TRACE

inTegration & haRmonizAtion of logistiCs opErations

D5.3: Regulatory Frameworks and Behavioral Change (A)

Horizon Innovation Actions | Project No. 101104278

Call HORIZON-CL5-2022-D6-02

Co-funded by the European Union

Dissemination level	Public (PU)
Type of deliverable	R – Document, report
Work package	WP5 – Opportunities and Innovation
Status - version, date	Final v2.0, 18/06/2025
File name	D5.3_(A)_Final (11/11/2025)
Deliverable leader	EPSILON
Contractual date of delivery	30/11/2024
Actual date of delivery	18/06/2025

List of authors

Author Name	Organization
Dimitris Polyzogopoulos, Markos Bonazountas	EPSILON
Ines Pentek, Tomislav Letnik	UM
Stathes Hadjiefthymiades, Vassilis Papataxiarhis, Anestis Papakotoulas	NKUA
Themistoklis Anagnostopoulos, Konstantina Papachristopoulou	INTRA
Maurizio Bernard, Marco Gardini, Marco Pesci	DIFLY
Alexandros Dalkalitsis, Panagiotis Georgas, Petros Arvanitis	HT
Lucrezia Lattanzi, Valentino Vaia, Emanuele Zarfati	MOD
Dimitris Koutras	CERTH
Paola Lorenzoni, Olivia Ferrari, Riccardo Laterza	ISIG
Alessio Masola, Paolo Burgio	UNIM
Anthony Dionigi, Florian Pühringer, Jonathan Fetka, Magdalena Bürbaumer, Lara Seel, Martin Berger	TU WIEN

Version History

Version	Date	Author	Description of changes
1.0	03.12.2024	Dimitris Polyzogopoulos	Final published version
2.0	18.06.2025	Dimitris Polyzogopoulos	Final published version with revisions

Peer Review

Version	Reviewer Name	Organization	Date
1.0	Kristijan PERČIČ	PS	November 30 2024
1.0	Lucrezia Lattanzi	MOD	November 26 2024

Quality Manager Review

	Reviewer Name	Organization	Date
	Dr Ioannis Neokosmidis	INC	

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Executive Summary

Changes of a large magnitude are underway, both in logistics and the transport sectors, impelled by rapid integration of autonomous systems, artificial intelligence technologies, and the need to switch to sustainable transport options. There is an emerging need in such an environment for flexible regulatory frameworks that can keep pace with the complexities ushered in by these changes while ensuring safety, security, and compliance with regulations.

Deliverable 5.3 covers large challenges and opportunities coming from these transitions, with a particular focus on the role of regulatory frameworks in promoting stakeholder behavior in the logistics sector. Amongst others, the deliverable underlines regulatory fragmentation, a need for performance-based regulations, and gives key priorities concerning cybersecurity and data protection. It goes even further to underscore the reality that international cooperation is also needed to lend coherency across borders, most especially in respect to autonomous technologies.

Besides that, it provides an in-depth analysis of behavioral change within the transport and logistics industry, focusing on how operators rise to new challenges and technologies. Increased orientation toward efficiency, sustainability, and customer-centric approaches within the sector powered through automation, data analytics, and clean technologies is underlined from this research. Diversification into rail and water transportation modes, embracing collaborative models of logistics through route optimization and infrastructure sharing, are identified as key behavioral changes through stakeholder surveys. It is here that blockchain, IoT, and cloud systems play an important role in enabling collaboration through the elements of transparency and efficiency.

Nevertheless, the report also cites significant barriers to these changes, including resistance to the adoption of technology, concerns about the security of data, and the high costs of implementation. Overcoming these hurdles will require not only technological development but also regulatory support that promotes innovation while also promoting security and cost-reducing measures.

The report concludes by making a set of strategic recommendations designed to nurture the regulatory environments that will foster both technological development and behavioral change. Its principal recommendations are the use of regulatory sandboxes for testing new technologies, improving cross-border regulatory harmonization, and giving incentives toward environmentally friendly logistics practices. In addition, this deliverable provides a structured policy roadmap and detailed recommendations for automated freight transport integration addressing legal definitions, safety standards, liability, data interoperability, and infrastructure needs.

Deliverable 5.3 concludes with a detailed design on how regulatory structures should fit within the dynamic requirements of the logistics industry to make sure that changes toward autonomous, artificial intelligence-driven, and sustainable transport solutions are implemented in a secure and effective manner. The adoption of appropriate behavioral modification strategies, while facilitating regulatory innovation, will keep the logistics industry thriving toward the challenges of a rapidly accelerating global market.

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Definitions, Acronyms, Abbreviations

Term/Abbreviation	Definition
AI	Artificial Intelligence
EU	European Union
GDPR	General Data Protection Regulation
DoA	Description of the Action
IPR	Intellectual Property Rights
UAV	Unmanned Aerial Vehicle
NDA	Non-Disclosure Agreement
DMP	Data Management Plan
Ethics Board	EB
DGA	Data Government Act
BVLOS	Beyond Visual Line Of Sight
EASA	European Union Aviation Safety Agency
ICT	Information and Communications Technology

1 INTRODUCTION

1.1 Purpose and Scope

This report intends to deliver the following for D5.3 - Regulatory Frameworks and Behavioral Change (A):

- A comprehensive analysis of prevailing and emerging regulatory frameworks related to logistics and transport sectors, in particular how these control frameworks shape and enhance stakeholders' behavior; and assessment of the trends of regulatory policy impacts on the take-up of autonomous systems, sustainable logistics practice, and synchromodal transport solutions within the TRACE ecosystem.
- An identification of gaps, challenges, and opportunities present in the harmonization of such regulations across borders, by analyzing international and national regulatory landscapes.

The scope of D5.3 extends to the recognition of some key areas like safety standards, data protection laws, environmental regulations, and cross-border compliance. This report also looks at how regulatory frameworks influence the behavior of logistics operators, technology providers, policy makers, and end-users with respect to how regulation might stimulate or hamper the uptake of innovative technologies, the enabling role of policy in the introduction of sustainable practices, and how stakeholders adapt to evolving regulations in a dynamic and digitized logistics environment.

Deliverable D5.3 will not only analyze the status quo of current regulatory compliance but also provide recommendations on future regulatory frameworks that contribute to further developing smart logistics with positive changes in industry-wide behavior. Various stakeholders are to be engaged through workshops and surveys, with the outcome being clear direction for both policy and business leaders as to how to drive innovation while ensuring safety, sustainability, and adherence to regulations across borders.

1.2 Relation to Other Work Packages

Deliverable 5.3 is related to several other WPs within the TRACE project, which makes it a crucial point where regulatory considerations and behavioural change meet at the crossroads of overall ecosystem development. It informs the results of previous WPs and future stages of the project by putting the spotlight on how regulatory frameworks shape innovation and stakeholder behaviour. More specifically:

- WP2 provided the conceptual framework and stakeholder engagement for the initial technology definition and requirements and stakeholder requirements, respectively. The outcome of D2.1 and D2.4 on the technical and operational aspects of the TRACE ecosystem provides the grounds for placing this innovation into the regulatory environment. D5.3 will further support this by supporting the process of ensuring that technology advancements as researched in WP2 are with consideration of current and forthcoming regulations but also informed by the feedback of stakeholders and interested parties as far as regulatory issues are concerned.
- D5.3 is highly relevant to WP4 since regulatory frameworks certainly lie at the very heart of the adoption of new technologies such as autonomous vehicles or synchromodal transport solutions. These regulatory policies will define how technology will be deployed and innovation shaped, thus feeding into WP4 while methods are developed for integrating technology in the real world.

- WP6 - Large-scale Demonstration Activities will also be directly impacted by the outcome of D5.3 because it informs the regulatory barriers and behavioral drivers that need to be considered when large-scale testing and demonstrations are performed. Successful demonstrations, especially in the case of cross-border logistics, will require harmonization between regulations and system functionality. D5.3 ensures that for these large-scale activities, full integration of regulatory considerations is available and informs WP6 about necessary measures for compliance.

1.3 Methodology for Framework and Behavioural Change

D5.3 follows a methodology that introduces a step-by-step process for reviewing the existing regulatory framework and its impact on behavioral change in logistic and transport industries. The key objective is to evaluate the manner in which regulations influence innovative technology adoption, such as autonomous systems and synchromodal logistics solutions, and driving stakeholder behavior in view of compliance, efficiency, and sustainability. The methodology has been organized into four stages:

- **Regulatory Framework Analysis**: This will involve a critical review of the international, EU, and national regulatory frameworks presently relevant to logistics, autonomous technologies, and sustainable transport. The areas will involve specific regulations concerning safety standards, data protection laws, environmental regulations, and compliance with cross-border trade regulations. Key sources include EU legislation, national laws, and industry standards. This stage identifies the gaps, challenges, and opportunities within the existing frameworks affecting the deployment of smart logistics solutions.
- **Stakeholder Engagement**: The deliverable will be underpinned by stakeholders' contribution through workshops, surveys, and interviews that collates current experiences from logistics operators, regulatory bodies, technology providers, and end-users. This would help understand the issue of how existing regulations are perceived to alter behavior and decision-making from a stakeholder perspective. The feedback collected will map out how regulatory frameworks facilitate or hamper the adoption of technology and behavioral changes toward sustainable practices.
- **Behavioural analysis:** This Deliverable provides a study of drivers of behavioural change in logistics and transport. Using principles of behavioral economics, TRACE assesses how regulations and policies incentivize or deter the adoption of autonomous vehicles, changing towards 'green' logistics practices, or measures for better data protection. Case studies are integrated into the body to provide examples of how regulatory frameworks have resulted in successful behavioral change in the recent past, especially regarding environmental policies and safety regulations.
- **Feedback Integration and Recommendations**: The collected data and information identified are integrated to develop recommendations that help in improving regulatory frameworks as well as promoting positive behavioural change. This sets of policy adjustments, identification of the best practices, and ways to go about harmonization across borders. Besides the feedback loop between the stakeholders and the regulatory bodies, recommendations ensure that there is not only alignment to the current needs but also with any future technological developments.

Following these steps, TRACE takes advantage of data-driven analysis and qualitative insight from stakeholders to ensure that the proposed regulatory frameworks meet not only safety and sustainability goals but also foster innovation and proactive behaviour adaptation. This is a unique approach to give an

in-depth assurance that Deliverable 5.3 will have concrete insight for policy makers and industry leaders in the development of a regulatory environment supportive of logistics and transport evolution.

1.4 Regulatory Landscape Overview

The regulatory landscape that controls and compliments the logistics and transport sectors is extensive and in continuous movement according to developments in autonomous systems, sustainable logistics, and data-driven technologies. Regulations are major drivers for both the development and deployment of emerging innovations, as they define safety, security, and compliance across borders. D5.3, gives a summary overview of regulatory frameworks at international, European Union, and national levels, and showcases how these influence the adoption of new technology, operational practices, and behavioural change for key stakeholders that are involved within the logistics ecosystem.

Overall, international organizations like the United Nations and ITF (International Transport Forum) provide general guidelines on cross-border transport, autonomous vehicles, and environmental sustainability in logistics. These guidelines provide a basis for regional and national regulations, especially on areas related to safety standards, interoperability, and trade facilitation. It includes key international agreements, such as the UNECE regulations on automated vehicles, setting global standards which provide an example for many countries when they design and implement their own regulatory frameworks that govern automated transport systems.

On the European Union level, the regulatory frameworks relating to data protection, environmental sustainability, and cross-border logistics harmonization are even more complete. To this end, the GDPR regulation delineates how personal data collection, dissemination, and protection are carried out with the real-time data across the logistics chain. The Mobility Package and the European Green Deal set ambitious targets in terms of a carbon footprint reduction in transport, further promoting the uptake of green technologies that directly affect how operations within the logistics industry are carried out, hence encouraging both technological innovation and compliance with sustainability goals.

On the other hand, at the national level, regulations are variable, especially in the way autonomous vehicle deployment, safety, and infrastructure requirements are considered. Some nations have worked on creating supportive regulations for smart logistics and automated transport, while others have stayed behind, making cross-border operations challenging. Such inconsistencies in national regulations pose a serious barrier to the widespread adoption of autonomous systems and synchromodal logistics. Ultimately, addressing such gaps will be important in facilitating frictionless international logistics. The identification of such gaps in the event of challenges allows policymakers to develop more coherent and facilitating regulatory environments, which enable innovative solutions to logistics to diffuse more widely.

2 ANALYSIS OF REGULATORY FRAMEWORKS

2.1 International and European Union Regulations

International and European Union regulations are pivotal in shaping the regulatory environment for logistics, autonomous systems, and sustainable transport. On the international level, key organizations such as the United Nations Economic Commission for Europe (UNECE) and the International Transport Forum (ITF) set the groundwork for regulatory policies influencing cross-border logistics, autonomous vehicles, and environmental sustainability in transport.

The UNECE's Regulation No. 79, which concerns the approval of vehicles with regard to steering equipment, sets out the framework for autonomous vehicle deployment, by focusing on the following:

- **Permission for low speed operations** (up to 60km/h), such as parking and highway lane-keeping assistance.
- **Driver override capability**, so that the driver will always be able to take over control when necessary
- **System monitoring**, that will notify the driver when intervention is necessary
- **The existence of fail-safe mechanisms** that will notify the driver and ensure that the vehicle can be stopped or controlled

Additionally, ITF recommends the introduction of clear safety protocols and cybersecurity measures for Automated Vehicles and encourages the development of data-sharing protocols thus guiding member countries to establish safety, interoperability, and efficiency in automated transport systems.

At the European Union level, there are regulations that help in the smooth integration of the transport system within the member states. The EU Mobility Package is composed of proposals with huge potential to increase efficiency and further transform transport in Europe: safest and most sustainable; one that tackles the main challenges-ensuring autonomous vehicles can be integrated into the road transport network and facilitate the reduction in carbon emissions across all transport modes. The European Green Deal is one of the key regulatory priorities for the EU, in pursuance of which Europe is to become the first climate-neutral continent by 2050. It includes particular measures aimed at transport emissions reductions, among which comes fostering "sustainable logistics" with green technologies, electrical vehicles, and alternative fuels.

As far as the regulation of civil drones in the EU is concerned, this is generally governed by the European Union Aviation Safety Agency (EASA), which has issued Regulations (EU) 2019/947 and 2019/945 in order to harmonize drone operations across EU member states. These rules, collectively recognized under the tagline of "Easy Access Rules for Unmanned Aircraft Systems (UAS)", offer a legal framework that deals with the safe operation of drones in European airspace while taking into account innovation in the unmanned aviation sector.

Regulation (EU) 2019/947 divides UAS operations into three categories: Open, Specific, and Certified. Each category is related to different levels of risk and requirements for operations. Likewise, as in the case of the "Open" category, it has been devised for low-risk operations that require only minimal authorization

if the drone weighs less than 25 kg and is subject to some limitations, such as keeping a line of sight and not flying over people. Higher-risk operations, such as those possibly flying BVLOS or in highly populated areas, would fall under the "Specific" category.

These would then require a risk assessment submitted by operators in order to be authorized. The "Certified" category is, like in traditional aviation standards, for the highest-risk operations, which generally involve larger UAS, and require full certification akin to manned aircraft. Regulation (EU) 2019/945 defines the technical requirements for UAS placed on the EU market, including such requirements as remote identification, geo-awareness, and operator requirements. Moreover, it introduces the CE marking for drones, guaranteeing that the product complies with the EU safety standards. Indeed, this regulation will create obligations for manufacturers and importers to make sure all drones placed on the EU market are in accordance with the requirements set.

The GDPR already plays a very important role for data usage in logistics and transport industries, that will be even more critical with continuous proliferations of autonomous systems and AI technologies. It guarantees that personal data is handled securely while facilitating the cross-border sharing of data so crucial for real-time logistics operations. As logistics is increasingly based on real-time data sharing, powered by sensors, compliance with the GDPR brings into place the privacy of the individual while offering business benefits in terms of operational transparency for those within the logistics chain.

The European Union implements an ambitious environmental policy under the European Green Deal, addressing carbon emission cuts to drive sustainability into the transport sector. These regulations spearhead the development of a low-emission transport system in which logistics operations align with the set environmental standards that foster the adoption of autonomous electric vehicles and sustainable transportation solutions. At the same time, since EU policies are oriented toward climate-neutral mobility, this drives the design of autonomous and sustainable logistics systems that will further encourage the use of innovative technologies that reduce environmental impact while increasing efficiency.

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2.2 National & Local Regulatory Variations (Greece, Italy, Slovenia)

The regulatory environment of logistics and autonomous transport systems in Greece, Italy, and Slovenia, the three countries where TRACE will be tested, follows various national and local approaches, all reflecting the different legal, economic, and infrastructural contexts of these countries. While they all follow the broader EU regulations, such as the EU Mobility Package and the European Green Deal, each country has also developed its own set of policies that dictates how autonomous vehicles and sustainable logistics solutions are developed and deployed.

- **Greece:** The regulatory framework of autonomous transport and smart logistics remains at an infant stage, focusing on either pilot projects or smart cities. Amidst certain steps taken by the Greek government in the digitalization process for transport and logistics systems, there is still limited national legislation with respect to autonomous vehicle testing and deployment. Consequently, cities like Athens have implemented urban mobility policies that have the dual purpose of trying to reduce traffic congestion and carbon emissions by encouraging the use of electric vehicles and sustainable transportation solutions. This is a policy in place, according to the Greek Ministry of Infrastructure and Transport, since 2020. On the other hand, however, Greece has not overcome specific obstacles to implementing national standards for autonomous vehicles; clearly, dedicated regulatory frameworks for testing and deployment maintain limited large-scale commercial availability.
- **Italy**: At national level, there is a more proactive approach to the regulation of autonomous vehicles and sustainable logistics. In fact, specific regulatory provisions have been envisaged, regarding the testing of AVs on public roads, following European Union indications but providing a national regulation framework. Legislation has been proposed in 2020 that allows for the testing and deployment of autonomous driving technologies, positioning Italy among the very first countries in Europe to introduce a dedicated legal framework for the testing of autonomous vehicles. While the national framework is on the move, Italy still faces a series of regulatory challenges in ensuring safety standards, public acceptance, and integration into existing transport systems. The local actions involve clean transportation for cities like Milan and Rome; there are huge investments in electric vehicle infrastructure and incentives regarding green logistic solutions.
- **Slovenia:** The country is much more streamlined within regulations regarding autonomous systems. Within the context of their smart city projects, pursuing goals in sustainable transport, autonomous buses, and electric cars are being actively tested within its cities like Ljubljana. Very much opposite to emitting pollutants into the environment, its focus goes toward developing transport without an ecological impact. The Slovenian Road Safety Act provides for testing of autonomous vehicles, in line with the relevant EU legislation but enables also local innovative development in autonomous mobility. The national government supports data sharing in logistics and urban mobility solutions, enabling the development of autonomous logistics hubs and electric transport solutions. Meanwhile, with all these advances, Slovenia still has some work to do in bringing local and national regulations into line with the broader EU framework, especially in cross-border transport and data protection.

Regulatory frameworks in Greece, Italy, and Slovenia address the combination of their national initiatives, policies at the level of local government, and the relevant EU regulations. In terms of principles on sustainable logistics and testing autonomous systems, all three countries have made some steps forward; levels of readiness on the path to adopting autonomous transport technologies. Enabling full potential for autonomous logistics, in particular, relies on much clearer national frameworks, like those of Greece, and further work on safety standards and alignment of regulatory requirements across borders.

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2.3 Cross-border Regulations in Logistics

As can be easily understood, cross-border regulations in logistics constitute a very important basis on which goods can flow across borders, especially with the increasing reliance on autonomous systems, digitized processes, and sustainable transport solutions in the sector of logistics. There is, therefore, a call for harmonization of regulatory standards, which is very critical to ensuring flows and reducing trade barriers and delays, particularly in cross-border logistics and supply chain management. In matters of safety standards, customs procedures, and data protection laws, though, large discrepancies still become very apparent and make cross-border operations more complex.

