIENT hydrogen-powered trucks are already in service in Germany. A single vehicle saves up to 69,000 kilograms of carbon dioxide emissions per year compared to conventional diesel-powered versions (Bayerlein et al., 2025). In addition, Mercedes-Benz eActros 300 electric vehicle transport trucks operate daily between Graz and Hödlmayr in Austria (Williams, 2025).

Solar-powered refrigerated trucks, such as those presented by TIP Group and Mitsubishi Heavy Industries, also represent an innovative approach. In these solutions, solar panels mounted on the vehicle's trailer provide energy for the cooling system, significantly reducing fuel consumption (Segreteria, 2023).

2.5. Policy directions and regulatory environment

Industrial developments are closely followed by EU and Member State regulations aimed at achieving climate targets and promoting sustainable freight transport. Under the regulatory package adopted by the European Union in 2024, carbon dioxide emissions from heavy-duty vehicles must be gradually reduced: –45% by 2030, –65% by 2035, and –90% by 2040 (*Clean and Sustainable Mobility*, n.d.). The regulation applies to newly sold vehicles and encourages manufacturers to develop new technologies.

Germany is playing a pioneering role in policy incentives. Following the introduction of a CO_2-based road toll system in 2024, zero-emission vehicles will be exempt from these charges until 2031, although this exemption may be modified after 2025 (*Electric Trucks to Remain Exempt from Tolls in Germany until 2031 - Electrive.Com*, 2025). In addition, according to the German transport strategy, at least 75% of new trucks put into service by 2030 must be low- or zero-emission vehicles (Guhlke, 2025). In practice, this will result in the emergence of an increasingly wide range of alternative technologies, such as electric, hydrogen, or HVO100-based vehicles.

The EU Emissions Trading System (ETS) is also undergoing a transformation: from 2025, road transport will be included in the quota system, making it mandatory for transport companies to purchase carbon dioxide quotas, which will directly affect operating costs (Pahle et al., 2025).

Also worth mentioning is the EU's policy of promoting combined transport, which aims to increase the share of intermodal transport (rail + road + waterway) by 2040, offering up to 90% CO_2 reduction potential, according to UIRR (Union internationale pour le transport combiné Rail-Route).

2.6. Market challenges and regulatory barriers

Although progress has been significant, market players face a number of obstacles. The current weight of electric trucks exceeds that of conventional vehicles, mainly due to the batteries. Vehicle weight and size limits, therefore, often put alternative-fuel vehicles at a competitive disadvantage, as they can carry less cargo. Several professional organizations, such as ACEA, are pushing for an update to the directives, particularly with regard to allowing longer trailers and higher axle loads ('European Manufacturers and Operators Urge EU Member States to Finalise Weights and Dimensions Revision', 2025).

3. Methodology

The aim of the study is to explore the expectations of industry and society regarding future road freight vehicles, with a particular focus on sustainability, technological development, and the regulatory environment. The research uses a qualitative approach based on secondary data, supplemented by thematic content analysis.

3.1. Research approach

The study is exploratory, qualitative research based on an analysis of relevant literature, policy documents, and practical examples. As the topic also has a strong future-oriented dimension (e.g., technological forecasts, transport policy objectives), the methodology is synthetic in nature and based on a combination of several types of sources.

3.2. Analysis method

The research used thematic content analysis based on the following main topics:

Technological developments (e.g., autonomous driving, electric and hydrogen propulsion, logistics digitalization)

Sustainability expectations (e.g., zero emissions, energy efficiency, circular economy)

Policy and regulatory directions (e.g., CO_2 targets, ETS, road tolls, infrastructure support)

Social and economic considerations (e.g., labor replacement, road safety, acceptance)

The structure of the individual subsections of the analysis was also based on these topics, allowing for the exploration of the relationships between the expectations.

