Kautz Studies in Business and Economics

ISSN 3141-6950 (ONLINE)
ISBN 978-615-6443-51-9
https://doi.org/10.14513/sbe.00634

VOLUME 1
AI, Sustainability and Digital Transformation: Shaping the Future of Business and Society

Freight transport decarbonisation and strategic procurement: a comparative analysis across Europe, China, and North America

Anikó Richter[1], Csaba I. Hencz PhD.[2]

[1]University of Sopron, Sopron, Hungary, ORCID ID: 0009-0005-0045-869X, aniko.richter@yanfeng.com

[2]Széchenyi István University, Győr, Hungary, ORCID ID: 0000-0001-7857-4686, hencz@sze.hu

Abstract: Freight transportation is one of the most important contributors to global greenhouse gas (GHG) emissions. This study analyzes and compares how sustainability targets and practices are being implemented in road freight across three key regions: Europe, China, and North America. The aim is to evaluate the challenges, opportunities, and lessons learnt. Multiple approaches were applied: (1) a comprehensive literature review of sustainability regulations and technological trends; (2) secondary data collection from sustainability reports in the automotive industry; and (3) a primary survey distributed to international forwarders and service providers.

The results indicate that Europe is mainly driven by regulatory decarbonization with strong commitments to electrification and intermodal freight, though infrastructure gaps remain. China demonstrates fast and strong progress in electrification and digital logistics platforms but faces challenges in implementation across regions. North America shows slower regulatory adoption but strong industry-driven initiatives in efficiency and alternative fuels. Results from the questionnaire indicate that cost pressures, **service** reliability, and infrastructure readiness are the most well-known challenges, while collaboration and digital transparency tools are seen as key points toward sustainability.

The study outlines a potential strategic route that can give direction to political decision-makers and to industry leaders for creating strong procurement strategies and a stable base for creating and implementing sustainable solutions within the local and global supply chains. It is confirmed within the study that even though each region takes a different path, the key drivers of success are similar: using new technologies, working together across industries, and keeping government rules in line with market needs.

Keywords: Carbon neutrality, CO_2 reduction, Cross region study, Decarbonization, Freight transport, Road freight, Sustainability

JEL Classification: Q55, L92, L22

1. Introduction

The global freight transport sector is under increasing pressure to reduce its environmental impact (Jing et al., 2025) while continuing to meet the growing demand for goods across regions. Road, ocean, and air transport are essential for supply chains and these transport systems are representing the core of the modern society (Engström, 2016), and these transport systems are the largest contributors to greenhouse gas (GHG) emissions worldwide (International Energy Agency, 2021) Road freight, as part of this global systems, is representing a fundamental part of it. (Engström, 2016; Eurostat, n.d.). In Europe, heavy goods vehicles (HGVs) reached their peak in 2023 (IEA, 2023; Smart Freight Centre, 2024; Reuters, 2024) representing 25.3% of road transport emissions, equal to 1807 billion tonne-km (Kliuyeva, 2022; Eurostat, n.d.; Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the Deployment of Alternative Fuels Infrastructure, and Repealing Directive 2014/94/EU (Text with EEA

Relevance), 2023) and overall global logistics freight transport represents approx. 8-10% of global emissions (Smart Freight Centre, 2024). This contribution is expected to rise if no major changes happen, as per expectations the share of road freight might raise to 40% by 2030, and by 80% by 2050 (European Commission, n.d.). Due to this potential high increase of the market share of road freight transport compared to other transport modes, it is essential to put a focus and identify how this aligned in reaching the global sustainability goals by 2030, and reaching full climate neutrality by 2050. To reach the global sustainability goals, a full operational mindset change is needed which supports the goals while bringing the freight transport into a more sustainable approach (Kumar et al., 2019).

Governments, industry players, and logistics service providers are now facing a dual challenge: ensuring efficient and reliable (Kumar Dadsena et al., 2019) delivery of goods, but also meeting ambitious sustainability targets, led by governments, on the regional and global level as well. The regional landscape of targets gives a very different base. As an example, the revised EU regulations under the Fit-for-55 package (Council of the European Union, 2023) sets a clear and challenging roadmap to reduce transport emissions of heavy-duty vehicles by 45% by 2030, 65% by 2035, 90% by 2040 (Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the Deployment of Alternative Fuels Infrastructure, and Repealing Directive 2014/94/EU (Text with EEA Relevance), 2023; Reuters, 2024). China has targeted to achieve carbon neutrality by 2060, supported by investments in low-emission logistics infrastructure (Li et al., 2025; Xie et al., 2025; Zhang et al., 2025; Zheng et al., 2025). Meanwhile, in North America, the U.S. Inflation Reduction Act (Inflation Reduction Act of 2022, 2022) and California's climate policies are creating new incentives for cleaner freight operations (*Current California GHG Emission Inventory Data | California Air Resources Board*, n.d.; Tostes et al., 2025).

Despite regional differences, the logistics and transport sector shares many common challenges: increasing fuel costs, the slow change to alternative fuels, and the need for digital systems that can increase efficiency. At the same time, there are opportunities in electrification, low-carbon fuels, and cross-industry collaboration. Several studies highlight that procurement decisions, starting with carrier selection, packaging strategies, and warehouse management, play an important role in reducing emissions (Balcombe et al., 2019; McKinnon, n.d.)

The study investigates the answers to the following main questions:

- How do the sustainability goals and implementation strategies of road freight transport differ in Europe, China, and North America?
- What are the main drivers and barriers on the route of decarbonization?
- How can strategic sourcing and procurement practices be leveraged to expedite the adoption of low-carbon transport solutions for road freight?