The EU regulations include the EU Customs Union, Single European Transport Area, among others, aimed at standardizing the processes with a view to reducing trade barriers among its member states. The simplification of customs procedures, employment of electronic customs declarations, and facilitation of customs clearance across borders are part of the EU Customs Code and the UCC legal framework. Such a regime does ensure logistics operations with ease because there is one system to deal with customs, and thus cross-border shipments or synchromodal transport are conveniently made possible. However, despite these, the external EU borders continue to raise challenges in the harmonization of their regulations with the non-EU states, which constitutes one continuous process of negotiation and adaptation in view of frictionless international trade. The lack of international harmonization on safety standards-especially on the deployment of autonomous vehicles and ITS-can be considered a barrier to cross-border logistics. The biggest barrier to the testing of autonomous vehicles is the dissimilar regulatory approaches being taken on by different countries. It delays the deployment of smart freight systems and autonomous trucks. Work was ongoing on global standards regarding autonomous transport systems under the auspices of UNECE's WP.29 and ITF.

All that makes cross-border logistics even more complicated, especially in the case of those regions where real-time data exchange for coordination, not only of autonomous vehicles but also of smart supply chains, is required. The GDPR regulates the collection, storage, and dissemination of personal data, thus controlling logistics data sharing across borders by the EU. While the EU had quite clear regulations, in most of the non-EU countries, their standards regarding data protection vary a lot, hence becoming a challenge for logistics providers to comply with local and international regulations at the same time. For example, the United States, China, and India have their respective data privacy laws; these do not align fully with the GDPR of the EU and hence limit data sharing and cross-border collaboration in logistics.

Other important concerns in cross-border logistics are those to do with environmental regulations. New legislations are set by countries to pursue international climate goals and reduce emissions from the transport sector. It is not easy to take up sustainable logistic solutions with the ambitious targets on emissions reduction set by the European Green Deal and Climate Law, while other regions are non-uniform with their environmental standards. Cross-border regulations should be cognisant of the variance in fuel standards, emissions reporting and the efficiency of vehicles to attain a green technology uptake with no hindrance on international trade and attainment of environmental objectives postulated by the European Commission 2019.

In conclusion, cross-border regulations in logistics are a blessing and an obstacle to international trade and uptake of autonomous and sustainable transport technologies. Even though regional initiatives such as the EU Customs Union and UNECE regulations have gone a long way in standardizing logistics, significant barriers remain on issues related to safety, data protection, and environmental compliance. While logistics systems continue to integrate and become more digitalized, an internationally harmonized regulatory framework will be indispensible in the future to ensure that the global supply chain continues to be efficient, secure, and sustainable.

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2.4 Gaps and Challenges in Current Frameworks

Regardless of the fact that substantial progress is being made to advance the regulatory frameworks for autonomous systems, sustainable logistics, and cross-border transportation, there are gaps in the few that exist, together with a number of challenges to seamless integration and wide-scale diffusions. This is mainly emanating from inconsistencies of regulatory standards, an area that will suffer from inadequate coordination across the national, regional, and sub-national levels of government, besides issues emerging from the evolving nature of technologies that often outpace the development of the regulatory process itself. All these challenges are further compounded by the complexity of cross-border logistics and integration of digital technologies, hence a requirement for an overall regulatory reform and international cooperation.

Another major inconsistency in present regimes relates to non-harmonization at national and regional levels of regulation regarding autonomous vehicles with regard to data protection laws. While European regulations like the GDPR impose some high standards concerning data privacy, inconsistencies in the implementation of the laws by individual EU countries create unevenness for the free flow of data across borders. For example, the rule on local data protection is different in many countries, and some have more stringent conditions than others; the real-time data exchange for cross-border logistics operations already is complex and cumbersome to handle. Regulatory frameworks for autonomous vehicles also range in scope: though countries such as Germany and the Netherlands have designed high-level legal frameworks, some EU members still have no clear regulations or standards regarding testing and deployment. This lack of regulatory alignment operates to delay the wide adoption of autonomous technologies while at the same time creating operational barriers to doing business across multiple jurisdictions.

The gap lies in the slowness of regulatory adjustments to keep up with rapidly changing technological innovation. Indeed, autonomous transport vehicles, AI-driven logistics systems, and blockchain technology are all outpacing the regulations that help control them. Take, for instance, that the UNECE's regulatory body has been working on setting standards for automated driving systems; still, globally, regulations for fully autonomous trucks have only reached the development phase. While these are still rapidly

developing technologies, it is difficult for policymakers to anticipate their impact and develop robust structures and frameworks which could address safety and liability concerns, as well as interoperability, adequately. In the absence of timely regulatory frameworks, there does exist a real risk that new technologies will be introduced onto the market before proper protocols on safety protection and liability protection are instituted, which raises grave questions about public safety and market stability.

Also, the fragmentation of regulatory approaches to cross-border logistics is still a challenge. For instance, the EU has had considerable advances in regulatory harmonization, for example, through initiatives such as the EU Customs Union and the Single European Transport Area. Yet, differences prevail across countries outside the EU in the way they handle cross-border transportation. For example, the United States has moved to implement regulations around autonomous vehicles on a state-by-state basis, creating a patchwork that complicates cross-border logistics for international companies. For example, in Asia, countries like China and India have developed their own frameworks about autonomous transport and data security, but those rules are sometimes quite far from both European and North American ones, causing logistical inefficiencies and problems of compliance for businesses operating on a worldwide basis.

Last but not least, environmental logistics regulations are also inconsistent. Special attention is given to green technologies and low-emission vehicles. With the EU Green Deal and the European Clean Transport Policy pressing on toward a carbon-neutral economy, different member states have different standards of sustainability in the sector of logistics. For example, Norway has powerful electric vehicle and electric cargo bike incentives, whereas others have been slower to implement policies supporting the uptake of sustainable transport. European Commission 2019) This leads to regulatory fragmentation, adding uncertainty for logistics companies trying to transition into green technologies amidst a complex set of varied local regulations.

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3 BEHAVIOURAL CHANGE IN TRANSPORT AND LOGISTICS

3.1 Initial study on behavioural change

Behavioral change in logistics operators refers to the extent to which firms operating within the logistics and transport sector change in approach and manner of doing business, break with established practices, attitudes, and ways of doing things in the face of new challenges, technologies, and expectations. These are driven by manifold motives, ranging from the need for better efficiency, sustainability, and responsiveness within the fast-changing logistics market. For example, logistics operators might be able to diversify into pure road carriage by introducing more sustainable modes such as rail and water. They also introduce new technologies, such as automation and data analytics, which enhance decision-making and cause a shift towards collaboration with other firms in the optimization of resources. Besides, the drive for decarbonization makes operators revisit the use of energy and carbon footprint in view of adoption of cleaner fuel and energy efficiency. Other forms of behavioral change entail the ability to adapt to changed policies, such as compliance with new regulations on emissions and safety or the responses to incentives devised to offer greener and more ethical practices. More customer-centric approaches, in conjunction with digital transformation and risk management, have become the prime focus of logistics operators in their quest to be competitive and resilient. The notion of behavioral change in logistics represents a shift in mentality and embedded practice within the industry, while also responding to modern demands and securing long-term success in a competitive way.

This report narrows down to behavioral change in the context of horizontal collaboration within logistics, which is becoming increasingly indispensable in shared logistical systems. In this matter, horizontal collaboration refers to collaboration among logistic companies at a similar level of the supply chain by pooling their resources together, sharing infrastructure, and optimizing routes. This will be paramount in minimizing operational costs, hence making the services more efficient while achieving the set sustainability objectives.

New technologies, such as those to enable blockchain for secure data sharing, the IoT for real-time tracking, and cloud-based systems ensuring seamless communication and integration of data, are important for various reasons. Such technologies create transparency, trust, and efficiency among the entities that would collaborate, thereby making it easier for logistics operators to collaborate even though they may be competitors. Other examples of how technology can lead to effective collaboration include collaborative TMS and platforms that enable dynamic route optimization and freight pooling.

But all this collaboration can take place among the logistics companies only when the first and foremost thing that needs to occur is the acceptance of these technologies. Some serious issues such as resistance to change, data security, and major costs for technology implementation have to be overcome. It is not just horizontal collaboration; with the willingness to adopt such technologies, companies will be better equipped for quick and timely responses to market demands. In this way, the industry becomes resilient and competitive.

In the following sections, a more detailed explanation of horizontal collaboration is given, including how it can be operationalized for a number of logistics operators. Additionally, it describes the TRACE platform as one proposed solution to support and reinforce this collaboration. The TRACE platform exemplifies

technology as an enabler of seamless information exchange, thereby enhancing logistics efficiency and contributing toward the common goal of efficiency and sustainability within the logistics industry.

3.2 Initial study on logistics collaboration

Both vertical and horizontal collaborations are feasible within the supply chain. Horizontal collaboration refers to collaboration among companies operating at the same level within the supply chain, such as among logistics service providers. While horizontal collaboration offers the biggest bundle of advantages in cost reduction, efficiency enhancement, and reduction in environmental impact, it also remains the most challenging to establish because firms may feel strong competition, lack of trust, and fear of information leaks. In particular, horizontal collaboration is very promising within urban logistics, where companies are allowed to improve vehicle utilization, reduce congestion, and lower emissions.

In logistics, horizontal collaboration can vary from transactional to complex alliances that would necessitate a joint decision-making system. Horizontal collaboration can be formal and informal and may be orchestrated under various configurations, including third-party led or open leader formats. Effective information sharing is one of the most relevant requirements regarding effective collaboration and hence also critical to infrastructure use, joint vehicle use, or shipment exchange. Another role of e-marketplaces and logistics alliances is that they act as confidence platforms via which companies connect and optimize. Strong communication and deployment of advanced ICT6 are, in fact, part of the core of successful horizontal collaboration.

The horizontal collaboration amongst the logistics companies comes with quite a number of considerable benefits, which make the strategy very viable for these firms. Firstly, there is the improved vehicle utilization, increased by about 10%, coupled with a good reduction in empty runs, reduced deliveries, and, finally, a reduction in kilometres travelled as high as 70% in some cases. This reduces congestion on the roads, energy consumption also drops, and cost of fuel decreases, with a drastic decrease in environmental impact-reduction of CO_2 emission by 23% among others.

Besides the environmental advantages, horizontal collaboration can result in lower transportation and warehousing costs, greater efficiency gains, which, in turn, enlarges demand and widens the customer base. With efficiency gains, more rapid and frequent deliveries are possible. This, in turn, improves service quality and increases the number of deliveries that will reach customers successfully. The clients' value proposition can be further improved through a broader and more comprehensive range of logistics services on offer.

It also unlocks opportunities for the optimization of logistical processes and the forming of new business partnerships, while better utilizing transport infrastructure, such as warehouses and consolidation centers. Sharing resources by companies leads to a reduction in costs of investment while at the same time increasing their flexibility to respond to the issue of new regulations and alterations in patterns of demand by customers.

For minor logistics companies, this horizontal collaboration increases their competitive advantage as well as bargaining power, making the entry barriers easier to cross for new firms. It also allows further optimization of human resources across the partner companies and quicker response times for urgent or

special delivery requests. Knowledge and experience exchange among collaborating companies further strengthens the overall logistics network.

This collaboration may finally lead to significant cost savings: general expenses can be reduced up to 18%, while the total company savings may constitute up to 4-6% of the company's total expenditure. These financial benefits, together with operational efficiencies, point toward substantial value added to logistics companies resulting from horizontal collaboration.

Some interesting conclusions came from studying the NexTrust project, a previous project with similar scope. The results indicate various significant benefits accruing to collaboration in supply chain networks. It reflects that companies from mainly FMCG sectors have a high interest in participating in future logistics collaborations. Furthermore, the success of such collaborations has a big dependence on the setting of standards. These companies have been motivated both economically and ecologically, with a double focus on profitability and sustainability. Nevertheless, the market still underestimates considerably the potential savings and gains in efficiency that will be achieved by logistics collaboration. The results from the NexTrust survey - Figure 3.1 - suggest that companies do not expect such positive results from collaboration probably due to lack of sufficient familiarity with the positive effects of collaboration cooperation itself.

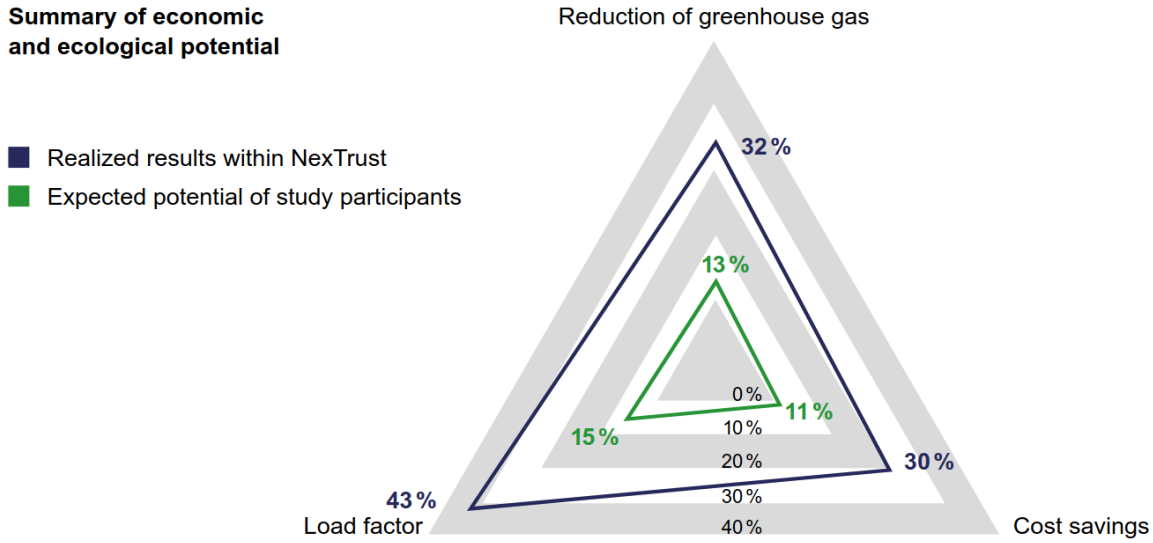

Figure 3.1 Expected potential and realised results of collaboration within the NexTrust project

The NexTrust survey also found that those companies that have experience of collaboration are more aware of the benefits of collaboration and are more willing to set up various collaborative projects in the future.

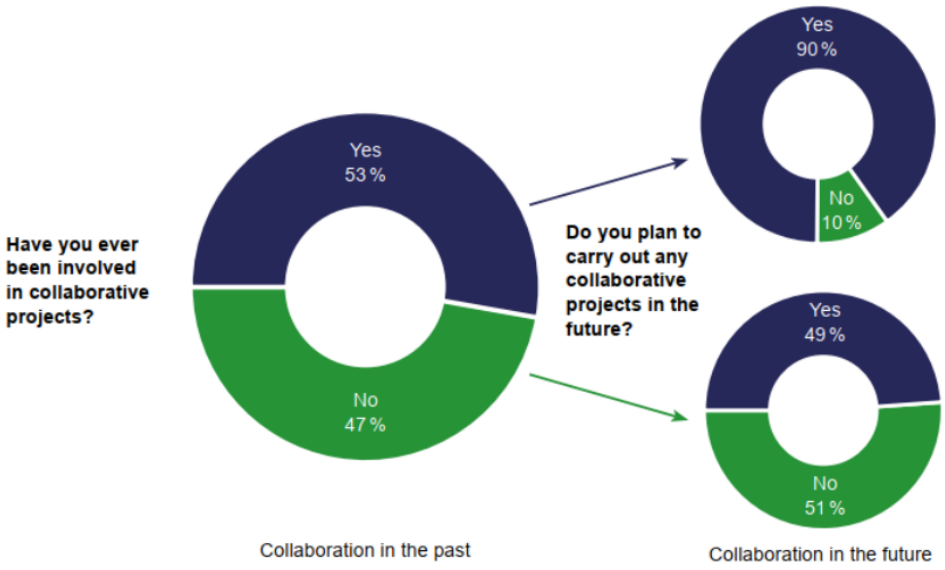

Figure 3.2 Experiences and willingness to collaborate in the future

The participants in the NexTrust survey also seemed to underestimate other benefits of collaboration like increase capacity utilization in transport (Figure 3.3), saving potential in GHG (greenhouse gas) emissions (Figure 3.4) and saving in potential costs (Figure 3.5).

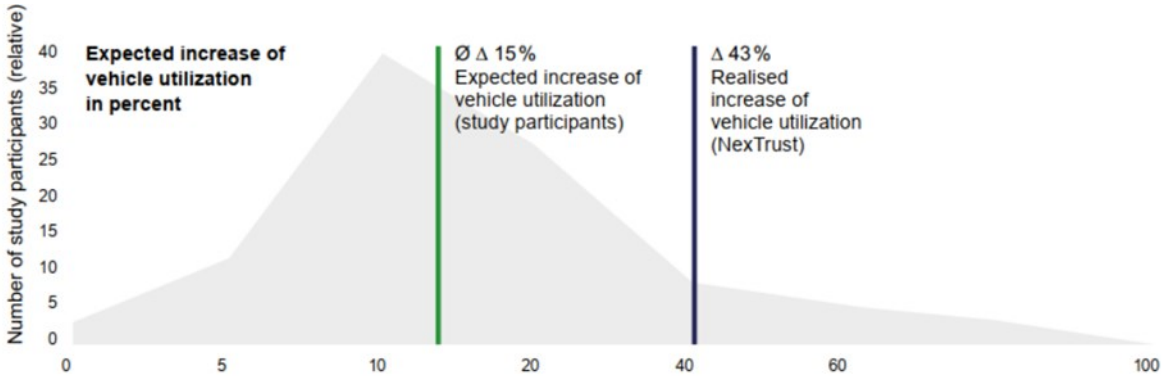

Figure 3.3 Expected and realised increases in capacity utilization in transport

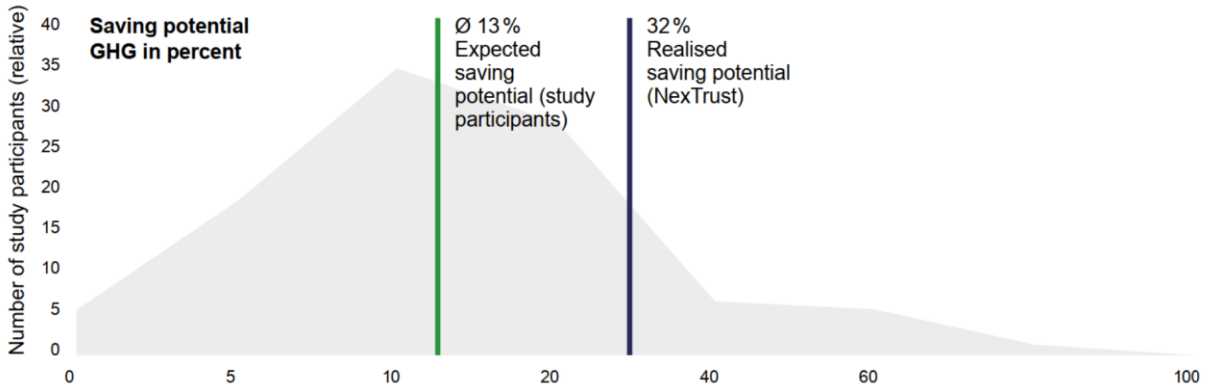

Figure 3.4 Expected and realised increases in GHG emissions

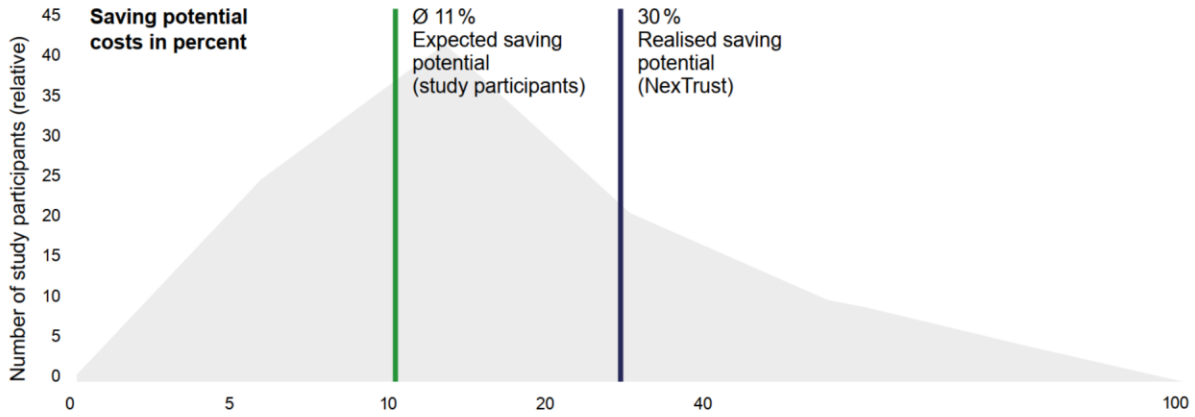

Figure 3.5 Expected and realised increases in cost savings

References:

- Collaboration in Supply Chain Networks - A GS1 Germany Study within the EU-Horizon 2020-Project NexTrust

3.3 Issues and challenges of collaborating logistics operators in shared logistics

Despite all the benefits of horizontal collaboration among logistics companies, a number of issues and concerns still keep many businesses away from practicing such collaborations. In fact, there is a lack of clear rules on the responsibilities, rights, and splitting of resources and revenues between partners. Unclear regulations about how to share orders, vehicles, infrastructure, and handling equipment increase the complexity of collaboration. Moreover, there is a lack of transparency about the elaboration of services

and cost-sharing that can undermine the trust between the future partners. Somewhat obviously, there is a lack of trust towards unknown or competing logistics companies. Finding suitable partners is also a problem in itself, given the heterogeneity of business objectives, operational processes, and the nature of goods moved. Long-term commitment to collaborate is another critical issue since firms might not stay committed to collaboration through time. Power imbalance among collaborating firms adds further complexity to the partnership in a situation where one partner dominates decision-making.