3.3. Data sources

The study relies primarily on secondary sources, which can be classified into the following categories:

Scientific articles and literature reviews, in particular regular literature reviews on the future of road freight transport (Ferguson et al., 2025), (Engholm et al., 2025), (Kallionpää et al., 2023), (Jungblut et al., 2024)

Recent news sources and case studies from leading international media outlets (e.g., The Verge, Reuters, FT) reporting on the practical introduction of autonomous and electric trucks

European and national policy documents, such as EU CO_2 regulations, ETS guidelines, combined transport strategy, or Germany's sustainability incentive packages

Industry analyses and forecasts, such as publications by DSV, ICCT, ACEA, and UIRR

When selecting sources, the researcher took into account current, reliable, and relevant materials from after 2020.

3.4. Scope and limitations of the analysis

The research does not include primary empirical data collection (e.g., questionnaire surveys or interviews), so the generalizability of the results is limited. The aim was rather to explore trends, identify scientific and industrial discourses, and synthesize the expectations of different actors (industry, regulators, society).

Some of my sources (media reports) may be overly optimistic about technological breakthroughs, as they are often based on company press releases. Environmental groups, on the other hand, may be overly pessimistic. For this reason, my conclusions are cautious.

Another limitation is that the policy environment examined (EU/Germany) cannot necessarily be generalized to other geographical contexts (e.g., the US, Asia), although the study attempts to present examples from several regions.

As a point of interest, let us look at the frequency analysis of keywords ("sustainability," "safety," "autonomy") occurring in policy documents and company press releases over time to see how the emphasis has changed.

2004 – Early focus: Laying the foundations for efficiency and sustainability

Sustainability: The 2001 White Paper (and its 2004 evaluation) already emphasized environmental considerations, particularly in relation to carbon dioxide emissions, congestion, and the strengthening of multimodal transport (rail, water transport). However, "sustainability" was still more of a background goal than a dominant keyword.

Safety: Road safety was a priority area, with a target of reducing fatal road accidents by 50% by 2010. Attention was paid to the development of passive and active safety technology (e.g., seat belts, ABS, speed limits).

Autonomy: This term did not yet appear in a technological sense during this period. The topic of digital and self-driving vehicles was not yet on the agenda in EU strategic documents.

2014 – The beginning of the digital revolution, security, and green transition

Sustainability: Sustainability was already a key element in the 2011 White Paper(*Plus and NVIDIA Collaborate to Advance AI for Level 4 Autonomous Trucks With Large-Scale World Models*, n.d.), which also defined the policy directions for 2014. The EU's goal was to:

- reduce CO_2 emissions from the transport sector by 60% by 2050,
- increase electromobility and urban public transport.

Safety: Remained a strategic priority. New emphasis was placed on driver assistance systems (ADAS, Advanced driver-assistance systems) and the development of transport culture (e.g., training, prevention). The development of TEN-T (Trans-European Transport Network) networks was also a goal in order to achieve safer infrastructure.

Autonomy: As a result of technological developments, self-driving vehicles were mentioned, mainly in the context of research and innovation programs (e.g., Horizon 2020). Autonomous mobility was not yet a widespread strategic goal, but was rather treated as a potential.

2024 – Intelligent and autonomous systems, green mobility in the spotlight

Sustainability: The 2020 European Green Deal and the 2020–2024 Sustainable and Smart Mobility Strategy have radically reinforced the role of sustainability:

Target: 90% reduction in emissions from the transport sector by 2050

Regulations on electric vehicles, zero-emission fleets, active mobility (walking, cycling)

Safety: The Vision Zero concept (zero fatalities) has become increasingly integrated into policies. On the regulatory side, ADAS (e.g., automatic emergency braking) has become mandatory, as have EU-supported C-ITS systems (cooperative intelligent transport systems).

Autonomy: By 2024, autonomous vehicles will have already appeared as a specific policy objective. The following topics have come to the fore:

Testing of SAE Level 3–4 autonomous systems within the EU,

Development of an ethical and legal framework (liability, data management),

Development of digital infrastructure to support autonomous transport (e.g., 5G, sensor networks).