The study links the academic perspective with practical insights from the automotive industry, including the author's own experience in procurement within the mentioned sector. By combining theory and practice, the Authors identify key challenges, highlight best practices, and suggest ways for making transport and logistics procurement more sustainable in each region.

2. Theoretical background and literature review

Transportation and freight procurement are increasingly recognized as a main area for emission reduction, not only because of the high contribution to global emission output, but also because of a high potential for technological and operational improvements. This literature review section focuses on policy frameworks, industry strategies, and comparative trends across regions without repeating the same figures mentioned above.

2.1. Decarbonization and political environment

From a global perspective, the Paris Agreement states warming limits to 1.5°C, which initiates transport decarbonization in energy and industrial sectors (United Nations Framework Convention on Climate Change, 2015), emphasizing the importance of reducing emissions. International alliances such as Drive to Zero and CALSTART (a non-profit clean transportation organization) initiated the Global MoU (Memorandum of Understanding) (Weber, 2024) on Zero-Emission Trucks. This official agreement between governments, cities, and industry leaders aims to support the global targets to reach zero-emission freight vehicles by 2030-2040 (Middlebrooks, n.d.)These Coalitions can give a framework and targets for companies, which can help to set procurement targets for low-carbon transport solutions. Research also highlights the importance of integrating digital logistics platforms, route and load optimization, and transport type combinations (intermodal) as policy-aligned solutions (European Court of Auditors., 2023).

2.2. Technology and green logistics

The European Green Deal (The European Green Deal - European Commision, n.d.) and other supporting regulations not only set emission reduction goals but also aim to improve infrastructure readiness and operational changes. For example, AFIR (Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the Deployment of Alternative Fuels Infrastructure, and Repealing Directive 2014/94/EU (Text with EEA Relevance), 2023) requires the EU to develop common charging networks and refuel stations to support a smoother acceptance of electric and hydrogen trucks (The European Green Deal - European Commision, n.d.). The EU member states have already implemented several pilot cases of low-emission freight corridors, combining electrified trucking, rail, and intermodal solutions, hydrogen and biofuel trucks as trials between key logistics routes (*Current California GHG Emission Inventory Data | California Air Resources Board*, n.d.): Trans-European Transport, Core Network.

In North America, adapting a common policy is uneven but improving. California's Advanced Clean Trucks (*Current California GHG Emission Inventory Data | California Air Resources Board*, n.d.) (ACT) Rule requires that all new sales of medium- and heavy-duty vehicles should be with zero emissions by 2035 in California, following the purpose of the state-level regulation called California Air Resources Board (*Current California GHG Emission Inventory Data | California Air Resources Board*, n.d.) (CARB). The U.S. federal Clean Trucks Plan is aligned with this to support battery-electric and hydrogen-powered trucks, supporting fleet modernization and using emissions-tracking systems (Balcombe et al., 2019).

China's approach is different than Europe or North America; it combines policy-driven fleet transformation with digital logistics, and is mainly driven by local, national reasons, not global ones. National-level plans, including the 14th Five-Year-Plan for Low-emission Transport (*The 14th Five-Year Comprehensive Work Plan on Energy Conservation and Emission Reduction – Policies*, 2025), highlight a shift in transport modes, investing in charging and fueling stations, and emphasize public-private collaboration to accelerate the adoption of low-carbon solutions in freight forwarding. (Ministry of Transport of the People's Republic of China, n.d.).

2.3. Barriers of implementation

The above-mentioned European green corridor trials are helping governments to assess feasibility, technological readiness, and operational effectiveness before these solutions are scaled for other areas. Reports and the pilot programs suggest that route optimization and cross-border harmonization of infrastructure will be crucial for achieving full compliance (Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the Deployment of Alternative Fuels Infrastructure, and Repealing Directive 2014/94/EU (Text with EEA Relevance), 2023).

In North America, unlike Europe, infrastructure scaling remains a key challenge due to significant geographical distances. Stronger government incentives and a more structured focus are also essential to be able to scale, which has not been seen yet.

In China, the major roadblock to implementing sustainable transport solutions is the strong cost pressure and customers' preference to choose cheaper solutions over sustainable options. Infrastructural gaps are also slowing down the acceleration, however several pilot programs are running in cities like Shenzhen that demonstrate how electrification of urban freight fleets can reduce emissions and operational costs (Jing et al., 2025; Teng et al., 2024).

2.4. Role of strategic procurement and supply chain

Across regions, companies are increasingly focusing on freight procurement and supply chain decisions, considering sustainability strategies ("What Drives Sustainable Procurement?," 2025). Academic studies and industry case studies show that combining technology solutions (electric/hydrogen trucks), operational efficiency (load factors, route optimization), and collaboration between suppliers, customers, and industry members (Zheng et al., 2025) drives the most significant reductions to reach better sustainability (European Court of Auditors., 2023). Including Scope 3 emissions in corporate reporting also strengthens the role of procurement as a key leverage for decarbonization.

Procurement, as a key leader of change, is able to implement sustainability criteria into contracts, which is already starting to be in place, pushing carriers to have more transparency in emissions, optimize packaging, and reinforce industry collaborations for low-carbon corridors. As the Author's experience, companies such as Yanfeng have also publicly documented efforts (Partner Code of Conduct, RSCI membership, recycled resin/upcycled seat innovations, downstream and upstream transportation ESG surveys) illustrate how Tier-1 procurement can create a path to sustainable logistics transitions.