There are also fears of loss of autonomy and impacts on company reputation, and threats from cybersecurity attacks on the technologies supporting information sharing. The integration of existing IT systems of logistics companies into a collaborative framework is rather challenging, as many companies are not willing to share required information. Poor communication and data management, due to a lack of proper technologies in most instances, hampers smooth information exchange, which is necessary to support collaboration.

Most collaborative initiatives between companies require the services of a neutral third-party coordinator who leads and administers the collaboration, but such a party that inspires trust may not be that easily found.

Organizational structures may not be suitably designed to foster collaboration, and the complexity of planning and optimizing jointly used logistics processes is an added encumbrance. The existence of legal barriers also limits the possible scope of intercompany collaboration. Resistance to altered circumstances for successful collaboration and a lack of recognition of the potential advantages constitute other obstacles in creating horizontal partnerships in logistics.

These challenges illustrate the difficulties in establishing effective long-term collaborations among logistics companies. The success of such partnerships depends heavily on accurate and timely information sharing, fair distribution of resources and profits, and the adoption of advanced information and communication technologies, such as the TRACE platform. This platform facilitates collaboration and optimization of logistics processes among a larger number of logistics operators. In the following subchapters, specific issues such as the ethics of data sharing, the management of intellectual property rights (IPR), and ethical practices with a focus on the TRACE platform will be discussed in more detail.

3.3.1 Ethics of the data

TRACE employs data collecting, processing and storing in multiple roles (personal and non-personal). The legal frameworks that apply are mainly the General Data Protection Regulation (GDPR), and the AI Act. A TRACE Ethics Code of Conduct applying to data takes place as an objective of Task T1.6 – Ethical and GDPR Issues. Moreover, T2.3 – Ethics and Societal Requirements provides the project with the data ethics requirements gathered from questionnaires, workshops, etc. The ethics tasks are overseen by the project's Ethics Board, led by the ethics expert ISIG, consisting of a representative from each partner, and complemented by two external ethics expert members.

The Ethics Board focus is on the data protection issues. Privacy is one of the most important aspects of required protection. While no personal data are to be shared among shareholders, certain aspects of

privacy may be compromised by inference from information aggregation. Other risks pertain to the AI employed by the TRACE project. Some of these risks, include discrimination (e.g. against persons living in specific areas), traceability of the AI decisions (justification and analysis of the decisions taken by AI), and transparency (ability to identify the whole data processing architecture).

After the analysis of the risks involved, and the estimation of the level of each risk, the data collection procedure will establish the kind of data that should be collected, processed and stored for the TRACE platform. If the processing of certain data is deemed to increase the risk significantly, one of the mitigating measures could be the elimination of these data from collection and processing.

Throughout the TRACE project, ethical and legal aspects are addressed in various activities, including the development of an Ethics Code of Conduct in WP1 (namely Task 1.6 – Ethical and GDPR Issues), ethical guidelines and workshops in WP2 (namely, Task 2.3 – Ethics and Societal Requirements), supported by the ethics expert partner ISIG and the Ethics Board, as outlined in the DoA and detailed in deliverable D1.2-Data Management Plan. In the following paragraphs, aspects of data ethics and responsible data handling practices related to sensor data are highlighted, considering the Streamhandler as a module in the integrated TRACE platform.

Logistics operators in shared logistics are facing a number of issues and challenges, part of which refer to considerations pertaining to the ethics of data. Partner INTRA supports the delivery of the TRACE platform to the logistics operators and also provides big data streaming and management, through Streamhandler, which will make use of data retrieved from sensors. While sensor data may not directly contain personal identifiers, it can still provide detailed insights into operational patterns and activities. Protecting the privacy and confidentiality of this data is essential to maintain competitive integrity and trust among stakeholders.

Data aggregation, access control and encryption are the measures employed to ensure data privacy and confidentiality. Sensor data aggregation can effectively prevent the identification of specific operational patterns that could give away sensitive information. The implementation of strict access control measures ensures that only authorized personnel have access to the data, while the utilization of robust encryption methods for data at rest and in transit safeguards against unauthorized access.

Even with sensor data, it is important to ensure that all stakeholders are aware of, and agree to, the data collection and usage practices, throughout the project implementation and beyond. One of the fundamental principles, in this respect, is the logistics stakeholders' informed consent. As part of the TRACE architecture design, provisions have been taken into account in order to clearly describe what sensor data is being collected, its purpose, and how it will be used in the TRACE platform, ensuring transparency. Owners of sensor data participate in the TRACE platform voluntarily and have the ability to withdraw their consent at any time, where applicable.

Compliance with data protection regulations remains relevant, even for non-personal data. Various regulations may still apply, such as the GDPR's stipulations on data security and the handling of potentially sensitive operational information. Conforming with such provisions, data retrieved from sensors is not maintained in the system for more than ten (10) days. Steps to ensure regulatory compliance like Data Protection Impact Assessments (DPIAs) and audits are already in place, as part of the activities in Tasks T1.6 and T2.3.

Beyond legal compliance, ethical data practices involve a commitment to doing what is right. Provisions are in place for minimizing data collection, where possible, in order to collect only the data that is necessary for the intended purposes and avoid unnecessary data accumulation. Streamhandler ensures that data management and oversight throughout its lifecycle are done responsibly. Most importantly, stakeholder engagement is part of the design of the integrated TRACE platform, thus ensuring their concerns and expectations regarding data sharing are understood and included in all development activities.

3.3.2 Intellectual Property Rights (IPR) management

IPR management pertains to one of the very basic and key roles of collaborative logistics, especially in complex ecosystems with various entities contributing through innovations, technologies, and data. The effective management of IPR will ensure that the contribution is recognized and acknowledged, protected, and used fairly for mutual benefit. This significantly reduces disputes on one hand and encourages innovation on the other.

A very key consideration in IPR management is that of ownership. The agreement between parties should state with exactitude who the owner will be of whatever form of intellectual property might be developed or put to use within such a relationship. Such an agreement can be done through clear contracts stating the ownership, license, and other monetary considerations like royalty payments. The usage conditions, to include the time and scope, should be stated in these contracts. Indeed, in multi-stakeholder collaborative environments such as TRACE, robust contractual frameworks should form part of effective IPR management. In fact, every party entering the platform should be asked to sign a contract stating the contribution in terms of intellectual property and mentioning the terms for protection, use, and possible sharing of proprietary technologies, methods, and data. Agreements present should allow for regular updates according to the growth in technology and enterprise needs. Also, the agreement should spell out whether generated IP is owned by an individual or collectively by collaborators. Regarding shared logistic platforms, one of the big challenges in its development has to do with IPR protection when there is an integration of technologies coming from different sectors. Take the case of UAV manufacturers and other vehicle manufacturers, say cargo bike producers; each must have their ownership rights to the technologies they have.

Even though a UAV and other vehicle, for whatever logistic reasons, might work together, ownership differentiation is important in the subject matter of individual innovations, say a flight system of a UAV or payload integration in a vehicle. Cross-licensing agreements allow for smooth collaboration while protecting the IPR of each party, and it should be no different in cases where some IP is jointly developed as an outcome of the integration process. Besides that, the type of platforms TRACE involves deals with sensitive information flow between systems, say a Hospital Management platform and a logistic network. This is where, for example, the hospitals might maintain patient information and TRACE maintains the logistics data, in which case it is important that both the platforms retain their IP ownership while ensuring protection of data. Data-sharing agreements will be required with explicit statements of boundaries on shared data for protecting both personal data per laws like the GDPR, but also the intellectual property.

Each party shall take responsibility for the security of its data and its protection against unauthorized access or leakage of sensitive information. An interesting example concerning this issue is given by LifeBox,

a smart connected payload that safely transports biomedical material. LifeBox can be installed on several vehicles, from UAVs to cargo bikes, passing through ground logistics solutions. This makes IPR management even more complex, as the smart features of the LifeBox and its tracking technologies have to be preserved while collaboration is made with different manufacturers of these diverse vehicles. There are agreements that need to be made to ensure ownership of respective technologies by each party involved-be it a vehicle manufacturer or creators of LifeBox-without any implicit IPR transfer through collaborative use.

The NDAs and strict measures for data protection shall be prepared in such a way as to retain the confidential information without leakage or legal non-compliance. Additionally, such disputes regarding IPR or data breach shall be taken care of through pre-agreed mechanisms, even before the various collaborations take off. Therefore, any such mechanism lays the ground for conflict resolution in a highly organized manner and leaves little room for disputes that can be dragging. Lastly, any effective IPR management strategy should entertain an exit strategy. Such an exit strategy will also explain how shared or developed IP intellectual property is to be disposed of in the case of the close of collaboration in order to ensure that original creators retain their rights after such partnership engagements. By incorporating these elements of the law and ethics into their business structure, companies have the ability to foster creative collaboration processes while protecting their intellectual property for mutual success.

3.3.3 Ethics of practices

In the context of TRACE, data ethics and legal guidelines are of paramount importance, given the central role of data collection, processing, and management in logistics operations and resource management. TRACE's dedication to ethical awareness is exemplified by the incorporation of specific initiatives within the following work groups:

- Quality Management & Risk Analysis (T1.2) - Encompass the timely identification and response to potential ethical and legal issues;
- Data & IPR Management (T1.5) - The Data Management Plan (DMP) document, which is updated on an annual basis, sets out the project's procedures for the collection, organisation, backup and storage of data generated throughout the project. The designated Privacy and Ethics Manager (PEM) is responsible for developing and ensuring the implementation of the DMP for each project partner;
- Ethical and GDPR Issues (T1.6) - An Ethics Board (EB) has been constituted to guarantee the continuous monitoring and adherence to national and international laws and regulations;
- Ethics and Societal Requirement (T2.3) - Encourages the participation of end-users and relevant stakeholders in the process of defining the technical and non-technical requirements for the co-design of the platform.

These initiatives provide a framework for understanding the ethical principles, legal obligations, and best practices that should guide the project. The involvement of end-users and stakeholders in the platform design is an area in which the ethics guidelines were particularly applicable during the initial 18-month period of the project. The following tables summarize the principles and standards enforced in this area.

Table 3.1 TRACE and Horizon Europe principles compared

TRACE principle	Description	Activities	Horizon Europe principle
Integrity	The project is designed to ensure that everyone involved is treated fairly and respectfully.	• Recruitment of participants • Feedback from participants	• Proportionality • Non-Discrimination
Voluntary participation	People must not be forced to take part in the project. The Informed Consent Form ensures this. Provide clear information on: 1. what is expected by participants' participation 2. the possibility to withdraw from the activity at any time without consequences.	• Recruitment of participants • Drafting informed consent • Distribution of informed consent	• Protection of personal data • Right to privacy
Protection of the volunteer participant and honouring the trust	The project aims to protect the well-being of those involved in its studies and respects their rights.	• Feedback from participants	• Right to physical and mental integrity • Protection of personal data • Right to privacy
Anticipating harms	The project takes steps to protect participants and their environment. It aims to prevent harm.	• Feedback from participants	• Right to physical and mental integrity • Ensuring high levels of human health protection
Avoiding undue intrusion	The project is safe and enjoyable for all participants.	• Recruitment of participants • Feedback from participants	• Right to physical and mental integrity • Proportionality • Protection of personal data • Right to privacy
Confidentiality and anonymity	The project respects the participants' right to privacy.	• Feedback from participants	• Protection of personal data • Right to privacy
Representation and misuse of expertise	The project only does research and provides services that the members of the consortium can do well.	• Reporting research results • Publishing research products and results	• Proportionality • Non-Discrimination

Table 3.2 TRACE and GDPR principles compared

TRACE principle	Description	GDPR principle
Non-incompatible use	Personal data should only be gathered for a good reason and not used in a way that is not allowed. Protecting personal data is important for scientific purposes.	• Lawfulness, fairness and transparency • Purpose limitation • Data minimisation
Access	The data subject has the right to access information about how their data is processed. This includes details about why it is being processed, what types of data are involved, and who it is being shared with.	• Lawfulness, fairness and transparency
Prohibition / exceptions	You must give your consent for us to process your data.	Purpose limitation
Informed Consent	Researchers must get permission from people they are studying. Covert research should only be used when there is no other way to get information or when usual sources are blocked by those in charge.	• Data minimisation
Automated decision	Automated decisions that affect people cannot be made without human input.	• Integrity and confidentiality
Notification and prior checks	The need for data processing must be evaluated and approved by national supervisory bodies. This helps data protection authorities understand how data is used. It also helps ensure transparency in data handling.	• Accountability

In addition, a study from the NexTrust H2020 project revealed that transport service providers are more inclined to participate in Collaborative Transport Networks (CTNs) given the availability of standards as a prerequisite, and if a neutral third party oversees the collaboration processes, ensuring fair treatment and confidentiality.

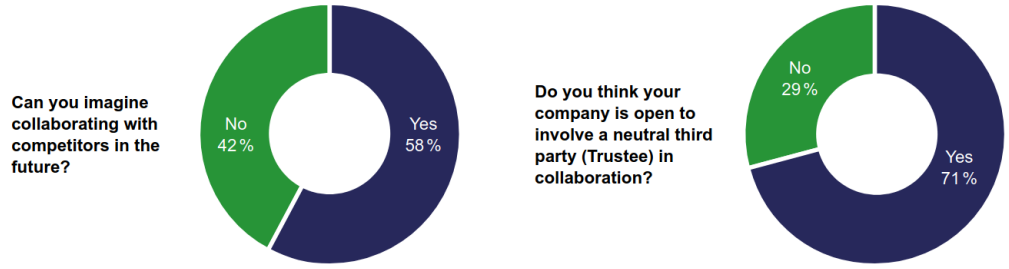

Figure 3.6 Survey on openness to collaborate

It can be seen, therefore, that the element of trust is of great importance regarding the success of a synchromodal network. The TRACE platform is being developed with the specific intention of fulfilling the role of a trusted third-party, addressing the ethical implications of data practices, integrity and individual rights in an increasingly data-driven world. Nonetheless, participants have specific responsibilities and liabilities for effective collaboration and compliance:

Table 3.3 Responsibilities of collaborative participants

TRACE principle	Description
Compliance with Regulations	Adhere to the pertinent legislation, including data protection regulations such as the General Data Protection Regulation (GDPR). This entails ensuring that data controllers and processors fulfil their obligations.
Data Sharing and Management	Implement transparent data sharing protocols to guarantee that all partners are aware of their responsibilities pertaining to data processing and to ensure the maintenance of data integrity and robust security measures throughout the logistics chain. Only the minimum amount of data necessary to achieve the intended purpose of the collaboration is shared, strictly limited to authorised personnel only. Furthermore, data should not be repurposed or shared more broadly.
Ethical Data Use	Ensure that ethical standards are upheld in the utilisation of data, including the obtaining of informed consent from data subjects and the avoidance of the use of biased or misleading data. Data usage does not discriminate against or otherwise disadvantage any party. Furthermore, it is essential that optimization and carrier-load matching algorithms are subjected to rigorous auditing to ensure that they are free from any form of bias.
Risk Management	Conduct risk assessments with a view to identifying potential threats to data security and operational integrity. Once these risks have been identified, appropriate controls must be implemented to mitigate them.
Collaboration and Communication	Foster transparent relationships to facilitate collaboration and information sharing.

Table 3.4 Liabilities of collaborative participants

Liabilities	Description
Legal Liability	Organisations may be subject to legal consequences for failing to comply with data protection regulations. These consequences may include substantial fines based on global turnover or specific penalties under national laws.
Reputational Damage	A failure to uphold ethical standards or mishandling of data can result in significant reputational harm, which in turn affects stakeholder trust and customer relationships.
Financial Consequences	In addition to legal penalties, organisations may suffer financial losses because of operational disruptions, or the loss of business opportunities caused by unethical practices or data breaches.
Joint Responsibility	In instances where multiple entities are engaged in data processing activities, they may be held jointly liable for any non-compliance, thereby necessitating the establishment of explicit agreements regarding the respective roles and responsibilities of each party.

While cooperation can provide a range of advantages, it sometimes involves setbacks that can reduce competitiveness. That is why this situation is commonly called "coopetition," when competition and cooperation between enterprises take place at the same time, developing intricate dynamics in logistics networks. One of the identified risks for logistics alliances is that of cartel, where there is a forming of agreement among some firms to raise prices and eliminate competition as it boosts anti-competitive conduct especially when the number of players has been reduced.

In synchromodal logistics networks the responsibilities for ethical practices vary, depending on the roles of the stakeholders:

- Logistic Service Providers-The collected, used, and shared data of the partners should be clearly communicated with full transparency in front of the relevant stakeholders. Besides taking serious

and strong measures to ensure that security has been implemented to avoid any breach or unauthorized access to sensitive information, accountability mechanisms relating to the data handling practices of the partners as well as the consequences of their logistics operations must be unequivocally clear.

- Customers and consumers: They give consent clearly to use their data and ensure that they are fully informed about the use of their data, including the various rights provided, such as access, correction, erasure, and consent withdrawal. On the other hand, logistic providers will be prompted to collect data only in relation to certain purposes, which needs to be done with regard to guidelines on ethical data minimization.
- Suppliers: They are also equally important to provide the correct and timely information on inventory and shipment, which is the hub of a good logistics plan.
- Regulatory Agencies and Industry Associations: Regulators should enforce laws such as the GDPR and give guidance on how data should be used ethically in the logistics sector. They must develop and update frameworks, detailing best practice with regards to ethical data management within logistics operations. Associations will communicate such ethical standards and best practices
- Technology Providers: Solutions to the technologies must be developed keeping in mind the ethical perspectives of how data practices can be achieved responsibly and in a manner which is not unfair.

The European Union has implemented various frameworks of data ethics in order to regulate trades concerning protection of the individual rights within a digital economy. Regulations implemented include General Data Protection Regulation, or GDPR, and the Data Governance Act, or DGA. While GDPR ensures a person's rights with respect to data regarding their identity, DGA allows for sharing and reuse of data in ways that are considered ethical, with quite a degree of transparency. Very recently, the so-called AI Act is a framework under development specifically to address issues related to ethics in AI among other issues emerging with technology.

3.4 TRACE survey on horizontal collaboration of logistics operators in shared logistics

Drawing from the literature review, where we outlined the primary benefits, conditions, and challenges of collaboration, as well as other relevant factors, we designed and distributed a questionnaire targeted at logistics companies. The purpose was to assess the collaboration readiness of logistics companies, identify key motivational factors, define the necessary conditions and soft measures for successful partnerships, and gain insights into their collaboration experiences. The questionnaire thus addressed the following areas:

- challenges faced by logistics companies that impact their operations
- past experiences with collaborating with other logistics service providers
- willingness to engage in collaboration with other logistics service providers
- types of collaboration that would be appropriate for the respondents
- potential collaboration areas that would be suitable for the surveyed companies

- benefits of collaboration that could enhance the willingness to collaborate
- essential conditions for ensuring long-term, successful collaboration among logistics companies

Data collection took place from April to September 2024 through an online survey. Initially, companies were invited to participate via email, and follow-up phone calls were made to encourage survey completion. This dual approach of email invitations and direct phone reminders notably enhanced the response rate. Ultimately, we obtained 84 valid responses from various EU countries that were deemed suitable for our study.