Table 1: Summary: evolution of concepts over time

Year	Sustainability	Safety	Autonomy
2004	Secondary objective	High priority (fatality reduction)	Not included
2014	Strategic goal (Green Transport)	Advanced systems and safety culture	Appeared at the research level
2024	Central EU climate objective	System-level regulation	Strategic goal, testing, and legal frameworks

Source: own editing

4. Findings

Based on the thematic content analysis, the expectations identified by industry and society can be classified into four main categories: (1) technological expectations, (2) environmental and sustainability expectations, (3) regulatory and infrastructure-related requirements, and (4) social and economic considerations.

4.1. Technological expectations

Industry clearly expects future trucks to feature a high level of automation, intelligent systems, and connected digital solutions. Based on the rapid development of advanced driver assistance systems (ADAS), self-driving functions, and machine learning-based navigation systems, the industry's goal is to reduce costs and human resource dependency.

Practical examples, such as the Aurora and Waymo tests, are already on the verge of commercializing Level 4 autonomy. At the same time, there is also an increased demand for safety from society – the expectation that artificial intelligence should operate at least as safely as a human driver (*Waymo Via Expands Partnership with UPS to Autonomous Freight Movement with Class 8 Trucks*, n.d.).

4.2. Environmental and sustainability expectations

Social and political pressure is increasingly pushing the industry towards zero-emission technologies. Sustainability expectations focus on electric drives, hydrogen fuel cells, and renewable energy-powered devices.

Projects by Scania (Bayerlein et al., 2025), Hyundai, and the TIP Group show that the industry is capable of adapting, but the transition is costly and slow. Social expectations, on the other hand, demand a faster transition, especially in light of climate protection goals (e.g., the EU Green Deal). These contradictions also present challenges for industrial decision-makers.

4.3. Regulatory and infrastructure requirements

There is a strong demand from industry players for a predictable, incentivizing, and technology-friendly regulatory environment. Measures such as toll exemptions for zero-emission vehicles or infrastructure support (e.g., charging network development) have a stimulating effect. In contrast, several regulatory barriers, such as vehicle weight limits, currently hinder the widespread adoption of alternative powertrains.

Social expectations also point towards regulation, namely in the form of active state support for the spread of climate-friendly technologies, for example, through subsidies and quotas.

4.4. Social and economic aspects

Society has two expectations: on the one hand, environmentally friendly, sustainable freight transport, and on the other, job protection and a people-centered approach to technological change. Digitalization and automation may replace jobs in the transport sector, which is why there is a growing social demand for managing the social transition, for example, through retraining programs and new employment models.

Here we must highlight the tensions:

Time pressure: Society and regulators expect immediate CO_2 reductions, but unfortunately, this is not a quick process.

Cost pressure: Green technologies are expensive and place a burden on industry, but ultimately, society also feels the pinch as everything inevitably becomes more expensive.

Technological tension: The promise of autonomous vehicles (fewer drivers, lower costs) is offset by the loss of jobs.

We should also mention Tesla Semi's replaceable battery concept and "Truck-as-a-Service" models as possible solutions to economic barriers and cost tensions.

4.5. Cross-cutting insights and emerging tensions

The analysis reveals several cross-cutting patterns that extend beyond the four thematic categories. A key finding is the growing mismatch between societal expectations for rapid decarbonisation and the industry's ability to implement technological and infrastructural change at the required pace. While companies invest in autonomous, electric, and hydrogen technologies, deployment is constrained by infrastructure gaps, regulatory uncertainty, supply chain limitations, and high capital costs.

Risks and uncertainties—such as the technological maturity of autonomous systems, cybersecurity challenges, and fluctuating support schemes—further shape stakeholder expectations and slow adoption. At the same time, the perspectives of industry, regulators, and society diverge: efficiency and cost reduction remain central to industry, whereas policymakers prioritise climate targets, and society emphasizes both sustainability and social protection. These interacting pressures underscore the need for coordinated public–private strategies to strike a balance among innovation, affordability, and societal acceptance.

