D3.2

Status-Quo and role-specific pain points of European freight and transport value creation system

FIR at RWTH Aachen University

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ABBREVIATIONS

1PL	First-Party Logistics Providers
2PL	Second-Party Logistics Providers
3PL	Third-Party Logistics Providers
4PL	Fourth-Party Logistics Providers
AI	Artificial intelligence
API	Application programming interface
ATS	Asset Tracking System
B2B	Business to Business
BE	Business ecosystem
BM	Business model
CEF	Connecting Europe Facility
CIF	Cost, Insurance, and Freight
CINEA	European Climate, Infrastructure and Environment Executive Agency
CIP	Carriage and Insurance Paid To
CO_2	Carbon Dioxide
CPT	Carriage Paid To
CRM	Customer Relationship Management
CSC	Container Safety Convention
CSV	Comma-Separated Values
DAP	Delivered at Place
DDP	Delivered Duty Paid
DG Move	European Commission's Directorate-General for Mobility and Transport
DLSP	Digital Logistics Service Provider

DPU	Delivered at Place Unloaded
EDI	Electronic Data Interchange
EDIFACT	Electronic Data Interchange for Administration, Commerce and Transport
EMSA	European Maritime Safety Agency
ERA	European Union Agency for Railways
ERP	Enterprise Resource Planning
ESG	Environmental, Social, and Governance
ETA	Estimated Time of Arrival
EXW	Ex Works
FAS	Free Alongside Ship
FCA	Free Carrier
FMEA	Failure Mode and Effects Analysis
FOB	Free On Board
GPS	Global Positioning System
ICT	Information and communication technology
IoT	Internet of things
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LSP	Logistics Service Provider
MTO	Multimodal Transport Operator
NFC	Near Field Communication
NSB	North Sea-Baltic

OCAP	Out of Control Action Plans
PDF	Portable Document Format
RD	Rhine-Danube
RFID	Radio Frequency Identification
RIA	Research and Innovation Action
SaaS	Software as a Service
SAP	Systems, Applications, and Products
SCM	Supply Chain Management
SME	Small and Medium Enterprises
TEN-T	Trans-European Transport Network
TEU	Twenty-foot Equivalent Unit
TMS	Transport Management System
TOS	Terminal Operating System
TSI	Technical Specification for Interoperability
UIRR	International Union for Road-Rail Combined Transport
VCS	Value creation system
VN	Value Network
WMS	Warehouse Management System
XML	Extensible Markup Language

1 Introduction

ReMuNet - Resilient Multimodal Freight Transport Network - is financed by the European Commission through the European Union's Horizon Europe research and innovation program under Grant Agreement No 101104072. It has been proposed by a consortium of 15 beneficiaries coordinated by FIR at RWTH Aachen University and will be lasting 36 months, having started in July 2023. The content of the project and the aim of the deliverable will be presented in the following.

1.1 Project Background

ReMuNet is tasked with identifying and signalling disruptive events while assessing their impact on transport corridors. By communicating alternative multimodal transport routes to logistics operators and subsequently to truck drivers, train drivers, and barge captains, it facilitates a more rapid network response. Furthermore, ReMuNet orchestrates route and capacity utilisation and enables synchromodal relay transport.

Additionally, ReMuNet is responsible for establishing comprehensive standards for the transnational description of multimodal nodes and transport routes, including infrastructure elements and their parameters. This forms the basis for a unified modelling language. To ensure maximum practical applicability and acceptance, these standards are developed by evaluating and consolidating existing description standards, supplementing technical and sustainability related descriptive attributes, and engaging in close collaboration with European transport companies, associations, and institutions.

ReMuNet's collaborative platform reduces entry barriers for regional transport companies, encouraging participation in multimodal transport, known for its lower average emissions compared to road freight transport. Intelligent routing algorithms prioritise low emission routes and modes of transport, enhancing transport efficiency and significantly cutting emissions. ReMuNet explores the integration of alternative drives to further support sustainability goals, aiding political and economic decision-makers in expanding and maintaining vital transport infrastructure.

ReMuNet's algorithm considers the impacts of disruptive events and strategically plans route distribution to maximise the efficiency of the multimodal transport network. Within the project a comprehensive Transport Failure Mode and Effects Analysis (FMEA) is conducted, including detailed risk analysis of disruptive events and potential transport disruptions, to transparently assess short and long-term effects on the multimodal transport infrastructure. ReMuNet's data pool expedites internal decision-making, supporting the development of business capabilities necessary to manage disruptions.

ReMuNet maintains a catalogue of transport Out of Control Action Plans (OCAP), containing quick reaction strategies to respond to potential transport collapses. Synchromodal relay transport is tested as the preferred transport mode to bridge failed transport routes. ReMuNet's algorithm provides real-time status updates on functioning transport nodes and edges, enabling flexible route adjustments. The algorithm calculates failure probabilities for transport routes and minimises congestion on alternative routes through intelligent distribution.