Figure 3.7 shows issues of logistics companies affecting their logistics processes.

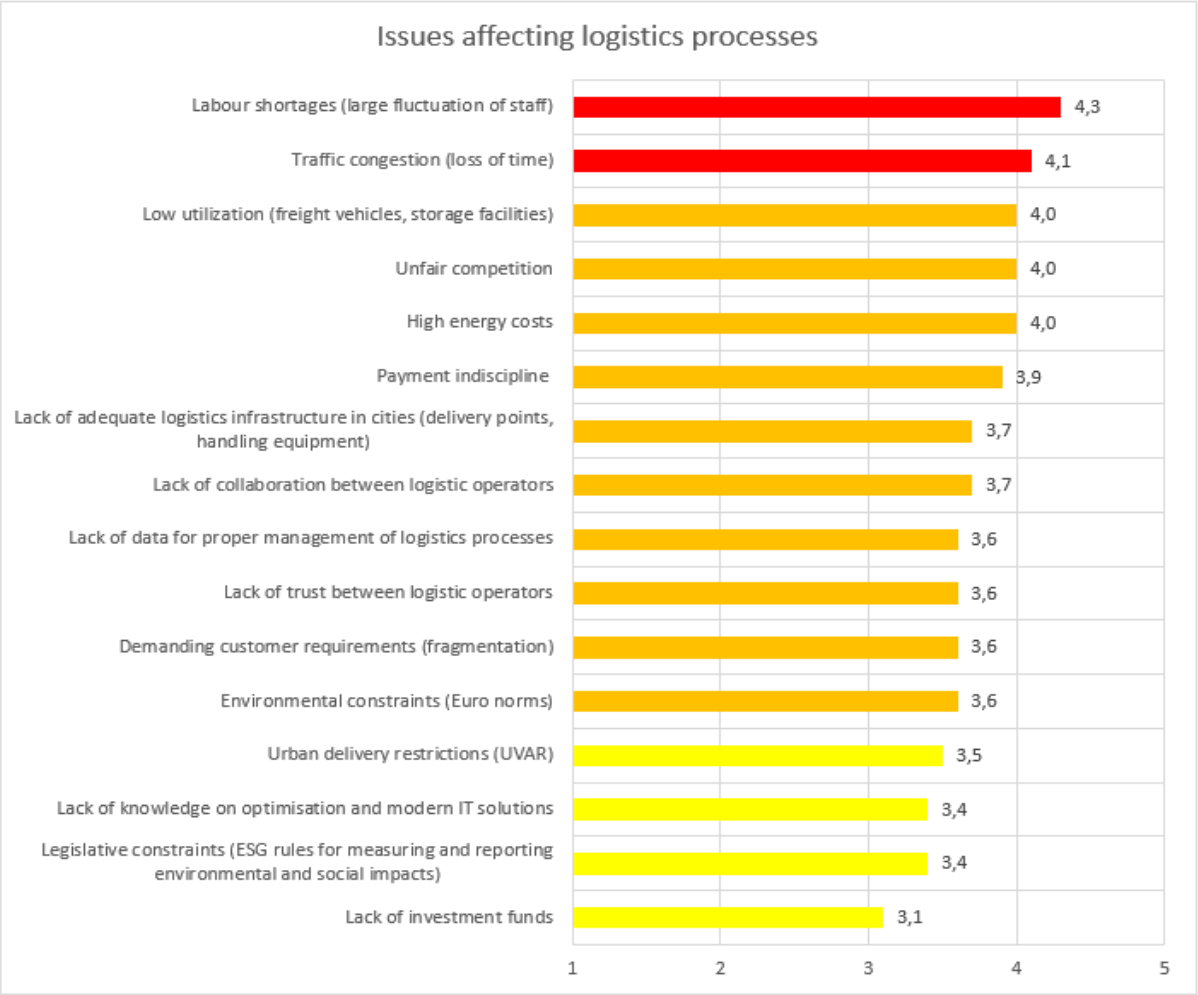

Figure 3.7 Issues of logistics companies affecting their logistics processes

The findings indicate that logistics companies are grappling with persistent challenges, including labour shortages, traffic congestion, underutilized vehicles and warehouse infrastructure, high energy costs, payment delays, and a lack of trust and collaboration between companies.

Further on, Figure 3.8 illustrates the percentage of logistics companies that have engaged in various forms of collaboration, as well as the percentage of companies that have never partnered with other logistics service providers.

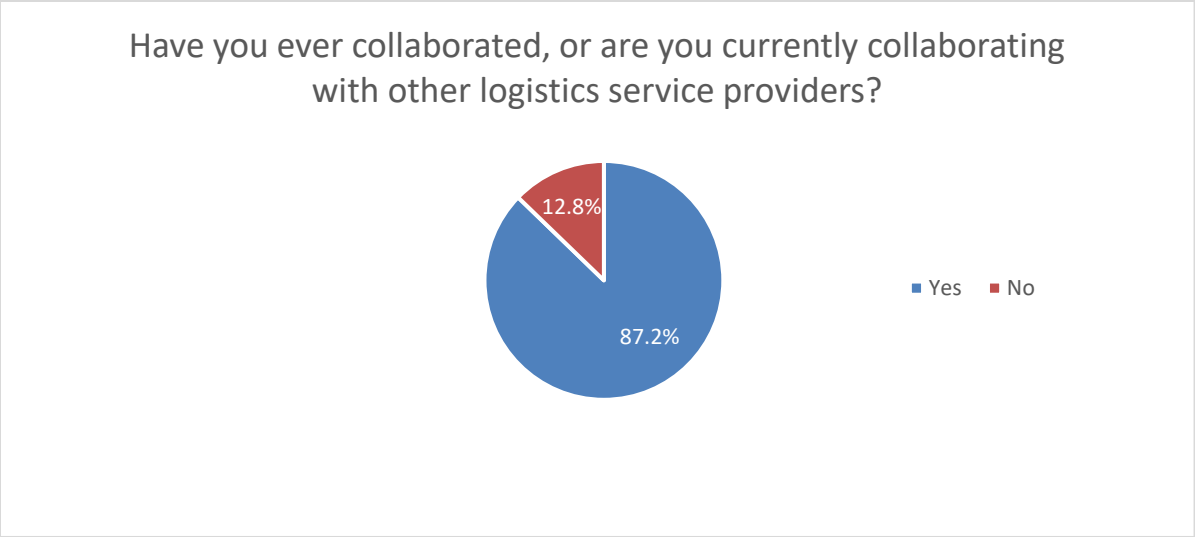

Figure 3.8 Percentage of logistics companies that have already collaborated with other logistics service providers

The survey data reveals that 87.2% of companies have already engaged in collaboration, while 12.8% of companies have not yet participated in any collaborative efforts.

Figure 3.9 presents the willingness of logistics companies to collaborate with other logistics service providers.

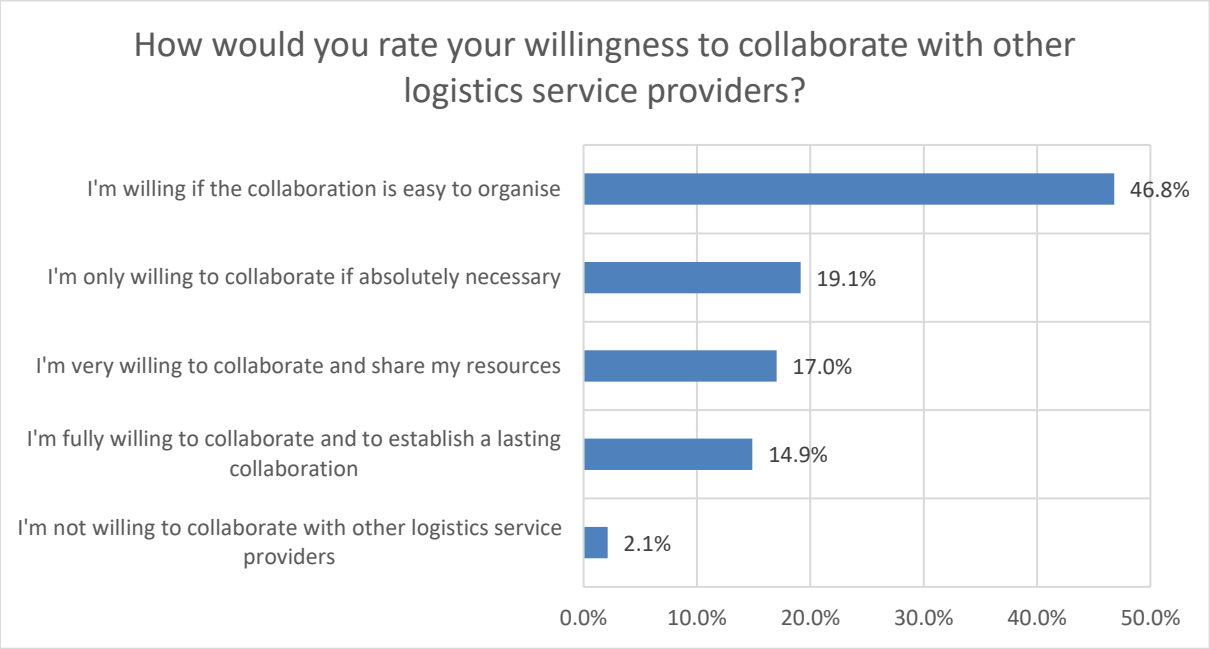

Figure 3.9 Willingness of logistics companies to collaborate with other logistics service providers

The majority of logistics companies (46.8%) are open to collaboration, provided that it is easy to organize. Additionally, 19.1% of companies are willing to collaborate if absolutely necessary, while 17.0% are prepared to share their resources. A further 14.9% are interested in establishing long-term collaborations. Only 2.1% of logistics companies are unwilling to engage in any form of collaboration with other logistics service providers.

All subsequent questions employed a Likert scale, first with companies rating the suitability of various forms of collaboration on a scale from 1 to 5. In this scale, 1 represents "Inappropriate" and 5 denotes "Very appropriate." The responses to this question are illustrated in Figure X.

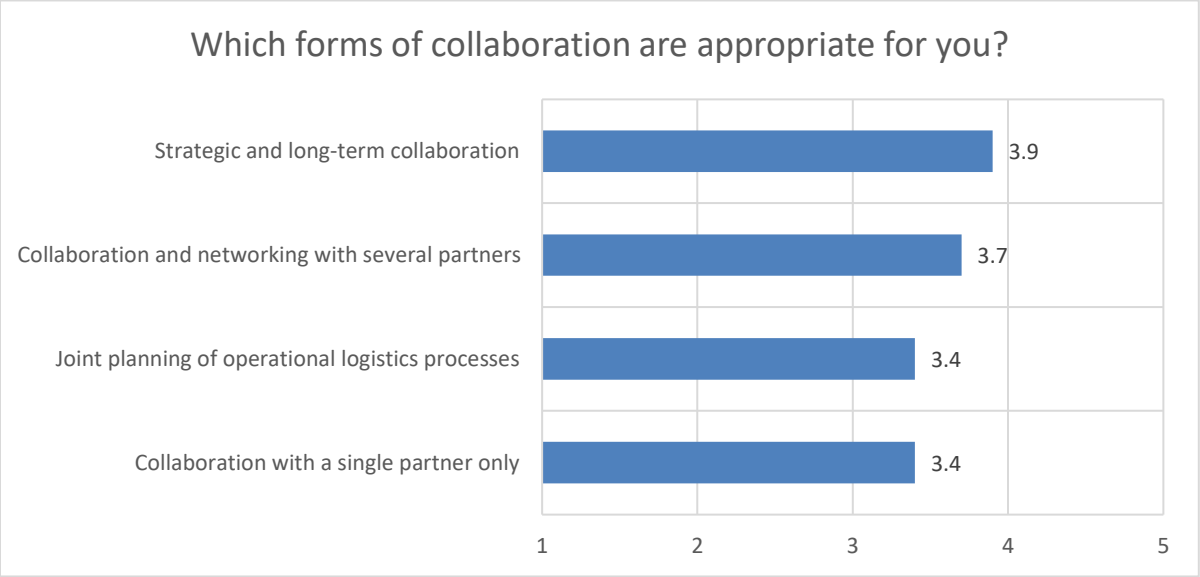

Figure 3.10 Forms of collaboration appropriate for logistics companies

Figure 3.10 shows that, long-term collaboration and networking with a larger number of logistics companies proved to be the most appropriate form of collaboration, indicating that companies want to collaborate, which further confirms the necessity and rationale of finding solutions that will enable long-term successful collaboration and networking with a larger number of logistics companies.

Hereafter, Figure 3.11 presents the responses on the most suitable areas of collaboration for logistics companies.

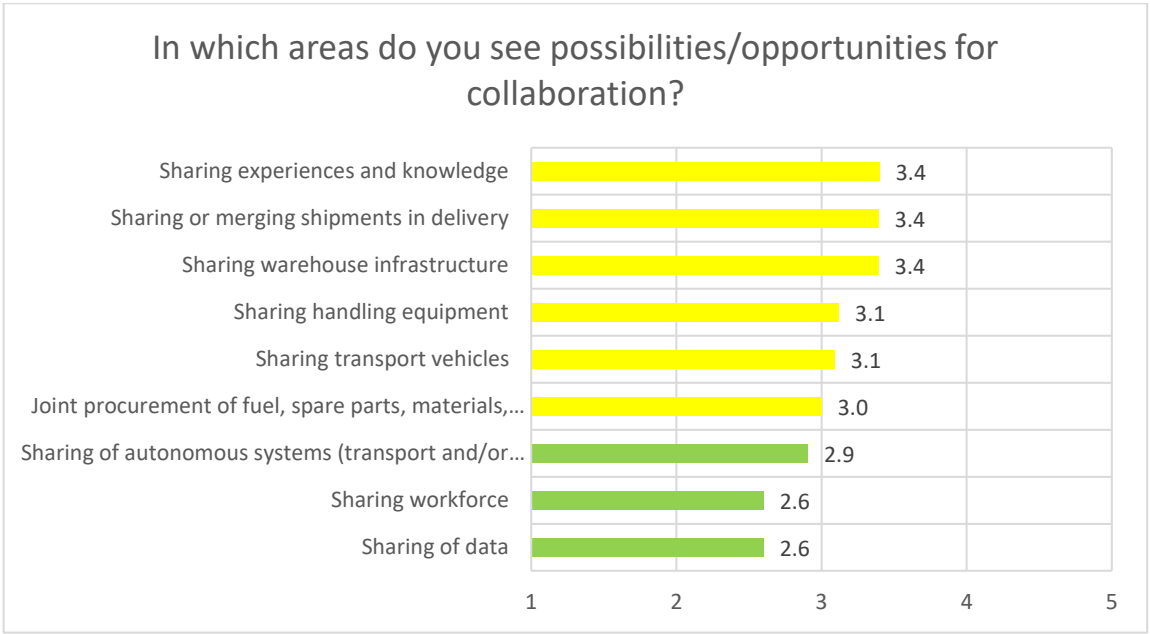

Figure 3.11 Forms of collaboration appropriate for logistics companies

Companies demonstrate a high level of enthusiasm for collaborating on joint delivery of shipments, sharing warehouse infrastructure, transportation vehicles, and handling equipment, sharing experiences and knowledge as well as for collectively purchasing fuel and spare parts.

Figure 3.12 shows which advantages of collaboration would most motivate logistics companies to collaborate with other logistics service providers. A Likert rating of 5 indicates the most important advantage, while 1 represents the least important.

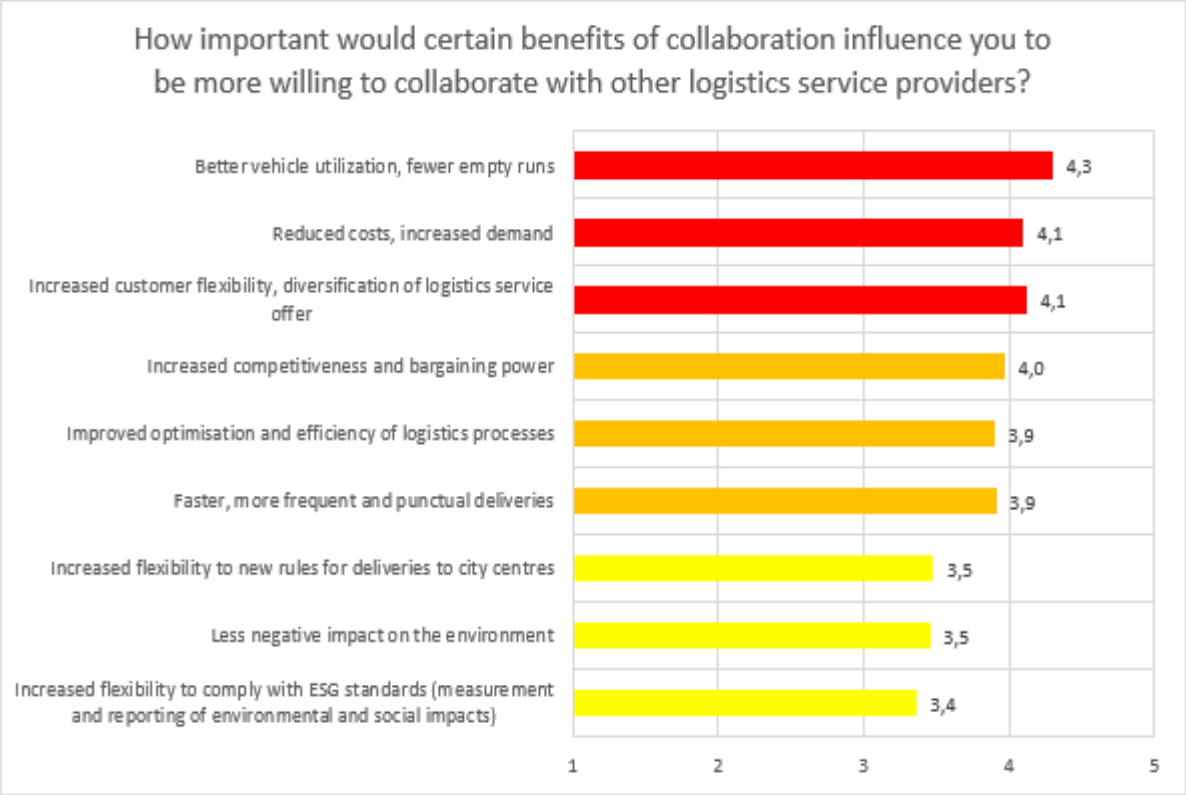

Figure 3.12 Benefits of collaboration that would most motivate logistics companies to collaborate

It is evident that logistics companies consider cost reduction and increased demand—the economic benefits—as the most important advantages. These are followed by better vehicle utilization, fewer empty trips, greater customer flexibility, and a more diverse range of logistics services. The least important benefits are perceived to be increased adaptability to new delivery regulations in urban areas, reduced environmental impact, and greater alignment with ESG standards.

Figure 3.13 displays the companies' responses about the necessary conditions for collaboration, with 5 indicating the most critical conditions and 1 representing the least important.