3. Methodology and case study

The study combines primer and secondary analysis. The methodology of this study consists of eight steps:

- Formulation of the search question and choice of keywords,
- definition of inclusion and extrusion criteria,
- search in databases,
- papers selection, discussion and analysis of the results,
- identifying participants for the survey, introducing the survey, summarizing the survey, clearing up the incorrect feedback,
- conducting an analysis of the survey responses,
- reporting of the results in combination and reference to relevant literature.

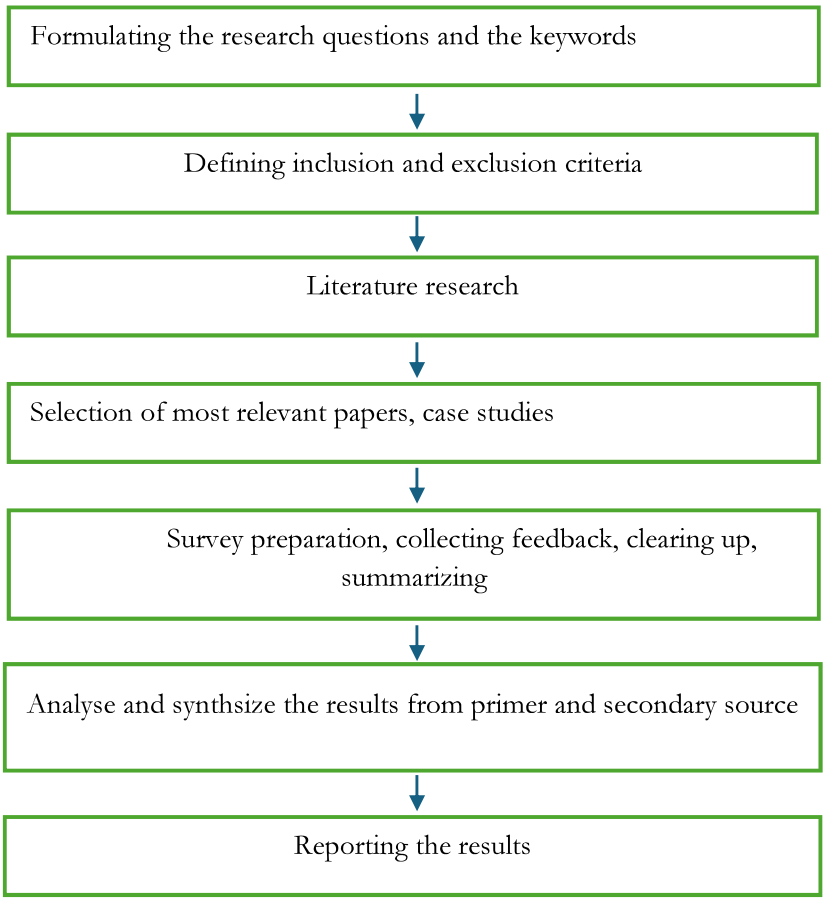

Fig 1: Methodology steps
Source: own editing

3.1. Research purpose and approach

This research aims to identify sustainability challenges and opportunities in freight transport, focusing on road transport in Europe, North America, and China, comparing their practices and identifying potential roadblocks and opportunities. The study combines secondary data analysis from government policies, published reports, academic literature, and primary data from a sustainability framework collected via a questionnaire of logistics service providers and freight forwarders, approaching procurement professionals in the automotive industry.

The study prefers this two-methods analysis, in order to capture both macro-level policy trends and micro-level operational insights.

3.2. Case study context

The Authors' experience is based on an automotive EMEA operations covering the interior, seating, and safety systems divisions, and the study targeted the related providers of the Author, focusing on freight forwarders and logistics service providers. While the Author is not responsible for resin and material procurement, however, this is a main contributor to sustainability, but transportation, packaging and contract logistics; therefore, the study is focusing on upstream and downstream logistics emissions for the context.

This context allows the study to:

- Examine how procurement decisions influence freight decarbonization emissions.(Johnsen et al., 2022; "What Drives Sustainable Procurement?," 2025)
- Identify difficulties and opportunities to low-carbon logistics solutions
- Compare regional differences in sustainability regulations, infrastructure, and supplier readiness.

3.3. Primary data collection

To confirm or refute literature insights, a short survey was prepared by the Author for freight service providers and sent to 60 companies, between the period of 20th August to 25th August 2025.

40 responses have been received and taken into consideration. This represents a 66.7% completion ratio.

Main objectives of the survey:

a) Identify how significant sustainability is in their strategy

b) Identify current sustainability practices (e.g., use of electric/hydrogen trucks, load optimization, digital tracking solutions).

c) Understand difficulties in adopting low-carbon solutions (infrastructure, cost, regulation).

d) Collect region-specific challenges and opportunities for sustainable freight.

e) Identify best practices across regions

Design of the survey is as follows:

- 9 short, structured questions (mix of multiple choice, Likert scale, open questions, matrix questions)
- Questions were prepared in bilingual (English/Hungarian), reaching higher participants
- Some questions were split into regional sections to identify the differences between North America, Europe, and China.

This survey provides quantitative and qualitative insights that can be combined with the literature review to help understand procurement decisions and future opportunities.

3.4. Secondary data analysis

Secondary data was collected from:

a) Industry reports

b) Policy documents

c) Academic literature: Studies on decarbonization strategies, fleet electrification, and freight emissions

The study focuses on articles published in the last one and two decades, from 2006 to 2026. The study excluded rail, ocean freight, and air transport and papers related to ecological sustainability. The study focused on road freight and automotive industry. The main database considered for the study was Scopus as it is considered the world's largest database of abstracts and citations.