ReMuNet’s collaborative platform treats small and large companies equally, aiming to integrate local players and connecting freight forwarders, carriers, terminal operators, and other key players in the multimodal transport sector. It enables the digitalisation of communication, contracts, handover protocols, and booking processes, and orchestration of synchromodal relay transport. Continuous interactive improvement is achieved through algorithm testing and validation using historical disruptive event data. The platform provides transparent and user-friendly access for small and medium enterprises (SME) to route network structures, scheduling, operators, and capacity booking in road, rail, and barge transport.

The platform's infrastructure includes basic backend functionalities, such as master data management, user administration, roles, rights, and user-friendly application programming interfaces (API) and interfaces to existing systems and data sources. ReMuNet provides an AI-supported transport system model capable of depicting the effects and impact intensities of various disruptive events on the transport infrastructure, recognising patterns, deriving failure probabilities, identifying bottlenecks, and evaluating alternative courses of action, thus reducing reaction time, and offering sustainable, event-based route alternatives and scenarios.

ReMuNet strives to integrate civil protection organisations into the collaborative platform, matching them with freight transporters, and using real-time data to display the status of functioning and failing transport infrastructure, enabling faster and more targeted aid transportation.

By integrating all relevant stakeholders via interfaces into ReMuNet, a wide variety of anonymous planning data is refined to create the necessary basis for decision-making. Clear data governance structures and data handling processes that comply with privacy policy specifications ensure secure and trusted information exchange. External data inputs are obtained through APIs and interfaces from multiple sources, enabling participatory planning.

1.2 Key Objectives of the ReMuNet Project

The concept of the Physical Internet foresees a seamless network where resources and assets can be shared openly and efficiently. ReMuNet’s **main objective is to support the achievement of this vision by giving the transport network the ability to prepare, respond, and adapt to disruptive events**.

In practice, ReMuNet uses digital technologies to holistically improve the resilience of the logistics and freight transport network. This includes making planning more robust and secure, reducing response times, and speeding up system recovery. ReMuNet also takes environmental aspects into account and aims to provide synchromodal transport options with the lowest emissions. This contributes to the implementation of the Physical Internet and helps to reduce the environmental impact of freight transport.

ReMuNet's key objectives are to:

Lay the foundation for a common standard to describe sustainable European multimodal transport networks for all stakeholders: ReMuNet creates comprehensive standards for the transnational description of multimodal nodes and transport routes including infrastructure elements and their parameters. This will lay the foundation for a uniform modelling language. To ensure maximum practice orientation and acceptance, the standards are developed by evaluating and consolidating existing description standards, supplementing technical and sustainability relevant descriptive attributes, and closely collaborating with European transport companies, associations, and institutions.

Reduce European inland transport emissions on the main run by over 50% in the long term: ReMuNet's collaborative platform lowers entry barriers for regional transport companies to participate in multimodal transport, thus facilitating combined transport which on average produces fewer emissions than road freight transport. Intelligent routing algorithms prefer low emission routes and modes of transport and increase transport efficiency, in turn significantly reducing emissions. To further contribute to sustainability goals, possibilities to integrate alternative drives are explored. Insights support political and economic decision-makers in expanding and maintaining the necessary transport infrastructures.

Enable the multimodal freight network to react and respond 20% more quickly to disruptive events until 2026 (in comparison to 2021): The algorithm considers the impacts of disruptive events and plans a robust route distribution to maximise the efficiency of multimodal transport system utilisation. Transport FMEA including risk analysis of disruptive events and potential transport collapses is conducted to make the short and long-term effects of disruptive events on the multimodal transport infrastructure transparent. A shared data pool accelerates internal decision-making and supports the development of business capabilities necessary to cope with disruptions. Catalogue of transport OCAPs containing quick reaction strategies to (upcoming) transport collapses ensure the ability to (re-)act. Synchromodal relay transport will be tested as the preferred type of transport mode to bridge failed transport routes.

Provide 50% more alternative transport routes in the face of disruptive events and make multimodal route planning 10-20% more accurate and efficient until 2026 (in comparison to 2021): The algorithm displaying the real-time status of functioning transport nodes and edges allows for flexible adjustment of route suggestions. Routes are calculated and forwarded to freight forwarders and navigation systems to ensure communication with drivers and barge captains. The algorithm determines failure probabilities of transport ways and minimises congestion on alternative routes via intelligent route distribution. A collaborative platform connects freight forwarders, carriers, and terminal operators, as well as other key players in the multimodal transport sector to gather real-time data and digitalise communication, contracts, handover protocols, and booking processes and orchestrate synchromodal relay transport. Continuous interactive improvement will be achieved by simulative algorithm testing and validation with historical data of disruptive events.