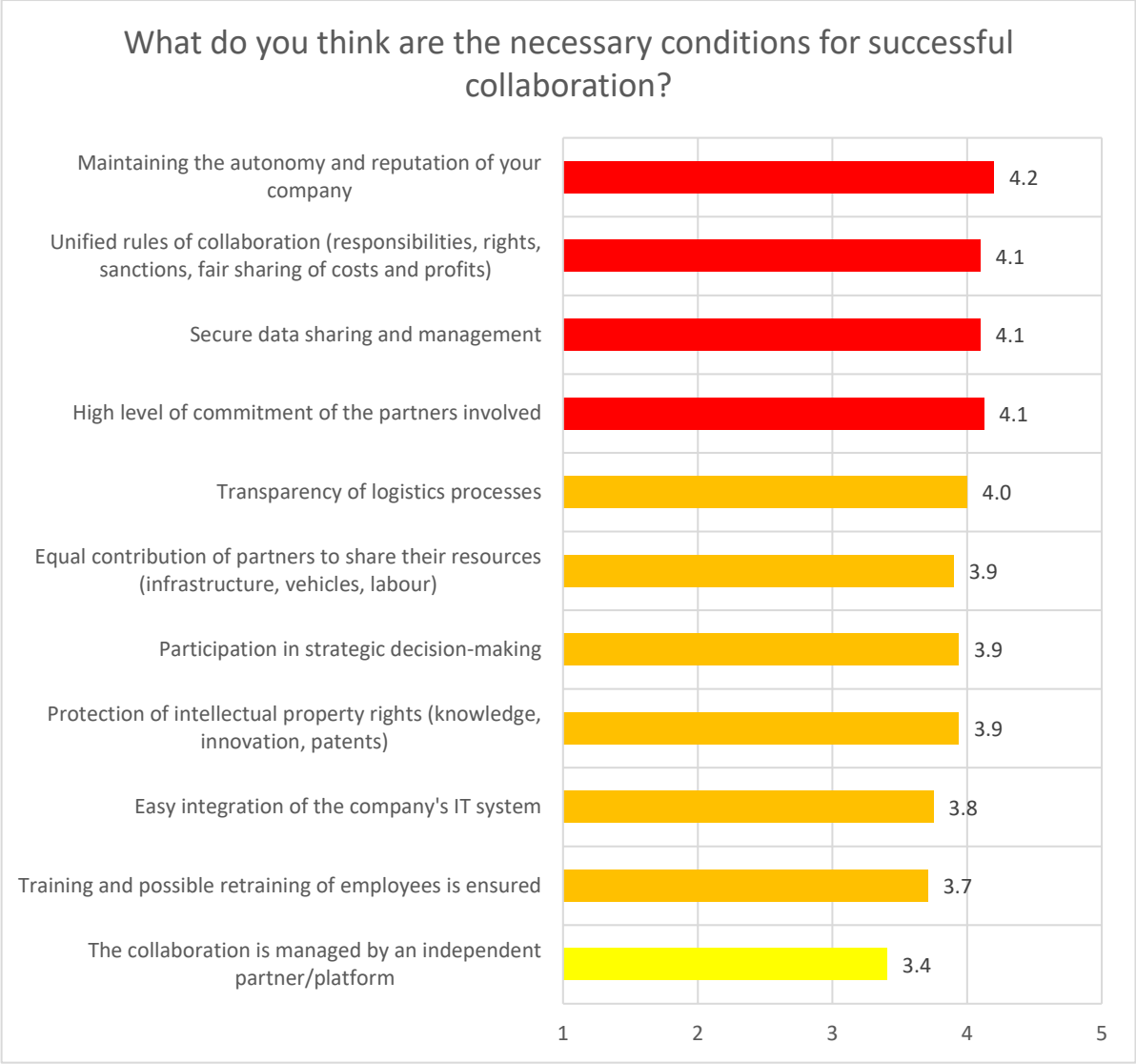

Figure 3.13 Conditions for successful long-term collaboration of logistics companies

The most crucial conditions for successful collaboration among logistics companies include maintaining company autonomy and reputation, standardized collaboration rules, such as fair distribution of responsibilities, rights, sanctions, and appropriate allocation of costs and revenues for joint logistics services. The less important conditions are having the collaboration managed by an independent partner or platform, ensuring employee training for intercompany logistics collaboration, and addressing intellectual property rights issues, such as company knowledge, innovations, and patents.

The analysis of the survey results regarding the readiness of logistics companies for collaboration, based on their past experiences with collaboration, is illustrated in Figure 3.14.

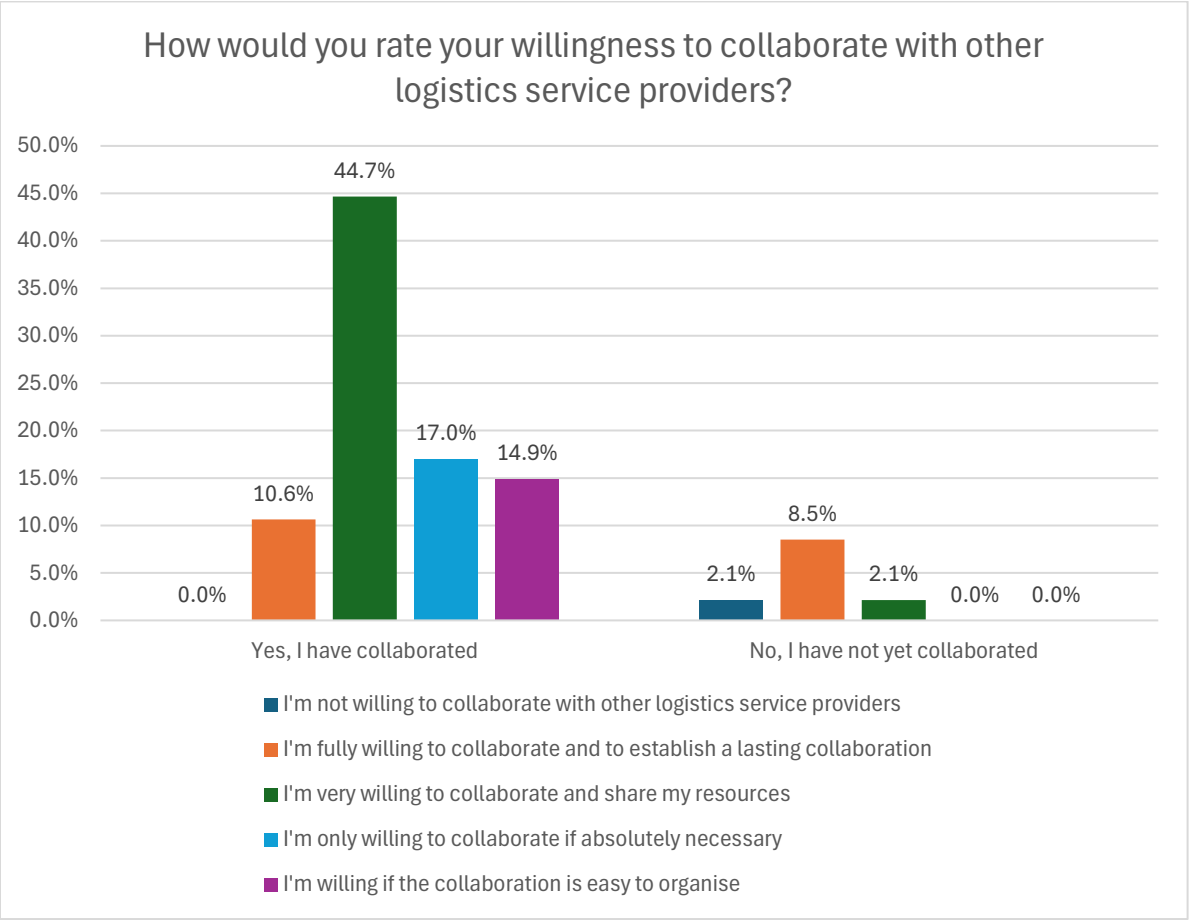

Figure 3.14 Comparison between the willingness of logistics companies for collaboration and their experiences with collaboration

Logistics companies with prior or ongoing collaboration experiences are more inclined to engage in various forms of partnerships with other logistics service providers. These companies exhibit a high level of willingness to share their resources, with 10.6% expressing readiness to establish long-term collaborations.

Companies that have previously engaged in or are currently collaborating with other logistics service providers generally exhibit a greater willingness to participate in various areas of collaboration, as illustrated by Figure 3.15.

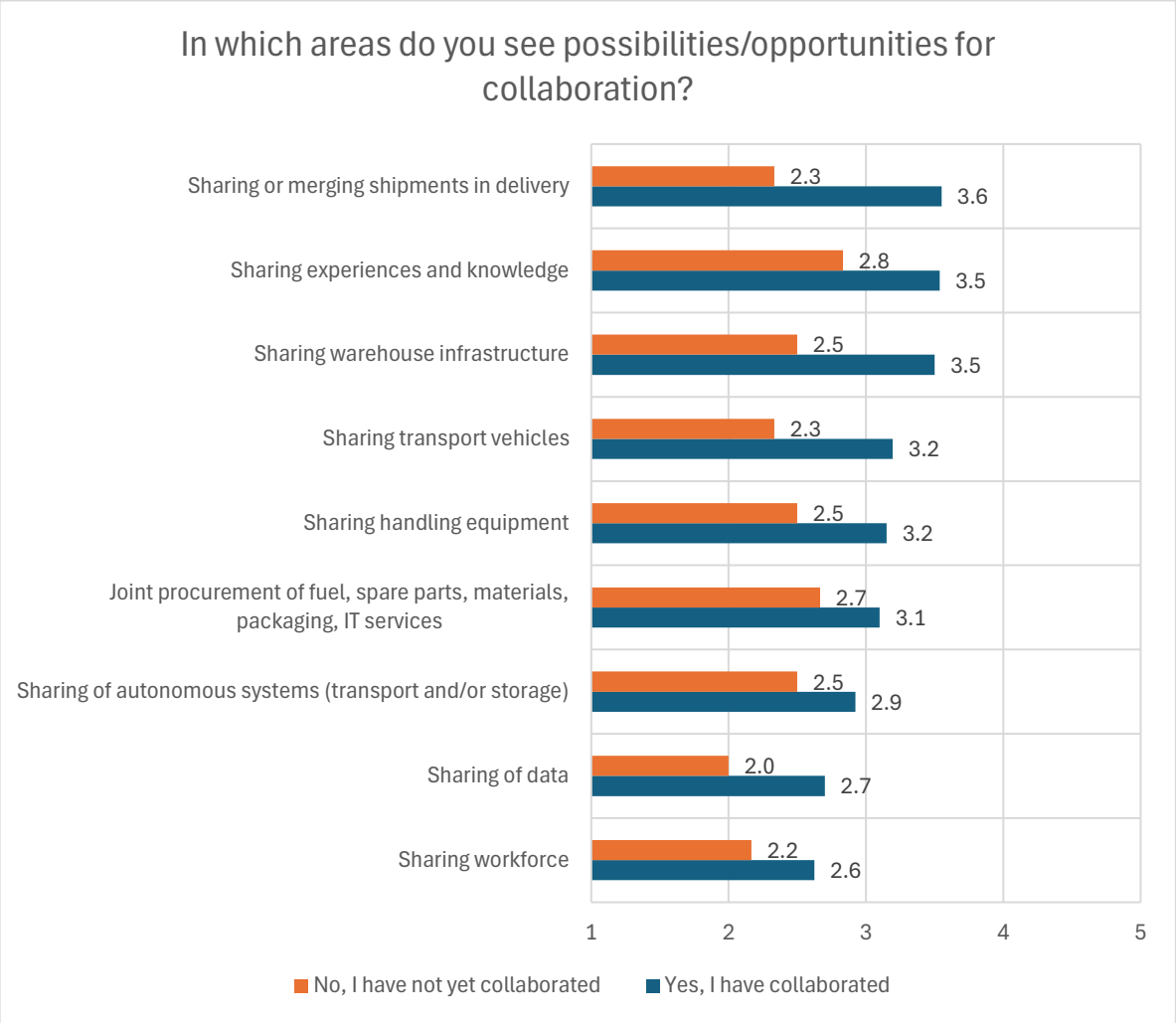

Figure 3.15 Comparison between the areas in which logistics companies see the most opportunities for collaboration and their experiences with collaboration

Figure 3.16 illustrates the awareness of logistics companies regarding the benefits of collaboration.

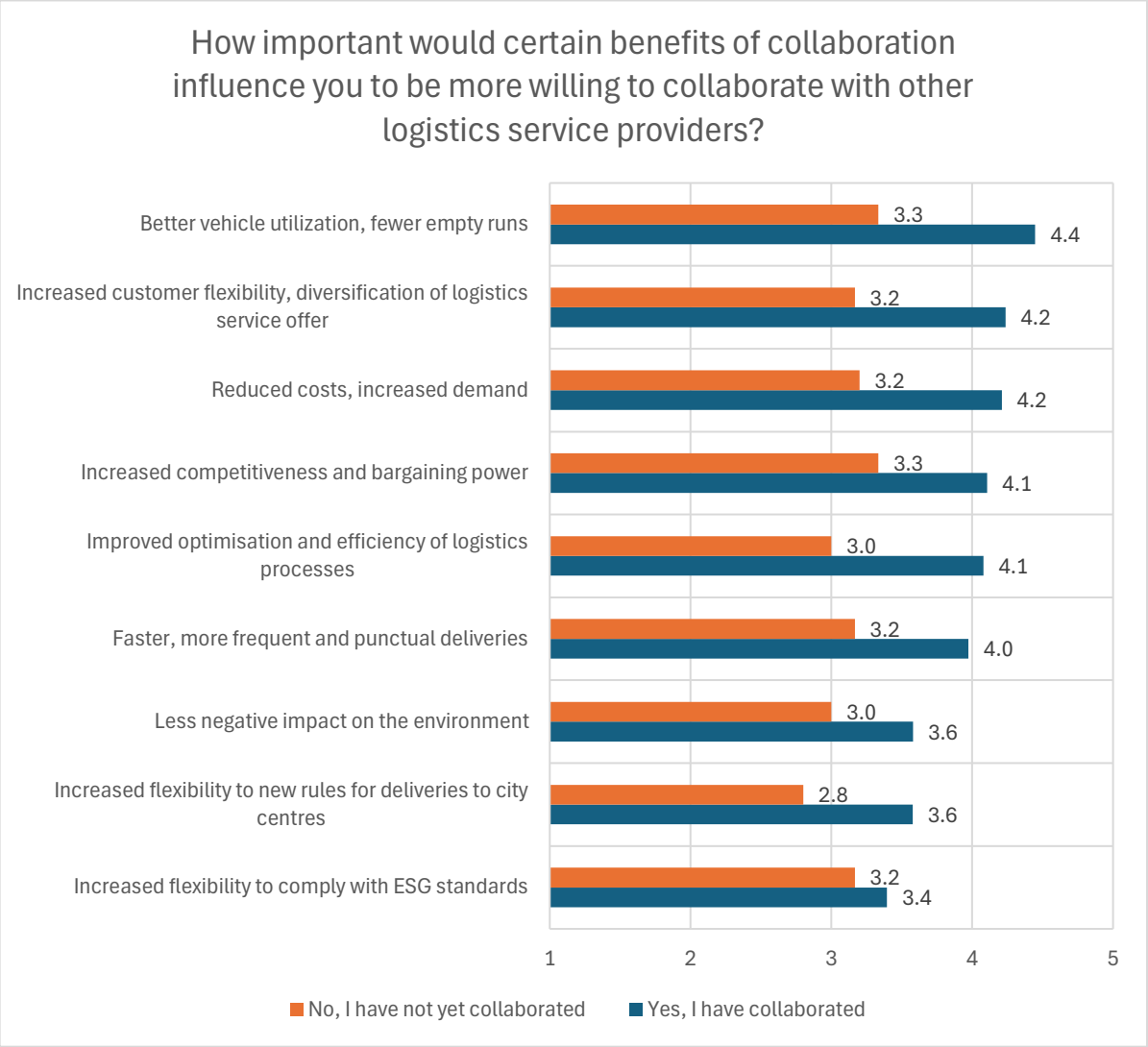

Figure 3.16 Comparison between the benefits of collaboration that would motivate logistics companies to collaborate and their experiences with collaboration

It shows that logistics companies with experience in collaborating with multiple logistics service providers have a much higher awareness of the advantages that such partnerships offer. This increased awareness correlates with a greater readiness to establish long-term collaborations with other logistics companies.

The results of comparison between the size of the logistics companies and their experiences with horizontal collaboration are illustrated in Figure 3.17.

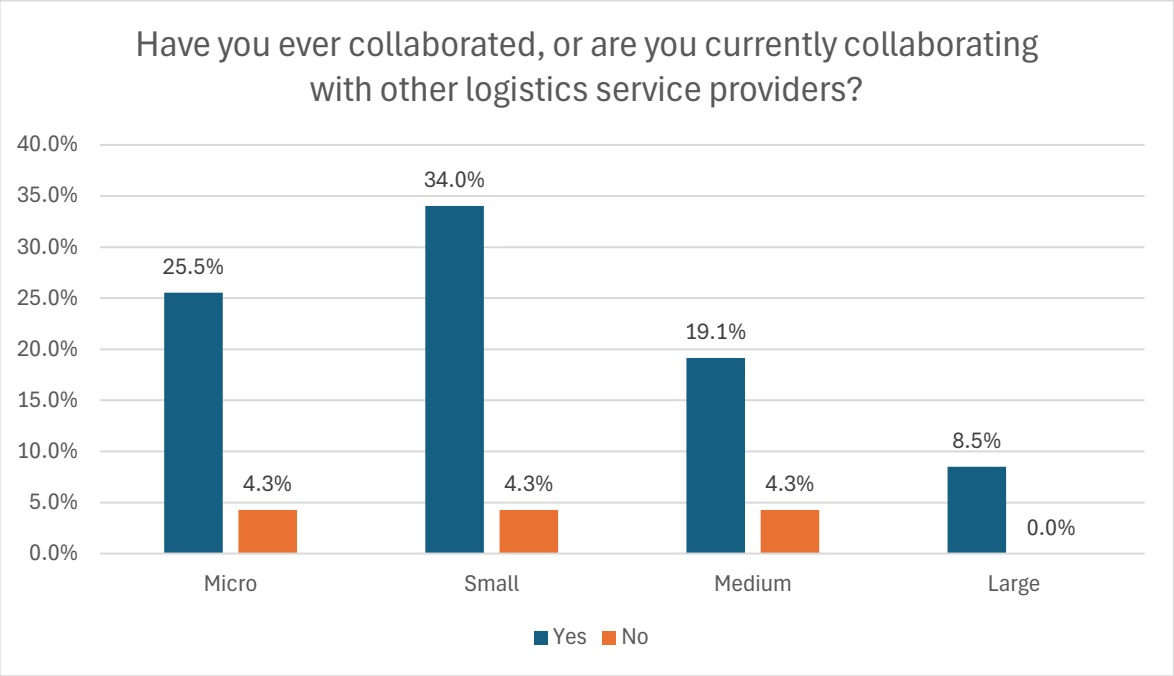

Figure 3.17 Comparison between the size of the logistics companies and their experiences with horizontal collaboration

The analysis of the survey responses by company size revealed that micro and small enterprises have more experience with logistics collaboration. As shown in Figure 3.17, large logistics companies that have ever collaborated with other logistics service providers account for only 8.5% of the total surveyed sample.

Lastly, Figure 3.18 compares various logistics companies based on their size and their readiness to collaborate.