The search was conducted in July and August 2025. The search strings have to demonstrate repeatability ("Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of

Systematic Review | Request PDF," 2025), with the identified keywords and its variations. Studies were categorized and sorted with thematic coding, while excluding duplication, excluding the not relevant papers. Coding units were being used (Mayring, 2014), and within a thematic analysis the major themes were identified as a., load and route optimization, digitalization, b., operative difficulties and infrastructure, c., governmental and industrial policies and regulations, d., procurement decisions in strategical planning. This analysis allows us to combine the findings and ensure consistency between regulatory expectations, industry trends, and real-life operational feedback.

3.5. Data analysis method

The survey data will be analyzed in a quantitative (percentages, trends) and qualitative way (open text responses). The qualitative answers were evaluated by the Authors within a thematic analysis, followed the method was used for secondary data analysis.

Regional comparisons highlight differences in potential barriers, opportunities, and country/supplier/industry readiness.

Using the same method for coding and thematic analysis, the findings are linked back to policy frameworks and corporate sustainability strategies, particularly in the context of the procurement role in influencing low-carbon logistics in transportation, focusing on road transport, as the main scope of this study.

4. Results

40 responses were received in the period from 20th August to 25th August 2025, representing a 66,7% completion rate.

4.1. Geographic operations

As per Table 1, the majority of the participants indicated that their primary operating region is Europe (58%), followed by global operation footprint who has active presence in all compared three regions (30%), North America focused companies (10%), exclusively China dominant company 2%.

Table 1: Regional distribution of participants

China	North America	Europe	Global (all 3 regions)
2%	10%	58%	30%

Source: own editing

4.2. Importance of sustainability

The rate of importance of sustainability, shown in Table 2 and Table 3, was evaluated in the respondents' transport strategy (on a 1–5 scale, 5 being the most important, 1 being not important).

Table 2: Importance of sustainability in company's strategy I.

Europe	N	Valid	23
		Missing	0
	Median		4,00
	Mode		4

North America	N	Valid	4
		Missing	0
	Median		4,50
	Mode		5
China	N	Valid	1
		Missing	0
	Median		4,00
	Mode		4
Global	N	Valid	12
		Missing	0
	Median		5,00
	Mode		5

Source: own editing via SPSS program

Table 3: Importance of sustainability in company's strategy II.

Region			Frequency	Percent	Valid Percent	Cumulative Percent
Europe	Valid	important	1	4,3	4,3	4,3
		more important	12	52,2	52,2	56,5
		very important	10	43,5	43,5	100,0
		Total	23	100,0	100,0	
North America	Valid	important	1	25,0	25,0	25,0
		more important	1	25,0	25,0	50,0
		very important	2	50,0	50,0	100,0
		Total	4	100,0	100,0	
China	Valid	more important	1	100,0	100,0	100,0
Global	Valid	more important	2	16,7	16,7	16,7
		very important	10	83,3	83,3	100,0
		Total	12	100,0	100,0	

Source: own editing via SPSS program

4.3. Challenges in reducing CO_2

Regional differences were questioned by the respondents to understand the potential barriers, as future risks and challenges, the regional split is shown in Figure 2.

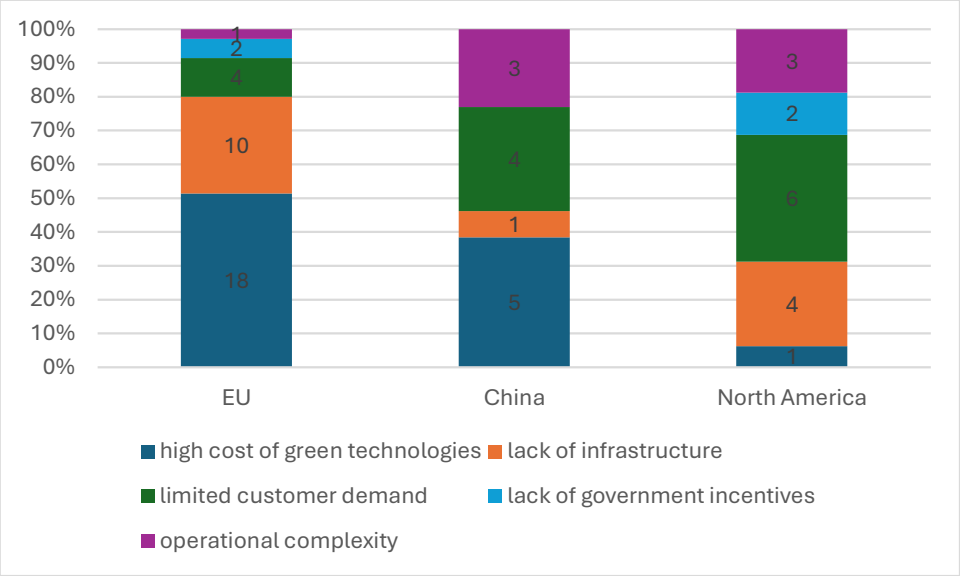

Fig. 2: Regional differences in recognized challenges
Source: own editing

4.4. Sustainable Solutions Implemented or Planned

During the survey, the Authors' goal was to identify the potential opportunities based on best practices of each region. The results shown in Figure 3:

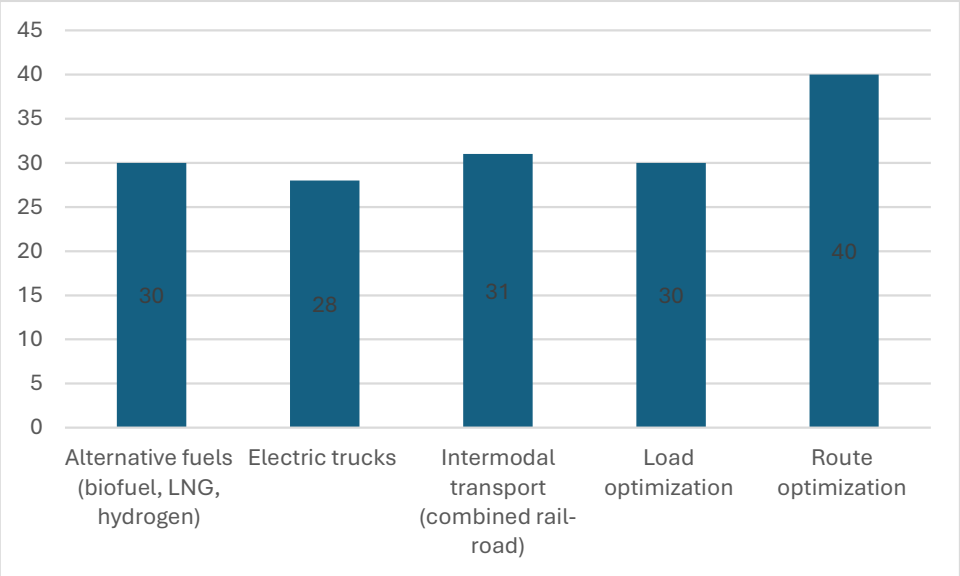

Fig. 3: Sustainable solutions implemented vs planned
Source: own editing

4.5. Fleet structure (Low-emission vehicles)

The survey collected an overview of available low-emission vehicles in the respondents' fleet versus available standard equipment, split by different regions, as per Table 4.

Table 4: Share of low-emission fleet by region

	0-10%	11-25%	26-50%	51-76%	76-100%
China	7	3	3	0	0
North America	11	3	2	0	0
Europe	23	6	5	0	1

Source: own editing

5. Discussion

5.1. Theoretical implications

The added value of this study lies in demonstrating that political decisions and directions represent a much stronger influence on the adoption of green solutions than previously estimated. Clear and stable rules set by policymakers, such as reduction targets, carbon pricing mechanisms, and long-term regulatory frameworks which are essential to provide companies with predictability, and to shape their sustainability strategies (Kannan, 2021; Kollmuss & Agyeman, 2002; "What Drives Sustainable Procurement?," 2025). Without clear goals, companies may end up with short-term and fragmented actions instead of real long-term change.

The findings also highlight the importance of behavioral and organizational factors. The behavioral intention of the companies is significantly influenced by individual attitudes, capabilities, and awareness of consequences, as well as recognized corporate social responsibility engagement (Khan et al., 2023; Kollmuss & Agyeman, 2002). This aligns with earlier research showing that sustainability strategies are not only shaped by external pressures but also by internal commitment, and managerial leadership approach (Kollmuss & Agyeman, 2002; "What Drives Sustainable Procurement?," 2025). In the automotive sector, for example, willingness and commitment toward sustainable solutions differ across regions and supply chain levels (Brammer & Walker, 2011). Sustainability is represented stronger in OEMs' strategies compared to other level in the supply chain. Within going down the supply chain, the weight of importance of sustainability often reduces, mostly due to cost involvement and resource constraints.

The analysis of the relationship between regions and the importance of sustainability strategy developed as follows: the survey results represent a strongly asymmetric pattern, so a comparative statistical test is not justified; however, descriptive analysis is recommended. In Europe, sustainability has been strongly considered as a strategic element, with the large majority of respondents categorizing it as "more important" or "very important." North American responses indicate a strong strategic commitment on sustainability, but due to the low sample size, the results are preliminary. The Chinese sub-sample is not suitable for evaluation and should be treated only as individual observations. Among global forwarders with active footprint in all analysed regions, sustainability is a particularly strong strategic priority, reflecting international regulatory expectations and pressures of prestige.

All these insights confirm that sustainability strategies are not uniform but strongly shaped by political, economic, and social aspects. The theoretical implication is that sustainability in logistics and supply chains cannot be understood as a global and universal way; but it must be analysed through the lens of regional governance structures, market dynamics, and organizational behavior. This reinforces the need for comparative and context-sensitive approaches in sustainability research, acknowledging that the drivers,

barriers, and strategic priorities vary significantly across different regions and also in different levels of supply chain members.

5.2. Practical implications

From a practical view, the study confirms that financial incentives are essential to overcome the high upfront costs of investments and to accelerate the speed of the green transition (Kannan, 2021; Kollmuss & Agyeman, 2002; "What Drives Sustainable Procurement?," 2025). Governments must invest in green infrastructure together with companies in order to accelerate the progress in an efficient way. This includes charging networks for electric trucks, intermodal hubs to support modal shifts, and renewable energy grids to help the acceleration of the decarbonization of logistics operations. Without such infrastructure, companies remain constrained by cost sensitivity and uneven regional conditions, which limit the speed of the implementation of sustainable solutions.