Table 2: Summary of cross-cutting insights and stakeholder tensions

Dimension	Key Insight	Main Stakeholder Tension
Technology readiness	Rapid progress in autonomy, electrification, and hydrogen, but uneven maturity and reliability	High expectations vs. limited large-scale deployability
Infrastructure	Charging and hydrogen networks remain insufficient; digital infrastructure varies regionally	Need for rapid expansion vs. high investment costs
Regulation	Strong climate ambition, but evolving rules (ETS, tolls, weight limits) create uncertainty	Predictability for industry vs. policy pressure for accelerated transition
Economics	Transition increases CAPEX/TCO; emerging models (TaaS, battery-swapping) only partly mitigate costs	Demand for affordability vs. rising operational costs
Labour and society	Automation promises efficiency but raises concerns about job displacement and acceptance	Technological optimisation vs. social protection expectations
Risk factors	Cybersecurity, supply chain constraints, and volatile support schemes	Need for innovation vs. risk aversion in adoption decisions

Source: own editing

5. Discussion

Based on the results of the research, it has become clear that the expectations of industry and society are aligned in many respects—particularly in the areas of sustainability, safety, and digitalization—but that there are conflicts between stakeholders regarding the speed of implementation and costs.

5.1. The issue of technology acceptance and social trust

From a technological point of view, developments have already reached a level where commercial application is realistic. Autonomous vehicles, for example, are already capable of safe transportation in certain environments. However, society is still skeptical in many cases: a lack of trust and technophobia can slow down acceptance. This challenge can only be overcome through transparent, regulated operation and strong communication.

5.2. The economic reality of environmentally friendly powertrains

Although there is strong pressure from society towards sustainability, alternative powertrains (e.g., electric, hydrogen) currently involve high investment and operating costs. A large-scale transition is therefore not realistic without government incentives and infrastructure support. However, long-term sustainability can only be ensured if industry and government work closely together.

5.3. Regulatory tensions and barriers to innovation

In many cases, existing legal frameworks are not keeping pace with technological developments. Overly strict or outdated regulations—such as weight limits and vehicle dimensions—restrict competitiveness. This is particularly true for heavy electric vehicles, where the weight of the battery reduces the useful load capacity. The regulation of future vehicles, therefore, requires a more flexible, technology-friendly approach. Consequently, we recommend relaxing axle load restrictions exclusively for zero-emission vehicles to compensate for the weight of the batteries, while respecting the physical load limits of the road infrastructure.

5.4. The role of the human factor

Although technological advances are significant, the future of road freight transport continues to depend on the human factor: social acceptance, labor market flexibility, and the adaptability of the education system. Retraining programs, the development of new professions, and a human-centered approach play a key role in a successful transition.

5.5. Integrated interpretation and strategic implications

The discussion highlights that the transformation of road freight transport is driven by mutually reinforcing technological, economic, regulatory, and social factors. Although industry and society share long-term objectives—decarbonisation, higher safety, and digital efficiency—the transition is slowed by structural constraints: infrastructure gaps, cost burdens, regulatory rigidity, and uneven social acceptance. These factors create a fragmented innovation landscape in which technological feasibility does not automatically translate into large-scale adoption.

A critical insight is that no single stakeholder group can independently overcome the barriers identified. Industry requires regulatory predictability and infrastructure investment; policymakers need credible technological pathways to meet climate targets; and society expects both environmental improvement and economic fairness. Coordinated action—public–private partnerships, harmonised regulation, risk-sharing mechanisms, and inclusive labor transition strategies—emerges as a necessary condition for a viable transformation. Without such alignment, the pace of implementation will continue to lag behind expectations despite rapid technological progress.

Table 3: Cross-cutting insights and strategic implications for stakeholders

Challenge Area	Core Tension Identified in Discussion	Strategic Implication
Technology acceptance	High technical maturity vs. low social trust	Transparent safety validation, regulated pilot zones, communication strategies
Economic burden of green technologies	Sustainability expectations vs. high CAPEX/TCO	Targeted incentives, public co-investment, scalable business models (e.g., TaaS)
Regulatory rigidity	Fast tech evolution vs. slow rulemaking	Adaptive regulation, weight/dimension revisions,

		innovation-friendly frameworks
Human factor	Automation benefits vs. employment risks	Reskilling programs, new job profiles, socially responsible transition planning
Infrastructure readiness	Market demand for zero-emission vehicles vs. insufficient charging/hydrogen networks	Accelerated infrastructure development, coordinated standards, corridor-based deployment
System-level coordination	Shared goals vs. fragmented stakeholder actions	Public–private partnerships, long-term roadmaps, risk-sharing mechanisms