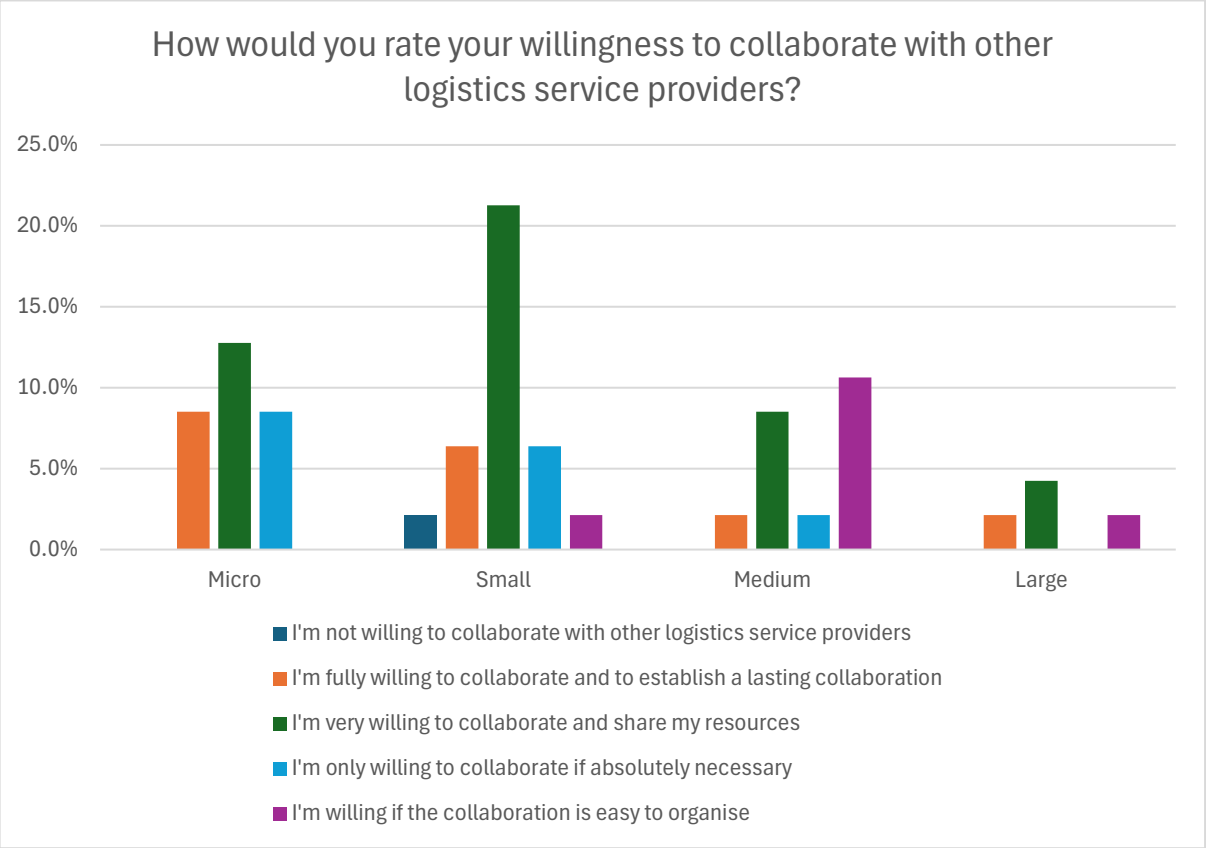

Figure 3.18 Comparison between the size of the logistics companies and their willingness to collaborate with other logistics service providers

It indicates that micro and small companies are generally more willing to engage in collaboration compared to medium-sized and large logistics companies. Notably, micro and small logistics companies are particularly distinguished by their willingness to share resources.

4 REGULATORY IMPACT ON TECHNOLOGY ADOPTION

4.1 Autonomous Systems and Regulatory Compliance

Greater incorporation of autonomous systems into logistics and transport generates exclusive challenges related to regulatory issues. Since continuous development of autonomous transport vehicles, drones, and AI-powered logistics keeps taking place, the updating of regulatory frameworks is continuously at stake to make such systems operate safely, ethically, and in compliance with existing laws. Compliance with regulatory standards would mean enabling the main deployment of autonomous systems by ensuring public safety, data privacy, and environmental sustainability.

The main challenge in regulating autonomous systems is the lack of uniform standards between regions and countries. While EU regulations provide a framework that addresses how to test and deploy autonomous vehicles, there is significant variation in how such standards can be implemented at the national level. As noted previously, such a lack of harmonization in one area leads to operational challenges for logistics companies and manufacturers in meeting the different standards set forth across jurisdictions; therefore, the implementation of autonomous technologies tends to progress slowly.

These challenges are addressed at the international level by international bodies such as the United Nations Economic Commission for Europe and the International Transport Forum, which worked toward establishing global standards for autonomous vehicles and automated driving systems. For example, the UNECE's WP.29 framework provides uniform technical standards on the testing and deployment of autonomous vehicles-a guarantee that protocols addressing issues such as safety, metrics of performance, and insurance will be applied uniformly across borders. Yet, the development of regulatory work often lags behind technological progress, so that regulating gaps emerge in the area of safety certification, liability, insurance for autonomous systems. Regulating gaps lead to uncertainty for manufacturers and operators that run a legal or financial risk by deploying autonomous systems against which complete regulatory frameworks may be developed afterwards.

Data protection and privacy play a vital role in governing the different variants of autonomous systems. Very often, drones or self-driving cars use real-time data collection, such as sensor data, GPS coordinates, or camera feeds, to execute their functions safely and effectively. In the European Union, there are stringent requirements set forth for how businesses collect, store, and share personal data under the General Data Protection Regulation. The fulfillment of GDPR requirements is especially challenging in respect to autonomous systems because the latter generate huge volumes of data and require cross-border data sharing in real time (European Commission 2016). The need for data anonymization, safe protocols of data transfer, and transparency in data management requires corresponding adjustments within organizations so that the protection of privacy of individuals would support operational efficiency of autonomous systems.

Safety compliance stands at the heart of autonomous system design and deployment, especially in logistics operations, where the stakes are usually high. The regulations touching on vehicle safety involve crashworthiness, collision avoidance systems, and fail-safe mechanisms that must be followed to the letter as these autonomous vehicles operate in a mixed traffic environment with human-driven traffic. This therefore creates the need for rigorous testing protocols and certification processes before the

deployment of autonomous systems into real conditions. Besides, regulatory compliance shall have to address issues on liability by laying down clear guidelines on responsibility in case of accidents or malfunctioning of the systems. In other words, regulators must continually revise safety standards with the evolution of technologies and increased adoption of autonomous systems in the logistics industry.

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4.2 Data Protection and Cybersecurity Regulations

The two critical considerations in the use of autonomous systems and smart logistics solutions are data protection and cybersecurity since these technologies rely on capturing, processing, and exchanging large volumes of real-time data. With increased penetration of autonomous vehicles, drones, and AI-driven logistics systems, ensuring data privacy and compliance with cybersecurity will be important to secure sensitive information for public confidence. The other set of critical guidelines with regard to data privacy and security management in the logistics industry is through regulatory frameworks, such as the General Data Protection Regulation within the European Union and different national cybersecurity legislations.

The General Data Protection Regulation, enacted in 2018 by the European Union, represents one of the most far-reaching global data protection regulations. It is considered a foundational block in setting the standards for how autonomous systems are developed to collect and store personal data and process such data in the logistics industry. Under GDPR, the placement and use of autonomous vehicles or smart city infrastructure by a logistics company will ensure personal data privacy and security through laws such as location data and sensor information. The exact consent for the collection of the data is to be given by the persons while, in the time being, the companies have to apply strong data encryption and provide ways to grant access and delete their information on request by the persons. This regulatory framework is intended to ensure a high degree of transparency with regard to data usage, giving users greater control over their personal information, while ensuring that the logistics companies maintain high standards regarding the protection of sensitive information on data privacy. For instance, the cybersecurity regulations themselves have been in development with the aim of tackling peculiar risks associated with autonomous technologies. The EU Cybersecurity Act established a relevant framework that aimed at raising cybersecurity across the Union by setting an unparalleled bar for securing its critical infrastructure, such as autonomous transport systems and smart logistically-interoperable networks. The Act requires the use of security patches and incident reporting mechanisms by a firm to adopt risk management and make the systems resilient against cyber-attacks. In relation to this, the NIST Cybersecurity Framework of the US is a non-binding framework through which the enhancement of cybersecurity best practices is done, and which now has increasingly been applied by the logistics firms worldwide to secure their operations.

Included in the demands of autonomous vehicles and smart logistics systems is the increasing risk of data breach and system vulnerabilities, whereby cyber-criminals look for connected infrastructure to perpetrate their nefarious activities. Logistic companies will have to introduce strong cybersecurity measures that will prevent unauthorized entry into their systems, encrypt data in motion, and ensure the

protection of autonomous systems from compromising or hacking in any manner during operation. For example, the very risk of a cyberattack in an autonomous vehicle may result in disastrous consequences: an accident, car theft, or sensitive data exposure. In this respect, cybersecurity regulations become not only a must to comply with but also a matter of safety and reliability features for autonomous logistics solutions.

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4.3 Environmental and Sustainability Regulations

The influence of environmental and sustainability regulations is increasingly significant, with particular emphasis on demands that the logistics sector should minimize its carbon emissions to align with the objectives of worldwide climate change initiatives. This transition to sustainable transport modalities and green logistics is being driven from the international level, such as the Paris Climate Accord, down to the regional level, with initiatives such as the European Green Deal hoping to attain carbon neutrality no later than 2050. What this means is that current measures for reducing emissions are strict, the use of clean energy vehicles is being promoted, and logistics operations are foreseen to embed sustainability into their processes and systems as part of mitigating the environmental impact.

The European Green Deal is one of the cornerstone regulatory frameworks within the European Union that accelerates the transition to a low-carbon economy, providing binding targets aimed at the reduction of emissions of greenhouse gases-the transport sector being responsible for approximately a quarter of global emissions. Regulations such as the EU ETS and the Clean Vehicles Directive will force logistics companies to switch toward EVs, alternative fuels, and other zero-emission technologies. Furthermore, the growth in numbers of low-emission zones within cities further compels logistics operators to switch toward greener fleets, since only vehicles with the set strict emission standards are allowed to enter such areas.

On a national level, this is furthered by several incentives encouraging the practice of green logistics; for example, the subsidy for electric trucks, infrastructural creations in support of the trucks through the charging points as already initiated in Germany, and the tax benefits that come from the integration of renewable energy sources into company operations in France. These incentives are in the form of financial aids that lower the economic barriers of transition towards green technologies, thereby helping firms to be at par with long-term sustainability performance.

Amongst others, the EU's Circular Economy Action Plan reduces waste by reusing and recycling supplies along the value chain. Besides vehicle emissions, sustainability regulations address more general aspects of logistics operations, such as energy efficiency, waste minimization, and use of recyclable packaging. This has encouraged logistics companies to adopt 'green' packaging and environmentally friendly warehouse management that has seriously reduced the general environmental footprint of their activities. According to European Commission, 2020, this may have led many logistics companies to use eco-friendly packaging and sustainable warehouse practices, thus seriously reducing the general environmental impact of their

operations. Since the current regulatory environment is in continuous flux, not only does adherence to these environmental regulations ensure legality, but also it provides an opportunity for companies to reposition themselves as leaders regarding sustainability.

4.4 Challenges in Cross-border Technology Integration

The challenges are, however, at their most significant in cross-border integrations of autonomous systems, AI technologies, and data-driven logistic solutions due to regulatory fragmentation among countries. Logistics companies adopting new technologies in their strides for greater efficiency and lowered costs struggle to deploy these innovations across different regulatory environments uniformly. The lack of harmonized legislation across countries inhibits the deployment of technologies such as self-driving cars, AI-powered platforms, and IoT devices within global supply chains, especially within the European Union and international trade partners.

The important challenges include the difference in standards for safety and testing levels for both autonomous vehicles and drones. Although some countries like Germany and the Netherlands have developed highly advanced regulatory frameworks related to the testing of autonomous vehicles, there are many that remain at the nascent stage in policy-making. It creates, therefore, operational inconsistencies across borders since companies need to consider a compilation of national regulations that are at variance on key aspects, such as safety protocols, liability, and data protection. This brings about regulatory fragmentation that eventually causes increased compliance costs and deployment delays of innovative logistics technologies, according to UNECE (2020).

Data privacy and cybersecurity add greater complications to the integration of technology across borders-particularly real-time data flows across regions. The European Union's General Data Protection Regulation has set an exceptionally high threshold as far as protection of data is concerned, while independent countries outside the bloc, like the United States and China, operate on different regulatory regimes with regard to data protection that do not correspond to those under the GDPR. All this further adds to a set of challenges faced by companies in achieving a balance between constant data privacy and cybersecurity, along with meeting the operational requirements of real-time data sharing in autonomous logistics.

Another key challenge includes technical interoperability issues in terms of infrastructure across borders. Besides regulatory hurdles, smart infrastructure-supporting vehicle-to-infrastructure communication systems and smart traffic management technologies-will be crucial to the smooth performance of autonomous vehicles. But the lack of shared standards for these technologies in many countries complicates integration; it means companies will need to adapt systems to local technical standards. Therefore, this raises operational complexity whereby such new technologies limit scalability, since firms have to invest in additional resources that will ensure compatibility with the local infrastructural setup.

The challenges of technology integration across borders point to a great need for better international cooperation, along with the harmonization of regulatory systems. Overcoming regulatory fragmentation, aligning data protection standards, and ensuring the technical interoperability of smart infrastructure are an integral part of allowing autonomous systems into the global supply chains, in addition to other emerging technologies in a seamless manner. It will eventually support a more efficient, secure, and sustainable logistics ecosystem.

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5 STAKEHOLDER ENGAGEMENT AND FEEDBACK

5.1 Workshops and Stakeholder Meetings

Workshops and stakeholder meetings play an essential role in shaping the development of regulatory frameworks and understanding the impacts of emerging technologies in the logistics sector. These forums provide a platform for diverse stakeholders—including logistics providers, technology developers, regulatory bodies, academics, and end-users—to engage in constructive dialogue, share insights, and collaborate on solutions that align technological advancements with regulatory compliance and societal goals. By fostering collaboration among different sectors, these events help identify the challenges, opportunities, and gaps in current regulatory frameworks, contributing to the continuous adaptation of policies in the logistics and transport industries.

Outcome of these workshops and meetings is the collection of real-world feedback from stakeholders, which is invaluable for understanding the practical implications of regulatory proposals. For example, in the context of autonomous vehicles, workshops organized by the European Commission have brought together transport regulators, vehicle manufacturers, and safety experts to discuss the safety standards, liability concerns, and testing procedures required to ensure safe deployment of autonomous systems on public roads. Feedback gathered from these sessions has led to more detailed and practical recommendations for the regulatory framework, addressing the specific needs and concerns of industry participants while ensuring that public safety remains a top priority.

Workshops focused on data protection and cybersecurity have been instrumental in aligning stakeholders' views on the GDPR and EU Cybersecurity Act, in addition to safety standards. These discussions highlighted needs for clear guidelines on the management of personal data, particularly in logistics systems that rely on real-time data collection from autonomous vehicles and IoT devices. For instance, workshops held by the EU Agency for Cybersecurity (ENISA) with logistics providers and tech companies have helped clarify how businesses can balance data security with the need for data sharing in cross-border logistics operations, while adhering to both data protection laws and cybersecurity regulations.

Stakeholder meetings focused on sustainability have been crucial in defining the role of green logistics in meeting EU climate goals. These discussions have brought together environmental organizations, logistics operators, and regulatory authorities to discuss the effectiveness of current carbon reduction policies and to propose solutions for promoting the adoption of electric vehicles and alternative fuels in the logistics sector. Feedback from these stakeholders has contributed to the creation of policy incentives, such as tax breaks for electric trucks and subsidies for sustainable logistics technologies, aimed at reducing the carbon footprint of the industry. Additionally, these sessions have underscored the need for cross-border regulatory alignment in sustainability standards to ensure that logistics companies can adopt green technologies seamlessly across EU member states.

5.2 Survey Results on Regulatory Compliance

Surveys conducted with key stakeholders, including logistics companies, technology providers, regulatory bodies, and industry experts, offer valuable insights into the current state of regulatory compliance in the

logistics sector, particularly in relation to autonomous systems and sustainable practices. These surveys have highlighted the challenges and opportunities stakeholders face when navigating existing regulations and adapting to emerging standards in areas such as data protection, safety, and environmental sustainability.

Lack of clarity and consistency in national and regional regulations concerning autonomous vehicles and AI-powered logistics systems, is of the key findings from the surveys. A significant proportion of respondents indicated that the regulatory landscape is often fragmented, with different countries and even regions within countries implementing differing standards for the testing and deployment of autonomous systems. For example, while Germany has a clear regulatory framework for testing autonomous trucks, other countries, such as Italy and Greece, are still in the early stages of defining their regulations for autonomous transport, leading to uncertainty and operational challenges for companies engaged in cross-border logistics. This regulatory fragmentation creates barriers for companies seeking to deploy autonomous solutions at scale, highlighting the need for greater harmonization across the EU and internationally.

Surveys indicate the growing concern among stakeholders about data privacy and cybersecurity in the context of autonomous systems. GDPR compliance was a common theme, with many respondents indicating that the regulation's requirements for data storage, consent, and cross-border data sharing are complex and resource-intensive to implement. In particular, logistics companies expressed concerns about managing the vast amount of real-time data generated by autonomous vehicles, drones, and IoT devices, while ensuring that they comply with GDPR and other national data protection laws (European Commission, 2016). Furthermore, stakeholders raised significant concerns about the cybersecurity risks associated with these systems, particularly the potential for hacking or data breaches that could compromise the safety and integrity of logistics operations. This underscores the importance of developing robust cybersecurity standards that can safeguard both data privacy and system security.

Concerns about data privacy and cybersecurity are highlighted the role of incentives in encouraging compliance with environmental regulations. Many logistics companies indicated that sustainability incentives, such as tax breaks for electric vehicles and subsidies for green technologies, play a significant role in motivating them to invest in low-emission transport and green logistics solutions. However, respondents also noted that the high upfront cost of transitioning to sustainable logistics technologies, such as electric trucks and autonomous delivery systems, remains a barrier to adoption. This finding suggests that while regulatory incentives are effective in promoting the adoption of sustainable practices, additional measures are needed to address financial barriers to widespread adoption.

Overall, the survey results underscore the importance of clear, harmonized regulations that provide a strong foundation for the adoption of autonomous technologies and sustainable logistics practices. The findings also point to the need for stronger compliance support mechanisms, including financial incentives, data management tools, and cybersecurity guidelines, to help stakeholders navigate the evolving regulatory landscape and fully capitalize on the opportunities presented by emerging technologies.

5.3 Incorporating Feedback into Framework Development

Feedback from a broad range of stakeholders is essential to developing effective regulatory frameworks that address the complexities of autonomous systems, data protection, and sustainability within the logistics sector. Feedback from logistics providers, technology developers, regulatory authorities, and end-users through surveys, workshops, and stakeholder meetings provides critical insights into the real-world implications of proposed regulations. Stakeholders emphasized the need for harmonization of autonomous vehicle regulations across regions, particularly within the EU, where regulatory fragmentation remains a challenge. For instance, feedback revealed that the varying safety standards and testing protocols across member states create uncertainty for companies looking to deploy autonomous logistics solutions across borders. In response, regulatory frameworks were adjusted to emphasize cross-border alignment, streamlining testing procedures and establishing more consistent safety protocols that could be applied uniformly across the EU, thus reducing compliance costs and enhancing regulatory clarity for businesses.

Concerns about autonomous vehicle regulations, feedback on data privacy and cybersecurity led to refinements in the GDPR compliance process. Many logistics providers expressed challenges in meeting the GDPR's requirements for real-time data processing and managing cross-border data sharing, particularly related to location data from autonomous vehicles and IoT devices. As a result, clearer guidelines were introduced for data anonymization, consent management, and data flow across borders, enabling companies to maintain compliance while optimizing operations. Additionally, cybersecurity concerns raised by stakeholders led to the development of more robust standards for data encryption and incident response, ensuring that the growing integration of autonomous systems in logistics would not compromise the security of data or operations.

Stakeholder feedback also influenced the development of sustainability regulations within the logistics sector. While companies expressed a strong commitment to adopting green technologies, they also pointed out the upfront costs associated with transitioning to electric vehicles and alternative fuels. In response, the regulatory framework was updated to include financial incentives, such as tax breaks and subsidies, for green logistics technologies like electric trucks and autonomous delivery vehicles. Environmental stakeholders emphasized the importance of integrating sustainability into supply chain management and procurement practices, which led to the introduction of regulations encouraging the use of eco-friendly packaging, sustainable materials, and carbon-neutral transport solutions. These changes are helping drive a shift toward more eco-friendly logistics practices while also addressing the economic challenges of adopting new, sustainable technologies

5.4 Stakeholder Collaboration for Behavioural Change

Stakeholder collaboration is a crucial element in driving behavioural change within the logistics and transport sectors, especially as the industry faces the challenges of integrating autonomous systems, sustainable practices, and data-driven technologies. By fostering collaboration between logistics operators, technology developers, regulatory bodies, academics, and end-users, stakeholders can align on shared objectives such as safety, efficiency, sustainability, and data protection. This collaborative environment helps to ensure that regulatory frameworks evolve in response to real-world challenges,

while also promoting behavioural change across the sector in adopting new technologies and business practices that benefit both the industry and society.