Majority of the respondents confirmed that they focused first on operational efficiency improvements (Figure 4), such as route optimization, load optimization, and packaging optimization, as for the companies this is a reachable achievement, since it brings immediate results, and it represents low-cost compared to high investment required developments. These digital, optimization tools creates for the companies reduced fuel consumption, and reduced emissions in a short and quick way, providing low-barrier entry points and ability to demonstrate to their customers a willingness to implement sustainable solutions (Ahmad et al., 2022; Ballot & Fontane, 2010; Nataraj et al., 2019; Pan et al., 2013; Teng et al., 2024; Zhang et al., 2025; Zheng et al., 2025). However, these digital optimization tools are only a short-term focus solutions, and can create a false sense when we are talking about sustainability achievements. Companies are looking for integrated solutions, offered by logistics service providers (LSPs) who are able to use a collaboration mechanism collecting different companies in one system and to design increasingly efficient logistics networks, while minimizing operating cost, and reduce traffic burden. These actions are low-cost, but in return, are able to deliver immediate efficiency results (Wang et al., 2017, 2020) to the companies, but these are not bringing long term and structural progress, which are required by governments, such as fleet electrification, using renewable fuels, or hydrogen adoption (Bhattacharjee, D. & Rittstieg, M., n.d.; Kannan, 2021; Smart Freight Centre, 2024).

The survey results also highlight significant pressures and different level of readiness in supply chains. Automotive OEMs are increasingly request low-emission solutions in transportation, yet they often attempt to eliminate cost-sharing, pushing the financial burden onto logistics providers and suppliers (Kannan, 2021; Smart Freight Centre, 2024). This imbalance not only limits the speed of acceleration of green solution but also creates tensions in global supply chains, particularly for smaller providers who are lack of resources to invest in high-cost technologies. This approach of the OEMs were highlighted in each region, no big difference is visible between the regions since the OEMs are the same usually. Unless new partnership models are introduced where OEMs share knowledge within their supply chains, invest tot he green solutions together with their Tier-1, Tier-2 suppliers jointly, and mentor their suppliers, the green transition risks being slowed by uneven structural conditions. Awareness of the environmental, social, and economic impacts of procurement decisions must be raised, since it is critical to create a more balanced and sustainable collaboration (Kollmuss & Agyeman, 2002).

Majority of the respondents highlighted clearly that the infrastructure is not ready in any region, except in China. Based on the survey result the availability of the required infrastructure is the less prepared in Europe between the analysed regions. The adoption of sustainable solutions and a smooth green transition are highly depending on the existing infrastructure, the available government incentives, and collaboration between the market leaders, and as well as on procurement strategies. Procurement plays a significant role in creating a resilient, low-carbon global freight system, but procurement is not enough to accelerate the transition, as

the global company mindset is required on top of it. The strategic procurement function within companies is shaped by corporate strategy, and the management commitment strongly influences individuals' approach and willingness to commit to sustainability (Khan et al., 2023). The role of procurement is also tied to the willingness of companies to pay for sustainability (Kollmuss & Agyeman, 2002; "What Drives Sustainable Procurement?," 2025). There is an existing trend that companies started checking green solutions within the standard freight tenders, however when the decision needs to be done, the usual way is considered staying with standard solutions and not investing into the more expensive, but environmentally friendly solutions due to the significant cost barrier.

In summary, the practical implications emphasize that while companies are making progress through digital optimization and efficiency measures, the structural decarbonization of fleets remains rare due to high upfront costs and lack of government incentives. Strong government support, coherent infrastructure, and collaborative supply chain models are essentials to accelerate the adoption of green solutions and to ensure that sustainability commitments also represents long-term solutions and not only short term actions.

6. Conclusion

This study confirms that freight forwarder companies across Europe, China, and North America increasingly recognize the strategic importance of sustainability, however the practical implementation of green solutions remain behind the ambitious targets of government and also of companies. (Kannan, 2021; Kollmuss & Agyeman, 2002; "What Drives Sustainable Procurement?," 2025). Road freight decarbonisation is a daily and actual topic, and already considered in global strategies of majority of the companies, but in parallel it is still a complex challenge shaped by regional governance structures, infrastructural difficulties, market dynamics, and supply chain behaviors.

Europe has a strong regulatory framework and policy, but cost barriers and infrastructure gaps remain significant obstacles for the companies. China has an advantage of significant government incentives, and they are in advance with quick implementation of green solutions under central planning and government-driven support, being market leaders in electrification and digital logistics, though uneven implementation across regions exists. North America, by contrast, relies more strongly on market-driven innovation and industry initiatives, progressing in a slower way compared to Europe and China. In regulatory, North America is fragmented, there are certain regions in advance compared to other states. In both North America, China and Europe, the demand-driven approaches, infrastructure readiness, and government incentives are critical accelerators of sustainable freight transitions.

The survey results highlight that operational efficiency improvements, such as route- and load optimization systems, and digital tools are widely implemented as less cost intensive but short-term solutions. The fleet decarbonization remains ambitious goals for many of the companies, and rarely implemented at this stage among the respondents, mostly due to the high investment cost upfront, and lack of government and OEM incentives. Stronger financial support toward mostly the smaller market players and stronger technological investments are essential to accelerate the road freight decarbonisation.

The survey findings also identified difficulties within supply chains. OEMs and some Tier-1 suppliers are showing increasing demand within their own suppl chains for finding low-emission transport opportunities, but they mostly face with the difficulties of implementing green solutions due to their significant financial burden, since the lower level of supply chains cannot bear the additional cost alone, withot receiving any support from OEMs nor government. This imbalanced situation are slowing down the transition unless new partnership models and collaborations within the market players are introduced, where the cost of investment but also the knowledge can be shared within the supply chains.

Ultimately, the adoption of sustainable freight solutions and the achievement of a smooth green transition depend on four pillars: infrastructure readiness, government incentives, collaboration among market players

including all levels of supply chain starting from OEM level, and procurement strategies. Strategic procurement is a key role for the future, and not only in designing the contracts having focus on sustainable solutions, but also it starts from supplier selection till cost contribution. Management commitment, personal attitudes, and corporate social responsibility engagement (Khan et al., 2023) are significantly influencing the willingness to invest in sustainability, but procurement alone is not able to lead the green transition, the global mindset of management is essential. Evidence from the automotive sector also confirms that sustainability priorities are strongest at the OEM level but already visible in Tier-1, Tier.2 level as well, however with less practical progress (Brammer & Walker, 2011).