Source: own editing

6. Conclusions and Recommendations

6.1. Conclusions

This study aimed to explore the industrial and societal expectations for future road freight vehicles, with a particular focus on technological, environmental, regulatory, and societal factors. Based on the analysis of literature and case studies, the following main conclusions can be drawn:

From a technological perspective, the key expectations for future trucks are automation, digitalization, and connectivity. The practical implementation of autonomous vehicles is already underway, particularly in the North American market.

From a sustainability perspective, there is a growing demand from society for zero-emission freight transport. The industry is moving in this direction, but the transition is facing economic and technological constraints.

At the regulatory level, the EU and some Member States (e.g., Germany) are seeking to encourage technological change through active climate policy measures. At the same time, the current legal and infrastructural environment does not always support a rapid transition.

From a societal perspective, accepting technological change, maintaining transport safety, and preserving jobs are key expectations. The human factor continues to be decisive in the acceptance of vehicles and the functioning of the transport system.

These expectations often point in the same direction, but in some areas — particularly with regard to implementation time and costs — tensions can be observed between industry, society, and decision-makers.

Overall, the findings indicate that the future of road freight transport will depend on the sector's ability to align technological feasibility, regulatory frameworks, economic realities, and societal expectations into a coherent and jointly supported transition pathway.

6.2. Recommendations

6.2.1. Encouraging technological developments and ensuring transparency

It is important for developers that technologies not only work, but are also understood and accepted by society. Therefore, transparent testing, public demonstrations, and communication campaigns are recommended for autonomous and alternative-fuel vehicles.

The development of open data formats and common industry standards can promote interoperability and faster technological diffusion.

Strengthening societal trust through transparent testing and shared standards is essential to accelerate the acceptance and diffusion of emerging vehicle technologies.

6.2.2. Expanding economic incentives and targeted subsidies

In order to promote the uptake of zero-emission trucks, it is recommended that purchase subsidies, tax and toll discounts be maintained and extended, particularly for small and medium-sized enterprises.

Expanding the charging and fuel infrastructure is essential: fast chargers must be installed along logistics hubs and major transport routes (e.g. TEN corridors) in accordance with mandatory coordinated EU guidelines, possibly with the involvement of private capital (e.g. IONITY).

A sustained and well-targeted incentive framework remains a prerequisite for lowering adoption barriers and enabling zero-emission technologies to reach commercial scale.

6.2.3. Creating a more flexible regulatory environment

Regulations must adapt to technological change. To this end, it is recommended that vehicle weight and size limits be handled more flexibly in the case of alternative-fuel vehicles.

Legal frameworks for transport safety should be designed in such a way that they do not hinder the development of autonomous systems, while ensuring controllability, rules of responsibility, and citizens' sense of security.

Regulatory adaptability will be decisive in ensuring that legal frameworks evolve in step with innovation rather than restricting its practical implementation.

6.2.4. Supporting people-centered transition and education programs

Jobs lost due to digitization and automation must be offset by retraining and vocational training programs. The aim of these is to enable transport and logistics workers to continue their work in new roles (e.g., vehicle monitoring, system maintenance).

Educational campaigns that present the future of transport in a clear and accessible way can help society adapt to technological change.

Human-centered transition strategies are critical to maintaining social acceptance and ensuring that workforce capabilities develop in parallel with technological change.

6.3. Concluding remarks

The future of road freight transport has already begun. The technology is there, climate protection is urgent, and social expectations are becoming increasingly clear. However, development alone is not enough for a successful transition: coordinated industrial, governmental, and social cooperation is needed to ensure that the vehicles of the future are not only technologically acceptable but also socially acceptable and sustainable.

The transition will succeed only if technological ambition, policy commitment, and societal acceptance advance together and reinforce one another in practice.

Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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