Continuous exchange of knowledge and best practices is key aspect of this collaboration is the. For example, workshops and stakeholder meetings have allowed logistics companies and autonomous vehicle developers to address the practical challenges of integrating autonomous vehicles, including regulatory compliance, operational efficiency, and safety concerns. These forums have highlighted the need for harmonized safety standards and clearer data privacy regulations for cross-border deployment of autonomous systems. Feedback from stakeholders in these sessions has informed regulatory updates and encouraged the adoption of more consistent regulations across the EU, helping to eliminate barriers for companies seeking to deploy autonomous technologies across borders (European Commission, 2020).

Stakeholder collaboration has been key in promoting sustainability initiatives within the logistics sector. Collaborative efforts between governments, environmental organizations, and logistics providers have led to the creation of policies and financial incentives aimed at encouraging the adoption of electric vehicles (EVs) and autonomous delivery solutions. These initiatives have contributed to the establishment of regulatory frameworks that reduce the carbon footprint of logistics operations while providing economic incentives for businesses to invest in green technologies. Feedback from logistics companies has also been instrumental in shaping these policies, particularly in offering tax breaks and subsidies for businesses transitioning to sustainable transport solutions, making it easier for companies to adopt these technologies despite the high upfront costs (European Commission, 2020).

Collaboration played an important role in addressing concerns related to data privacy and cybersecurity. As autonomous systems in logistics increasingly rely on real-time data collection from vehicles and IoT devices, stakeholders highlighted the need for clear and consistent data protection regulations that safeguard user privacy while enabling operational efficiency. Discussions involving data protection experts, cybersecurity professionals, and logistics providers have helped to balance data security with the need for cross-border data sharing in logistics operations. This collaboration has led to regulatory updates that include stronger cybersecurity standards and clearer guidelines on data sharing, ensuring that autonomous logistics systems can operate securely, in compliance with GDPR, and without compromising data privacy (European Union Agency for Cybersecurity, 2021).

6 POLICY RECOMMENDATIONS AND FUTURE DIRECTIONS

6.1 Harmonizing Cross-border Regulations

In this perspective, harmonization of cross-border rules plays an important role in making autonomous systems, sustainable transport technologies, and smart logistics solutions function smoothly and effectively in a global context. Growing digitization and automation of logistics and transport systems, in turn, have gradually increased the demand for consistent regulatory frameworks in different regions. The inconsistent rules across nations, especially on issues like autonomous vehicle testing, data privacy, and environmental standards, stand out as major barriers to the smooth running of logistics networks and, therefore, have greater implications for multinational companies operating across borders. Thus, harmonic regulatory requirements are a pre-condition not only to foster technological innovation but also to ensure regulatory compliance and efficiency in cross-border logistics operations.

The most important problem the variation of national standards for technologies such as autonomous vehicles raises is how to harmonize cross-border regulations. What this means is that the inconsistency has thrown up a patchwork regulatory environment where companies are compelled to play by different standards in every country, making deployment of autonomous systems harder and operationally expensive. Efforts have been directed towards creating international standards for the testing and certification of autonomous vehicles, such as the UNECE WP.29. The process of regulatory alignment, however, has been slow against the backdrop of that progress, and further collaboration will be required to come up with a global normative framework that allows the use of autonomous logistics systems across borders.

Cross-border data protection regulations create complexities for global logistics operations: the differences between the General Data Protection Regulation in the European Union and the laws governing data collection from other countries create hurdles for cross-border data flows and hurt, in the process, logistics companies that rely on real-time data from autonomous vehicles and IoT devices for cross-border data. This, in turn, means that international cooperation on data protection is highly relevant to finding a balance that allows countries to share data across borders, at the same time protecting individual privacy. Global harmonization of such regulations is going to be very important to making sure companies can operate with a minimum level of legal uncertainty and without conflicting requirements at different levels.

It is also required that the environmental regulation of logistics and transports be harmonized, in order to be able to work their way upward with consistency in attaining goals of sustainability. While the EU has ambitious carbon reduction targets under the European Green Deal, other regions have more varied levels of commitments to sustainable logistics. Whereas for Norway and the Netherlands, there were significant incentives for the adoption of electric vehicles and alternative fuels, for countries like India and Brazil, significant economic and infrastructural barriers remain in place for the execution of green logistics policies. Clearly, standardization at a global level is an essential step toward harmonizing environmental standards and promotion of international agreements on the reduction of emissions for the uniformity of sustainable logistics approaches. By aligning laws on sustainable transportation technologies and carbon

emissions, governments make sure companies with operations across regions have a level playing field, fast-tracking the move into a low-carbon global economy.

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6.2 Recommendations for Future Safety Standards

While the application of autonomous systems to logistics and transport continues to expand, robust and adaptable safety standards will be highly important. Future safety standards will need to change with the times of complexities regarding autonomous vehicles, drones, AI-powered logistics systems, and ever-connected transport infrastructure. Moreover, unified, flexible, and globally harmonized regulations concerning safety will be indispensable in allowing the public and the seamless integration of autonomous technologies.

There should be internationally consistent safety standards set for autonomous vehicles and AI logistics. While regions like the EU and the United States have made efforts toward the creation of a national framework for testing autonomous vehicles, there still remains a lack of global uniformity in safety protocols, especially for cross-border operations. International standards on such aspects as testing procedures, vehicle safety certification, and driverless vehicle safety procedures by organizations like UNECE WP.29 will guarantee that autonomous vehicles from any other country conform to the same set of safety standards. Harmonization will further reduce regulatory complexity and operational risks for companies and increase public trust in autonomous technologies, with vehicles held to higher standards of safety across regions.

Dynamic safety standards that can keep pace with the rapid technological change need to be constituted. While AI-driven logistics platforms and autonomous vehicles are developing at an unprecedented rate, safety standards are required to be flexible to make sure technology upgrades are undertaken continuously. For example, safety principles need to account for new and emerging technologies such as machine learning and vehicle-to-vehicle/infrastructure real-time information sharing that are being increasingly integrated into the development of the autonomous transport systems. Safety standards should be underpinned by regulators adopting a performance-based approach, where the intent of the standards is the ability of the system to achieve safety outcomes rather than prescribing specific technologies or methodology to achieve those outcomes. This would give the opportunity for the standards of safety to move along with the times, make it possible to include new innovations and yet maintain the same level of safety.

In the context of autonomous systems, cybersecurity is fast becoming an integrated feature of safety. Both autonomous vehicles and AI-powered logistic systems rely on real-time data exchange and IoT connectivity. Ensuring integrity and security of highest order becomes prime importance. Future safety

regulation would also involve requirements related to cybersecurity in order to avoid vulnerabilities such as hacking and data breach. Policies and regulations should be clearly laid down regarding data protection, secure communication, and response protocols in case of cyber threats so that such systems are safe against external attacks challenging safety. Considering the serious consequences of vehicle control and operational integrity in case of an attack on the cyber systems of an autonomous system, cybersecurity should be treated as an intrinsic part of any future safety framework.

Most important is that safety standards development is collaborative through constant dialogue among regulators, industry players, academics, and safety experts. Such workshops, stakeholder meetings, and pilot projects provide a very good avenue for best practices sharing and lessons learned, not to mention real safety data which may form the basis for the refinement and improvement of safety standards. By allowing the development process to be continuous and collaborative, development can respond more effectively to evolving sector needs. This will ensure that at the time of deploying more advanced technologies in logistics, the issue of safety would not be compromised.

6.3 Supporting Innovation through Flexible Policies

There is a call for flexible policy measures that will ensure innovation in the logistics and transport industries, driven by autonomous systems, AI technologies, and sustainable transport solutions. Traditional and rigid frameworks of regulation cannot often keep pace with a fast-evolving landscape of technologies and can potentially hamper innovation and delay the large-scale deployment of state-of-the-art solutions. This means that, to create an enabling, dynamic, and forward-looking atmosphere, policy should adopt flexible and adaptive regulations that allow for experimentation, collaboration, and make room for technological advancement in safety, sustainability, and alignment with greater societal objectives.

Regulatory sandboxes promote innovation through flexible policy measures: controlled environments that enable the testing of new technologies in real-world conditions, with basic safety and regulatory standards still met. The regulatory sandboxes provide a testbed for innovation, enabling the practical application of businesses to come into effect with autonomous vehicles, drones, and AI-driven logistics systems without possible cases of non-compliance with current regulations. The regulatory sandbox for autonomous vehicle testing in the UK, for example, has given companies the ability to try out driverless technologies on public roads while, at the same time, the government can observe safety outcomes and make adjustments to regulatory frameworks based on results. These types of initiatives foster innovation by creating a safe space to experiment, which lets developers refine their technologies while building trust into regulatory frameworks.

Performance-based regulation is one of the crucial elements for encouraging innovation. Instead of dictating specific technologies or processes, performance-based regulations give companies the choice of how to achieve key policy goals such as safety, efficiency, and sustainability. For example, policymakers might set targets for the reduction of emissions from self-driving fleets in sustainable logistics but leave it to companies to decide how to meet those targets by switching to either electric vehicles, hydrogen-powered trucks, or alternative fuels. This flexibility will enable the enterprise to innovate and select technologies that will serve them best in terms of operations, thereby driving competition and uptake of

green technologies within the logistics sector. Apply performance-based regulation that will allow the regime to enable innovation without making it over-restrictive due to over-specification but rather guide through general goals inviting continuous technological advancement.

Cooperative policy-making will be important to support innovation. Indeed, consultation with a broad array of stakeholders-industry participants, regulators, technology developers, and academics-allows policy officials to better understand the practical problems and opportunities created by emerging technologies. Work through workshops, public consultations, and stakeholder meetings can enlighten the drafting of more responsive policies able to be flexible and well-matched to industry needs. The regulatory framework for autonomous vehicles, for instance, within the EU has been heedful of their being safe, data privacy, and operation requirements since it underwent a long consultation process with all its stakeholders and yet there is still ample room for innovation. In that respect, flexible policy evolving with technological development-continuous dialogue between regulators and industry players-ensures that innovation is not dampened by indifferent regulations.

6.4 Trends in Regulatory Frameworks for Emerging Technologies

Autonomous systems, AI, IoT, and sustainable transport solutions are a few examples of emergent technologies that constantly reshape these industries. Thus, the regulatory frameworks continue to change with time to catch up with the innovations. Indeed, from how governments and their agencies approach the regulation, one can identify a number of key trends, driven by needs for safety, efficiency, environmental sustainability, and protection of data. This would be critical toward the understanding of various ongoing trends that would help predict how future regulations would be promoting or challenging the wide-scale adoption of autonomous logistics systems and smart transport solutions.

One irresistible trend in development is that of performance-based regulations. Instead of 'command and control' approaches, where specific technologies or ways of operating are prescribed, performance-based regulation focuses on desired outcomes-safety, efficiency, and sustainability, for example-while leaving businesses free to choose how these are attained. This is where autonomy and AI-driven logistics systems will very much come into their own in a world where regulation will need to keep pace. Take, for example, the EU Mobility Package: it encourages emissions reductions from transport but leaves it to industry how to achieve it-through electric vehicles or another such technology, like hydrogen-powered systems. This flexibility allows for innovation: companies can test new technologies to achieve the regulatory goals while fostering competition in the sector.

Another trend is dynamic and adaptive regulatory frameworks, which will keep up with technological development. Many times, emerging technologies outrun the capabilities of traditional regulatory mechanisms to set up comprehensive rules and regulations, and thus need adaptive regulations that can take advantage of new innovations quickly. The regulatory bodies are more and more tending towards a sandbox approach whereby companies are allowed to test emerging technologies in real-world environments under the oversight of the regulators. Regulatory sandboxes let innovators test autonomous vehicles, drones, and AI-powered systems in a controlled environment without running the risk of non-compliance with obsolete regulations. All this can be illustrated by initiatives dealing with autonomous vehicle testing in the UK or the regulation of artificial intelligence by the EU, both permitting flexible regulatory conditions to test such innovations-the said conditions are always open to modification with

the evolution of technology. These allow companies to innovate within the frameworks, while permitting safety and adhering to the basic principles of safety.

Cross-border collaboration is increasingly becoming a key trend in the establishment of rules governing autonomous systems and data-driven logistics regulations. The more international logistics has grown, the more pressing the need for unified regulations across countries and regions has become. Inconsistencies in safety standards, data protection laws, and environmental regulations pose significant challenges to the smooth operation of autonomous transport systems and AI logistics solutions. Most international regulatory bodies, such as the UNECE WP.29 for autonomous vehicle standards and the OECD for cross-border data privacy, lead in developing common global safety standards and data privacy frameworks that could apply universally. However, as autonomous logistics systems continue to be developed, reinforcement of global cooperation will be essential in building these unified regulatory standards so that technologies are deployed safely and efficiently across borders to support international trade and global supply chains.

Ethical issues in deploying technologies are fast becoming a key regulatory focus. As AI, machine learning, and other data-driven technologies start to proliferate, the regulators have started to put greater emphasis on trying to address a number of the ethical implications for these technologies. Concerns about algorithm bias, opaque decision-making processes, and job impacts all combine to drive regulators to ensure such technologies are developed and used responsibly. The Artificial Intelligence Act of the EU hopes to ensure that clear guidelines are in place on ethical use, together with safeguards against biased algorithms and AI technologies operating in a transparent and accountable manner. The more this technology is integrated into logistics and transport systems, the more urgent it will be to ensure those technologies conform to ethical principles as a means of maintaining public trust and responsible adoption of autonomous logistics technologies.

6.5 Policy Roadmap and Recommendations for Automated Freight Transport

6.5.1 Policy Roadmap

As a next step, a roadmap was created to better outline a policy implementation plan for the integration of automated freight transport into European regulatory frameworks. Further goals of this roadmap include the encouragement of behavioral change among stakeholders, as well as regulatory harmonization.

Table 6.1: Policy Roadmap

Phase	Timeline	Policy Actions	Responsible Entities	Expected Outcomes
Phase 1: Pilot Enablement	2025–2026	• Establish national and EU-wide regulatory sandboxes for automated freight pilots (e.g., AV trucks, autonomous last-mile delivery drones). • Define test corridors with harmonized data-sharing protocols.	DG MOVE, National Ministries of Transport, EASA, UNECE WP.29	Safe and legally compliant experimentation environments for AV freight.
Phase 2: Cross-border Legal Alignment	2026–2027	• Harmonize definitions, safety standards, and operational protocols for AV freight systems across Member States. • Publish EU-wide guidance for autonomous freight corridor certification.	EU Commission, Member State regulators, UNECE WP.29	Legal consistency across borders, enabling seamless cross-border freight automation.
Phase 3: Certification and Liability Frameworks	2027–2028	• Develop and adopt a unified AV freight vehicle certification system (trucks, drones, rail). • Clarify liability, insurance, and incident reporting frameworks.	EU Parliament, National Road Agencies, Insurance Supervisors	Greater legal certainty for industry actors and insurance providers.
Phase 4: Operational Incentives and ESG Integration	2028–2030	• Introduce incentives for green AV freight fleets (e.g., subsidies, tax exemptions). • Require ESG and data-sharing compliance for public procurement eligibility. • Mandate carbon reporting and cyber-risk assessments.	EU Commission (DG CLIMA, DG MOVE), EASA, Member States	Sustainable, interoperable AV freight systems aligned with the Green Deal and Digital Europe goals.

This roadmap supports a gradual but firm policy shift toward a harmonized and innovation-friendly regulatory environment that encourages safe deployment of automated freight technologies while directly responding to observed gaps in cross-border harmonization, liability handling, and infrastructure readiness. By embedding sustainability incentives and privacy guarantees, this roadmap suggests a policy alignment with European objectives on digitalization and decarbonization whit an eye towards future developments.

The proposed roadmap outlines an ambitious, yet realistic step that takes into account what has been learned from TRACE and other similar projects in the European Union. Although some activities (e.g., pilot empowerment and early green incentives) are already in progress, others (e.g., full certification or pan-European standardization) hinge on the evolving context of legal, political, and technical variables. Therefore, this roadmap combines short-term readiness with overall strategic alignment in the long term.

6.5.2 Behavioral Strategy Alignment Across Phases

Each phase of the roadmap takes into consideration specific behavioral change mechanisms, aiming to encourage adoption and minimize the resistance

Phase 1: Pilot Enablement: Regulatory sandboxes allow for an immersive experience for stakeholders, addressing their worries and building confidence.

Phase 2: Cross-border Legal Alignment: Harmonized and clearly defined rules remove perceived risk and uncertainty, thereby fostering cross-border cooperation and confidence among foreign partners.

Phase 3: Certification and Liability Frameworks: Public awareness campaigns and open legal systems enhance roles and responsibility understanding, dispelling fear of liability and encouraging participation.

Phase 4: Operational Incentives and ESG Integration: Incentivization schemes (e.g., subsidies, tenders) generate extrinsic motivation, while ESG integration contributes to organizational values and a stronger reputation.

6.5.3 Recommendations for Automated Freight Transport Policy Integration

Establish a Single Legal Definition for Automated Freight Vehicles

For ensuring regulatory homogeneity across the EU, there has to be a harmonized legal definition of automated freight vehicles. That means defining standard classes and taxonomies for various automated freight systems, e.g., road-based (in alignment with SAE levels) and air-based drones (following EASA categories). There should be one common framework to avoid confusion, support uniform compliance, and enable certification across Member States.

Apply EU-wide Safety and Operating Standards

There must be a harmonized framework of operational and safety rules for autonomous freight vehicles to move legally and safely across borders. These must delineate technical standards, operational limits, and control systems. Harmonization with the existing international frameworks of UNECE WP.29 and the International Transport Forum (ITF) ensures compatibility with global best practice while facilitating easier national regulator acceptance.

Mandate Data Interoperability and Real-time Sharing

Automated freight systems should operate within a robust digital ecosystem where logistics data is securely shared in real time. This requires adopting open API standards and enforcing compliance with the Digital Transport and Logistics Forum (DTLF) reference architecture. Data must be transmitted through platforms that uphold GDPR requirements and ensure both transparency and traceability, while enabling real-time coordination among freight operators, infrastructure managers, and public authorities.

Develop AV-specific Insurance and Liability Frameworks

Legal certainty is most important to adoption of autonomous freight technology. Governments must develop open regimes of liability that assign responsibility in the event of accident, system failure, or algorithmic fault. Insurance arrangements for owners of AV fleets must be based on such regimes so that

fleet operators, technology suppliers, and third parties are appropriately insured and appropriately encouraged to manage risks well.

Introduce Green Incentives for Sustainable AV Freight Fleets

Environmental sustainability must be incorporated into AV deployment strategies. Financial incentives, such as tax credits, toll reductions, and subsidies, are to be linked to the emission performance of autonomous freight trucks. Electric AV trucks and drones are to be prioritized by policymakers in urban low-emission zones as part of measures to ensure logistics automation in line with the EU Green Deal and climate neutrality goals.

Secure Digital Infrastructure and Enforce Cyber Resilience Standards

Autonomous freight relies on high-capacity, high-speed digital networks. For ground and satellite location networks and edge/cloud distributed computing networks to offer low-latency, constant connectivity for 5G corridor investments. AV freight carriers will need cybersecurity certification, with aggressive data protection, intrusion prevention, and system redundancy protocols to protect critical transport assets.

Expand Cross-border Pilot Projects and Regulatory Sandboxes

To enable learning and policy development, Member States should promote the creation of transnational living labs and sandboxes. These contained environments allow for in vivo testing of AV freight systems under different operating conditions. Prioritization should be given to core trans-European corridors where there is a necessity for cross-border coordination, allowing iterative optimization of harmonized technical and legal frameworks based on field evidence.

7 BEHAVIOURAL CHANGE RECOMMENDATIONS

7.1 Behavioural Change Methods

A multi-dimensional behavioral change is required for allowing the seamless induction of new technologies and collaborative methods to the operations of logistics companies. A few of the various ways in which this may be facilitated are discussed in the sections below.

Holistic Training Programs

The very first step towards efficient behavioral change is through basic training entailing holistic programs. Such a program has thus to address not just the technical skills required for the adoption of new technologies, but also the cultural aspects of collaboration. Training basically supports the logistics company in such a way that it understands benefits arising from collaboration, how it can make use of new systems, and adapt to changes in an effortless manner. Investing in training, the company provides the employees with experience and the self-confidence necessary for accepting new technologies and collaborative practices.