In conclusion, while regional approaches differ, the success factors are the same in each regions: clear regulatory frameworks, shared financial responsibility, technological innovation, and procurement-led collaboration. Without these, the global freight sector risks fragmented progress and delaying the real green transition. With them, however, a resilient, low-carbon freight system can be built, which aligns on economic efficiency with environmental responsibility, and secures the long-term sustainability of global supply chains.

7. Limitations and future research

- Survey responses may be limited by the company's willingness to share sensitive operational data.
- Regional comparisons are constrained by differences in data availability and reporting standards.
- The study focuses on road transport, not covering all upstream supply chain emissions.
- A larger-scale survey should include domestic Chinese logistics companies to test whether adoption rates differ from those that participated in the current survey.
- Comparative analysis between OEM sustainability requirements and actual cost-sharing practices could provide insight into systemic bottlenecks.
- Research within a longer time frame on the impact of environmental tolls and green corridors in Europe could help to understand the cost impact on supply chains.
- Case studies of leaders (e.g., DHL's GoGreen strategy, Kuehne+Nagel's Net Zero Carbon program) could help identify best practices and future opportunities.

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.

References

Ahmad, S., Sarwo Utomo, D., Dadhich, P., & Greening, P. (2022). Packaging design, fill rate and road freight decarbonisation: A literature review and a future research agenda. *Cleaner Logistics and Supply Chain, 4*, 100066. https://doi.org/10.1016/j.clscn.2022.100066

Balcombe, P., Brierley, J., Lewis, C., Skatvedt, L., Speirs, J., Hawkes, A., & Staffell, I. (2019). How to decarbonise international shipping: Options for fuels, technologies and policies. *Energy Conversion and Management, 182*, 72–88. https://doi.org/10.1016/j.enconman.2018.12.080

Ballot, E., & Fontane, F. (2010). Reducing transportation CO_2 emissions through pooling of supply networks: Perspectives from a case study in French retail chains. *Production Planning & Control, 21*(6), 640–650. https://doi.org/10.1080/09537287.2010.489276

Bhattacharjee, D., & Rittstieg, M. (n.d.). *Boosting zero-emission truck adoption*. McKinsey & Company. https://www.mckinsey.com/industries/logistics/our-insights/can-zero-emission-trucks-become-viable-and-what-will-it-take-to-boost-adoption

Brammer, S., & Walker, H. (2011). Sustainable procurement in the public sector: An international comparative study. *International Journal of Operations & Production Management, 31*(4), 452–476. https://doi.org/10.1108/01443571111119551

Council of the European Union. (2023). *"Fit for 55": Council adopts key pieces of legislation delivering on 2030 climate targets*. Consilium. https://www.consilium.europa.eu/en/press/press-releases/2023/04/25/fit-for-55-council-adopts-key-pieces-of-legislation-delivering-on-2030-climate-targets/

California Air Resources Board. (n.d.). *Current California GHG emission inventory data*. Retrieved December 7, 2025, from https://ww2.arb.ca.gov/ghg-inventory-data

Engström, R. (2016). The roads' role in the freight transport system. *Transportation Research Procedia, 14*, 1443–1452. https://doi.org/10.1016/j.trpro.2016.05.217

European Commission. (n.d.). *Multimodal and combined transport—Mobility and transport*. Retrieved December 7, 2025, from https://transport.ec.europa.eu/transport-themes/logistics-and-multimodal-transport/multimodal-and-combined-transport_en

European Court of Auditors. (2023). *Intermodal freight transport: EU still far from getting freight off the road* (Special report 08/2023). Publications Office of the European Union. https://data.europa.eu/doi/10.2865/86233

Eurostat. (n.d.). *Freight transport statistics—Modal split*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Freight_transport_statistics_-_modal_split

International Energy Agency. (2023, September 26). *Road transport – Analysis*. https://www.iea.org/reports/road-transport

Inflation Reduction Act of 2022. (2022). *Inflation Reduction Act of 2022*. Energy.gov. https://www.energy.gov/lpo/inflation-reduction-act-2022

International Energy Agency. (2021). *Global EV outlook 2021 – Analysis*. https://www.iea.org/reports/global-ev-outlook-2021/policies-to-promote-electric-vehicle-deployment

Jing, H., Chen, Y., Ma, M., Feng, W., & Xiang, X. (2025). Unlocking global freight transport decarbonization potential: Role of modal shifts. *Transportation Research Part D: Transport and Environment, 148*, 105025. https://doi.org/10.1016/j.trd.2025.105025

Johnsen, T. E., Caniato, F., Meqdadi, O., & Miandar, T. (2022). Swimming against the tide: Supplier bridging roles in diffusing sustainability upstream and downstream in supply networks. *International Journal of Operations & Production Management, 42*(10), 1605–1629. https://doi.org/10.1108/IJOPM-02-2022-0110

Kannan, D. (2021). Sustainable procurement drivers for extended multi-tier context: A multi-theoretical perspective in the Danish supply chain. *Transportation Research Part E: Logistics and Transportation Review, 146*, 102092. https://doi.org/10.1016/j.tre.2020.102092

Khan, O., Bellini, N., Daddi, T., & Iraldo, F. (2023). Effects of behavioral intention and dynamic capabilities on circular economy adoption and performance of tourism SMEs. *Journal of Sustainable Tourism, 31*(8), 1777–1796. https://doi.org/10.1080/09669582.2022.2066683