Role Modelling and Leadership

Another effective way is the role model effect through the use of firms that have past experience in collaboration to assist other and less experienced firms. A real-time demonstration of how the new technologies and methods of collaboration have been integrated successfully by the firms with experience in this regard will be able to extend the required support and incentives to the ones less experienced. Real-life examples and success stories of theirs might be a great motivator and will most likely influence the other enterprises to adapt the same customs and technologies. Moreover, such peer influence will be elemental in ensuring the adoption process is accelerated and collaboration given a notch higher.

Incentive Systems and Recognition

Establishing a proper system of incentives and recognition is a key mechanism in reinforcing desired behaviors and promoting pervasive acceptance of new technologies and collaborative practices. Employees' motivation and compliance with new technologies and collaborative practices can be radically improved when the employees showing outstanding performance in handling new technologies and practicing collaboration are rewarded. The recognition and celebration of these achievements embed the new practices in the corporation culture and reinscribe the desired changes in behaviors.

Pilot Projects and Gradual Implementation

Starting pilot projects, like what the TRACE platform represents, allows companies to test new technologies and approaches in smaller implementations before a full-scale rollout. In this way, the company can find problems, sort them out, make necessary adjustments, and show the wider company how benefits are reaped from the new methods. In fact, pilot projects provide the perfect environment to iron out the processes and demonstrate the business value of new technologies, thus making it easier for the rest of the company to transition.

Fostering a Collaborative Culture

Long-term success would depend on setting up an environment that embraced innovation and collaboration. It requires a change in the mindset of the persons within the company by illustrating benefits in the long run through the use of new technologies and collaborative practices which will integrate them into the core values of the company. Smaller and micro enterprises may, with longer experience in collaboration, use workshops and other interactive formats in order to provide positive experiences from collaboration and technologies such as the TRACE platform. With such innovative approaches, logistics companies will collaborate and find better ways to optimize logistic processes in shared logistics.

Ongoing support and resources

Continuous support and resources-whether it be user guides or technical assistance-will also go a great way in ensuring seamless transitions to new technologies and collaborative approaches. Continuous support helps in timely dealing with problems to maintain momentum. Companies will then have much better ways of going through the challenges in a comprehensive way to assist and sustain strategic collaboration for the longer term.

Knowledge Platforms and Best Practices

The knowledge platforms that show the best practices and benchmarks of the industry will have much valued insight into companies that have not taken up collaboration or new technologies. From an understanding of how other companies implemented changes to similar areas-areas into which logistics companies now seek to introduce their own changes, practical strategies and insights can be obtained to assist in guiding the adoption process. The same can serve as a good source for successful strategies and continuous culture.

These behavior change methodologies have the potential to be implemented by logistics companies in order to be better prepared for the new technologies and collaborative approaches.

7.2 Trust-strengthening mechanisms for shared logistics operations

In shared logistics operations, the first step towards productive cooperation involves creating trust among the partners. Many best-practice case studies from both Europe and elsewhere in the world have identified the various methods and mechanisms that logistics companies apply to create trust among themselves, so that their operations are much more efficient.

Collaborative Networks and Alliances

One very effective way of working is to establish collaborative networks and alliances of logistics companies. For example, the ASTRE association, founded in 1992, unites 160 SME logistics companies across Europe. Enabling the transfer of transport orders between members, ASTRE facilitates them to achieve higher levels of operational flexibility and therefore meet the demand of customers with effectiveness. Other associations, such as 24 Plus and WCA provide a mutual opportunity to coordinate and develop a sense of mutual trust as well as sharing of resources for the firms associated with it.

Shared Logistics Pools

Another very good example is the Sphinx Pool, launched in 2012, which involves seven manufacturing companies, a logistics service provider, and retail partners. Within this pooling scheme, FM Logistic will play the neutral and trusted partner by managing joint orders and coordinating deliveries from manufacturing sites to retail outlets. This team approach has delivered frequency increased 2.5-fold, lowered inventory levels in stores, and considerably better vehicle utilization. This collaboration is in the form of trusting collaboration for maximization of logistics.

Joint Transportation Initiatives

Joint transportation initiatives also contribute to building trust among logistics partners. A partnership between a Moroccan juice manufacturer and a Turkish biscuit producer, for example, addressed the issue of underutilized transport capacity by consolidating their shipments. The outcome was a 15 percent decrease in the cost of transport and a twofold increase in logistic operations within a few years, thereby revealing the benefits offered by shared logistics in terms of cost efficiency and better use of resources.

Similarly, P&G partnered with Tupperware to better utilise transport space by co-delivering heavy detergents and light, bulky products. In this case, collaboration improved vehicle space utilization from 50% to 85%, shaved off 17% from transportation costs, while simultaneously drastically decreasing CO2 emissions; proof once more that trust-based collaborations result in very relevant environmental and economic benefits.

Digital Platforms for Logistics Collaboration

Digital platforms have emerged as strong enablers of trust and collaboration among the logistics companies. Saloodo! and Eurosender rank among leading platforms that host digital marketplaces where companies can find a transport partner, fill unused vehicle capacity, and thus optimize their logistical operations. Such platforms support thousands of logistics companies around the world, supported by the principles of mutual benefit in transparency, which assure companies participating in these platforms of the trust that is established in the platform and in each other's collaborative work.

Urban Consolidation Centres (UCCs)

Urban Consolidation Centres are likewise effective mechanisms in engendering trust over shared logistics operations. The creation of an Urban Consolidation Centre in the French city of Saint-Etienne under the framework of a European project is an alternative model of the central platform; this coordinates deliveries within the urban area, which themselves are under guarantee of compliance with legislation concerning environmental aspects and optimizes last-mile logistics. By consolidating shipments from multiple logistics companies and facilitating the use of low-emission vehicles, the UCC reduced the environmental impact of urban deliveries and fostered a spirit of collaboration among the participating companies.

Cross-Supply Chain Collaborations

Cross-supply chain collaborations, such as the partnership between UCB and Baxter, further illustrate the importance of trust in shared logistics. Sharing transport from UCB and Baxter enabled more volume to be moved. The logistic service provider H. Essers was added to the partnership for the purposes of multimodal transport; this provided a CO2 reduction of 50% and major cost savings. The heart of this

partnership is TRI-VIZOR, a company responsible for the optimization and organization of combined transport of goods from both companies. TRI-VIZOR deploys the cloud supply chain management through a platform called the "Cross Supply Chain Cockpit," which it developed in cooperation with Microsoft Azure.

Shared Infrastructure and Facilities

Besides digital platforms and UCCs, shared infrastructure such as parcel lockers and distribution hubs has also proved to be potent symbols for trust reinforcement among the logistics partners. Based on this vision, PostNL opened its parcel lockers to other delivery companies in the Netherlands. In that way, customers can collect parcels from various carriers at a single point, and these carriers will be able to expand their capacity accordingly. The greater such cooperation and customer convenience to commit to joint infrastructures, the more confidence there will be between independent logistics companies that might be in competition with one another.

Examples include the open parcel locker network in Vienna, called WienBox, where several logistic players operate under the same conditions with advantages in flexibility and efficiency in last-mile delivery. Again, shared infrastructure does not mean worse service quality or higher costs; rather, it brings in a collaborative environment.

Micro Consolidation Centres and Last-Mile Delivery Solutions

Recent projects, such as MCCs in Berlin and Bologna, show that shared logistics facilities are becoming an increasingly important element of urban environments. Centres where last-mile deliveries are consolidated and completed using zero-emission vehicles offer a location for a variety of logistics companies to come together and share resources. MCCs build trust among their logistics partners because they offer a neutral facility for consolidating and redistributing goods, so that all concerned make the most of the shared use of infrastructure.

In conclusion, these practices demonstrate that trust-enhancing mechanisms are essential to the success of shared logistics operations. Logistics companies are able not only to achieve operational gains through engaging in collaborative networks, leveraging digital platforms, and sharing infrastructure but also create valued, long-term partnerships based on mutual trust and shared benefits. These strategies would add to the sustainability and competitiveness of the logistics operation in an increasingly interconnected global market once properly executed.

7.3 Conditions and methods for successful collaboration in shared logistics

Based on the issues identified that prevent logistics companies from collaborating, a few pivotal conditions have been explored as necessary for ensuring that long-term logistics collaboration in shared logistics will be successful.

One of the preconditions is a full integration of IT systems and ICT. This will be important for easy cooperation and ensuring that all the partners can access and use required data without problems. The other important prerequisite is that there should be an independent coordinator or management system

such as TRACE platform. Such platforms can coordinate the collaboration so that it runs accordingly and fairly.

It needs an efficient data exchange, storage, and management system that is secure to instill confidence among the participating companies. A system that will ensure protection with transparency of the data to trace and have control over the logistics operation. Such transparency is elemental in creating trust and being able to make sure that partners are totally aware of how the operations are being executed.

Another major variable here is a clear and consistent specification of rules and conditions under which collaboration is to be carried out. These should pertain to responsibilities, rights, penalties, and the collective objectives of collaboration. There needs to be well-defined specifications on cost and revenue sharing among the different companies equitably in such an arrangement. Selection of appropriate collaboration partners is another major pre-condition for successful collaboration wherein compatibility between different companies, on the lines of goals as well as resources, could ensure greater prospects of partnership success.

New technologies at place, such as ICT, artificial intelligence, and machine learning, are very critical to enhanced collaboration. These will enhance operational efficiency and enable more sophisticated logistics planning and execution. Besides, all the partners should contribute equitably to the sharing of resources, including infrastructure, vehicles, and labour, as a means of maintaining fairness and balance within the collaboration.

Another area where the collaboration is needed is strategic planning. Companies must work together through all the stages of planning for aligning strategies and objectives. Finally, there should be frequent measurement of performance of both the overall collaboration and the companies themselves to ensure continuous improvement of, and also to ensure that the partnership will continuously benefit all parties concerned.

In other words, the key condition for successful logistics collaboration is an effective and secure system of data exchange, storage, and management. It is on this basis that trust between the logistics companies is built up, coupled with transparency, traceability, and well-set operational rules for considerable long-term success.

8 CONCLUSION

8.1 Key Findings and Lessons Learned

Several potential regulations on autonomous systems, sustainable logistics, and data-driven technologies identified through development and implementation have provided important conclusions and lessons for use in future policy development and technological deployment in the logistics sector. It is relevant to understand challenges, opportunities, and vacuums in current regulatory approaches that might shape more effective frameworks for the integration of new technologies in logistics operations.

The main finding is a need for regulatory harmonization across regions and jurisdictions. Regulatory fragmentation across borders has grown as one of the key impediments to the deployment of autonomous vehicles, drones, and AI-powered logistic solutions. Whereas EU regulations create a level playing field in safety and data protection, there are still substantial variations in national regulations that raise obstacles for companies operating across borders. The result has been higher costs of compliance for logistics companies, delays, and uncertainty. Therefore, the salient insight underlying this example is that international harmonization of safety standards, data privacy regulations, and environmental standards would be crucial for seamless operations across the global supply chain. Global collaboration driven by UNECE WP.29 and OECD would be conducive to establishing unified regulations that efficiently facilitate the cross-border deployment of autonomous logistics systems.

Another key finding is the need for flexibility in regulatory frameworks, to accommodate the pace at which new technologies are developed. Traditional, prescriptive regulations often simply move too slowly for the rapid evolution of autonomous systems, AI, and sustainability solutions. The lesson here is that performance-based regulations allow business to innovate while reaching safety and sustainability goals without specifying certain technologies or methods. Moreover, it was explained that the introduction of regulatory sandboxes allowed companies to test new technologies in controlled environments and enabled regulators to adapt standards to emerging technologies as they gathered more data from real life. It is such flexibility within regulatory approaches that creates enabling environments for innovation, with the assurance that new technologies will not compromise safety and ethical standards.

Key takeaways from data protection and cybersecurity would therefore concern the measures necessary to increase the orientation of standards towards cybersecurity. Since solutions for smart logistics and autonomous systems rely heavily on real-time data exchange and IoT connectivity, any gap in cybersecurity determines wide exposure to hazards of public safety and violation of operational integrity. What this teaches is that cybersecurity should be integrated right from the design phase into the safety standards so that autonomous technologies are safe from cyberattacks and data breach. Moreover, there should be harmonization of cross-border regulations on the privacy of data for smooth and secure data flow between different countries that will allow the proper working of autonomous logistics systems and AI-powered transport solutions with due respect to user privacy.

The most important thing learned is stakeholder collaboration towards the creation and fine-tuning of regulatory frameworks. In ensuring that regulatory drives are truly successful, there is a constant need for industry stakeholders, technology developers, academics, policymakers, and end-users to engage. Such collaboration makes certain that regulations are practical, forward-looking, and effective to deal with real

deployment issues while fostering public trust and encouraging innovation. These regular consultations and workshops allow the regulator to get valuable feedback, best practices, and lesson learned directly by those who are deploying the technology. The regulatory frameworks will be able to keep pace with the evolving needs in the logistics and transport sectors.

In summary, the key findings and lessons learned underscore that regulatory harmonization, flexible frameworks, cybersecurity integration, and stakeholder collaboration are some of the major contributors to the successful deployment of autonomous systems and sustainable logistics solutions. These will be important inputs in the development of future regulatory frameworks-one that will support technological innovation while safety, security, and sustainability remain at the heart of the transformation in the logistics sector.

8.2 Final Recommendations

The integration of autonomous systems, artificial intelligence technologies, and sustainable transport solutions into logistics requires far-sighted, adaptable regulation able to maintain the pace of technologies developed while considering safety, sustainability, and ethical standards. In the last sections, this report gathers some closing remarks, drawn from the different parts of the document, to develop suggestions on the setup of future regulatory frameworks with better alignment of support for the deployment of these emerging technologies across the sector, considering:

1. Harmonization of cross-border regulations is a key issue: Autonomous logistics systems should be allowed to move around seamlessly across various regions. Regulatory fragmentation remains one of the major impediments to the broad diffusion of autonomous technologies, particularly as logistics operations increasingly span multiple countries. International cooperation and establishment of global safety standards are important in keeping to the minimum the complication brought on by divergent national regulations. The international body, therefore, such as UNECE WP.29 and OECD, must continue efforts toward the creation of harmonized frameworks for testing, data protection, and environmental standards for autonomous vehicles. This will help reduce compliance costs, cross-border operations flowing smoothly, and the facilitation of growth in autonomous logistics technologies globally.
2. Flexibility in regulatory frameworks will ensure that innovation occurs without hindrance and guarantees adoption of emerging technologies in a manner that is proper, safe, and efficient. It is recommended that the regulations be performance-based, leaving space for companies to achieve desired outcomes such as safety, sustainability, and efficiency using different technological approaches. This flexibility in regulation will inspire innovation in that companies can choose the best technologies that suit the achievement of regulatory goals. Finally, regulatory sandboxes are to be extended such that both autonomous systems and AI technologies can be tested and experimented on in specially controlled testbeds whereby the degree of both safety and regulatory compliance can be observed and adapted accordingly. Such measures will support innovation while maintaining public safety and operational integrity.
3. Cybersecurity has to be integrated into the standards of safety regarding growing risks attributed to data-driven logistics systems and autonomous vehicles. Since those technologies rely so much on real-time data exchange and IoT connectivity, it is so important to take measures to make them secure from cyber-attacks. Regulators should include cybersecurity requirements in safety standards to ensure strong data protection, secure communication protocols, and incident

response measures in place. In the light of significant safety and operational reliability risks that data breaches or hacking incidents would cause, cybersecurity has to be part of the regulatory framework for emerging technologies.

4. The development and prioritization in providing financial incentives for green technologies and integrating sustainability goals into the entire logistics ecosystem have to move at a similar rate to the regulations about sustainability. The regulatory framework should support the transition to electric vehicles, alternative fuels, and carbon-neutral solutions in logistics, but it also needs to ensure that, if these are to overcome the financial barriers confronting many logistics providers, governments must ensure they are scalable and accessible to large corporations and small businesses alike. Policies should make it easier for innovative environmentally friendly technologies to become widely adopted, without causing prohibitive upfront costs for long-term sustainability goals, such as carbon neutrality and zero-emission transport.
5. It is quite important that stakeholder collaboration be at the core of developing an effective regulatory framework. Best practices, data, and insights that inform responsive and adaptive regulations should be shared on a regular basis among industry leaders, technology developers, academics, and regulators. Consider incentives for a regular cadence of workshops, public consultations, and feedback loops to ensure practical and forward-looking regulations. That means an open and collaborative attitude by the policymakers would ensure that regulatory frameworks can be increasingly nimble, accommodate future technological advances, and still protect public interests.
6. These features should be developed within an instrument that exhibits flexibility, harmony, and cooperation at the global level if the world supply chain is to effectively and efficiently integrate autonomous systems, AI technologies, and sustainable logistics solutions. Cross-border harmonization, cybersecurity integrations, performance-based regulation, and sustainability incentives are areas of prime importance in which the policy framework can help create favorable conditions for innovation to flourish while ensuring that benefits accruing from new technologies are used safely, securely, and responsibly.

8.3 Future Work and Next Steps

With the integration of autonomous systems, AI-driven technologies, and sustainable solutions, the work on regulatory frameworks, too, needs to move ahead in order to support such advancement with effective, adaptive, and comprehensive regulations. Future efforts would, therefore, go toward refining the already existing regulatory frameworks in light of emerging challenges and to adapt to new technological developments. In the following steps, both the cooperation of the stakeholders and data-driven insights will play their role in shaping the regulatory landscape to ensure successful integrations of autonomous logistics systems into global supply chains.

One of the immediate future work priorities will be the harmonization of cross-border regulations. As logistics networks are increasingly part of a global system, there is an urgent need for international harmony in safety standards, data privacy laws, and environmental regulations. The consequent steps that will follow are international dialogues through UNECE WP.29 and OECD in the way of harmonizing standards on autonomous vehicles, their cybersecurity measures, data protection, and legislators of the participating jurisdictions. This will involve the development of common frameworks for testing the

roadworthiness of autonomous vehicles, real-time data sharing, and interoperability between national and regional regimes. regulatory fragmentation barriers can only be overcome by the cooperation of countries and their regulatory bodies to have smooth cross-border operations in logistics. This was based on findings from UNECE 2020; OECD 2020.

Once the integration of the autonomous systems into logistics operations takes effect, there will be continuous updates needed in the safety protocols to account for changing technology. This will be done through the development of performance-based regulations that focus on safety outcomes rather than specific technologies, while allowing innovation and flexibility to thrive in concert with ensuring public safety. Within this process, regulatory sandboxes will remain integral to the goal, providing a controlled environment in which new technologies are tested out and developed in real-world conditions. Future work will be dedicated to the proliferation of these sandboxes, both nationally and regionally, with the aim of expanding the space in which autonomous systems can be tested within diverse logistics contexts.

There is also a need for addressing the ethical and social implications of autonomous logistics, as the sector increasingly shifts toward AI-driven decision-making and increased automation, which will require the highest level of ethical clarity for responsible deployment of technologies. This is about algorithmic bias, transparency of data, and the impact it has on employment. This means regulatory bodies will have to work with industry players and ethics experts to clearly outline the ethical bounds for AI in logistics to ensure biases do not perpetuate with autonomous systems and that their operations become more transparent and accountable. These ethical frameworks will be important in the maintenance of public trusts and ensuring a fair deployment of new technologies. Data privacy and cybersecurity continue to be a major concern and number one on most regulatory works. As logistics operations continue to rely on real-time data from autonomous vehicles and IoT devices, ensuring data security, securing systems from cyberattacks continues to be at the top of mind. Future activities will invest in further developing cybersecurity regulations, building global standards in data management. This is foreseen to develop more ways of safeguarding operational integrity and personal privacy by incorporating cybersecurity measures within safety regulations. As this technology gets more interconnected, international cooperation will be pivotal for unified approaches to data protection and cybersecurity-to make seamless logistics networks seamless and secure, too.

Future work on regulatory frameworks for autonomous systems and sustainable logistics solutions will be channeled toward cross-border harmonization of regulations, adaptation of safety standards, resolution of ethical issues, data privacy, and cybersecurity. This means further collaboration by stakeholders, regulators, and technology developers in the formulation of flexible and responsive but globally aligned frameworks that support innovation and ensure safety, security, and sustainability within the logistic sector.

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