Kliuyeva, K. (2022, June 14). *European Environment Agency: Analysis on road transport gas emissions*. European Shippers' Council. https://europeanshippers.eu/european-environment-agency-analysis-on-road-transport-gas-emissions/

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8*(3), 239–260. https://doi.org/10.1080/13504620220145401

Kumar, A., Calzavara, M., Velaga, N. R., Choudhary, A., & Shankar, R. (2019). Modelling and analysis of sustainable freight transportation. *International Journal of Production Research*. https://www.tandfonline.com/doi/abs/10.1080/00207543.2019.1642689

Kumar Dadsena, K., Sarmah, S. P., & Naikan, V. N. A. (2019). Risk evaluation and mitigation of sustainable road freight transport operation: A case of trucking industry. *International Journal of Production Research, 57*(19), 6223–6245. https://doi.org/10.1080/00207543.2019.1578429

Li, X., He, L., Cui, Q., & Chen, H. (2025). Environmental and economic impact of modal shift policy in China's freight transportation. *Transportation Research Part D: Transport and Environment, 140*, 104617. https://doi.org/10.1016/j.trd.2025.104617

Mayring, P. (2014). *Qualitative content analysis*. https://www.scribd.com/document/342254401/Mayring-2014-QualitativeContentAnalysis

Middlebrooks, G. (n.d.). *CALSTART*. Retrieved December 7, 2025, from https://calstart.org/

Ministry of Transport of the People's Republic of China. (n.d.). *Ministry of Transport of the People's Republic of China*. https://www.mot.gov.cn/

Nataraj, S., Ferone, D., Quintero-Araujo, C., Juan, A. A., & Festa, P. (2019). Consolidation centers in city logistics: A cooperative approach based on the location routing problem. *International Journal of Industrial Engineering Computations*, 393–404. https://doi.org/10.5267/j.ijiec.2019.1.001

Pan, S., Ballot, E., & Fontane, F. (2013). The reduction of greenhouse gas emissions from freight transport by pooling supply chains. *International Journal of Production Economics, 143*(1), 86–94. https://doi.org/10.1016/j.ijpe.2010.10.023

Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure and repealing Directive 2014/94/EU. (2023). *Official Journal of the European Union*. http://data.europa.eu/eli/reg/2023/1804/oj

Reuters. (2024). Emissions-free truck prices need to drop by 50% to compete with diesel, study says. https://www.reuters.com/sustainability/emissions-free-truck-prices-need-drop-by-50-compete-with-diesel-study-says-2024-09-11/

Smart Freight Centre. (2024). *Annual report 2024*. https://www.smartfreightcentre.org/en/about-sfc/annual-report-2024/

Teng, F., Zhang, Q., Chen, S., Wang, G., Huang, Z., & Wang, L. (2024). Comprehensive effects of policy mixes on the diffusion of heavy-duty hydrogen fuel cell electric trucks in China considering technology learning. *Energy Policy, 185*, 113961. https://doi.org/10.1016/j.enpol.2023.113961

International Energy Agency. (2025). *The 14th five-year comprehensive work plan on energy conservation and emission reduction.* https://www.iea.org/policies/14799-the-14th-five-year-comprehensive-work-plan-on-energy-conservation-and-emission-reduction

European Commission. (n.d.). *The European Green Deal.* https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Tostes, B., Henriques, S. T., Heun, M. K., Brockway, P. E., & Sousa, T. (2025). Global transport emissions 1850–2020: Historical drivers and lessons for transport decarbonization. *Transportation Research Part D: Transport and Environment, 148*, 104998. https://doi.org/10.1016/j.trd.2025.104998

United Nations Framework Convention on Climate Change. (2015). *Paris agreement.* https://unfccc.int/process/conferences/pastconferences/paris-climate-change-conference-november-2015/paris-agreement

Wang, Y., Ma, X., Li, Z., Liu, Y., Xu, M., & Wang, Y. (2017). Profit distribution in collaborative multiple centers vehicle routing problem. *Journal of Cleaner Production, 144*, 203–219. https://doi.org/10.1016/j.jclepro.2017.01.001

Wang, Y., Zhang, S., Guan, X., Peng, S., Wang, H., Liu, Y., & Xu, M. (2020). Collaborative multi-depot logistics network design with time window assignment. *Expert Systems with Applications, 140*, 112910. https://doi.org/10.1016/j.eswa.2019.112910

Weber, C. (2024, May 22). CALSTART's Global Drive to Zero program announces new global MOU endorsers at the International Transport Forum. CALSTART. https://calstart.org/new-global-endorsers-announced-at-itf-2024/

What drives sustainable procurement? Insights from the theory of planned behavior. (2025). *International Journal of Operations & Production Management, 45*(13), 28–52. https://doi.org/10.1108/IJOPM-02-2024-0164

Xie, Q., Wu, Y., & Zhang, R. (2025). The effects of transportation structural adjustment policy on carbon emission: Evidence from China. *Journal of Cleaner Production, 522*, 146213. https://doi.org/10.1016/j.jclepro.2025.146213

Zhang, F., Gallagher, K. S., Deng, M., Liu, H., Orvis, R., & Xuan, X. (2025). Assessing the policy gaps for achieving China's carbon neutrality target. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.4c12478

Zheng, Q., Liu, S., & Tan, J. (2025). Stable networks, responsible firms? The differential effects of supplier and customer network stability on CSR performance. *International Journal of Operations & Production Management*. https://doi.org/10.1108/IJOPM-04-2025-0273