Create new approaches for benefit-sharing cost-efficient business models and integrate 30% more companies (>50% SMEs) into the multimodal freight transport ecosystem: ReMuNet offers an open collaborative data platform, which does not differentiate between small and large companies and integrates local players. The platform provides user-friendly access for SMEs to route network structures, scheduling, operators, and capacity booking in road, rail, and barge transport. The platform infrastructure includes basic backend functionalities, e.g., master data management, user administration, roles, and rights as well as user-friendly APIs and interfaces that connect the platform to other systems and data sources.

Predict the impact of disruptive events on multimodal transport corridors with a 90% higher accuracy until 2026 (in comparison to 2021): ReMuNet provides an AI-supported transport system model able to depict the effects and impact intensities of various disruptive events on the transport infrastructure, recognise patterns, derive failure probabilities, identify bottlenecks, and evaluate alternative courses of action. This will lead to shortening reaction time by offering sustainable, event-based route alternatives and scenarios.

Enable civil protection organisations to set up aid delivery logistics for crisis areas 25% faster in 2026 (in comparison to 2021): ReMuNet integrates civil protection organisations into the collaborative platform and matches them with freight transport companies. The network status will stay updated by using real-time to display functioning and failing transport infrastructure while taking new makeshift transport ways into account. This approach will enabling a faster and more focused aid transportation into crisis areas.

Create a unified data pool that portrays the real-time utilisation of multi-modal European transport infrastructure in compliance with data protection regulations: By integrating all relevant stakeholders via interfaces into the ReMuNet, a wide variety of anonymous planning data will be refined to create the necessary base for decision making. Clear data governance structures and secure data handling processes will be implemented to meet privacy policy specifications. External data input is pulled via APIs and interfaces from multiple different sources enabling participatory planning.

1.3 Objective of Deliverable 3.2

The ReMuNet project focuses on enhancing multimodal transport ecosystems along two essential European Trans-European Transport Network (TEN-T) corridors: the North Sea-Baltic (NSB) and Rhine-Danube (RD). The overall objective of ReMuNet's third work package is to design a collaborative platform that enables high operational interconnectivity for event-based, synchromodal relay transport, tailored to the unique characteristics and requirements of these corridors. Within this work package, Task 3.2 investigates and documents the current European multimodal transport ecosystem, identifying key pain points and defining the core value proposition of the ReMuNet solution. This task sets the stage for innovative business model (BM) development, laying the groundwork for the ReMuNet solution to be effectively integrated into existing transport ecosystems.

Task 3.2 kicks off with a comprehensive analysis of the current ecosystem using Business Ecosystem Mapping to capture the unique features of the NSB and RD corridors. This mapping draws on extensive desk research, surveys, and workshops, supplemented by detailed interviews with a range of stakeholders, many of which were initiated in Task 1.1. These interviews help to establish archetypical role profiles for central actors, documenting their exchange relationships and specific pain points, and highlighting the responsibilities and challenges faced by each role. By visualising the transport processes, including information and financial flows, ReMuNet creates a clear picture of how value moves through the system, allowing the team to identify inefficiencies and establish the requirements for an improved platform model. Insights gathered through this process are synthesised in a Value Stream Model developed collaboratively through workshops. This model provides stakeholders with a clear understanding of the system's existing structure, mapping the flow of information and resources while highlighting key challenges and areas needing improvement. By creating a common understanding of these value flows, the Value Stream Model informs the development of a catalogue of requirements that guides the platform's design, ensuring it is closely aligned with the ecosystem's pain points and specific needs. This catalogue of requirements serves as the foundation for ReMuNet's platform ecosystem. Designed using the Ecosystem Design Canvas, the ReMuNet platform is structured to provide tailored solutions that adapt to each actor's specific role within the network, fostering sustainable business models that are both cooperative and competitive - a "coopetitive" approach. This design enables role-specific adaptations and supports the development of sustainable practices that align with the ecosystem's goals. ReMuNet's iterative approach to design also ensures flexibility, allowing the platform to evolve alongside the transport ecosystem as new roles or needs emerge.

Deliverable 3.2, one of two formal outcomes of Task 3.2, consolidates these findings and insights. Led by FIR at RWTH Aachen University with the support of industry experts and academic researchers, Deliverable 3.2 provides a comprehensive description of the NSB and RD ecosystems, using Business Ecosystem Mapping to structure the existing local value creation systems and summarise role-specific pain points and needs. This deliverable also prepares the way for integrating the ReMuNet solution by facilitating a shared understanding among stakeholders, essential for building resilience in cases of rerouting or disruptions. The unified approach provided by Deliverable 3.2 enables ReMuNet to establish easily implementable solutions and develop a robust transformation methodology for the current ecosystem. Building the ReMuNet platform on a thorough understanding of the existing ecosystem allows for a smoother transformation process. By aligning ReMuNet with existing structures and processes, changes become more accessible and comprehensible to all involved stakeholders, thus enhancing acceptance and effectiveness within the multimodal transport network. This approach also supports the platform's long-term sustainability, making it a practical and widely acceptable solution for the European multimodal transport network.

The insights gained in Deliverable 3.2 will be instrumental for subsequent stages of ReMuNet's development, particularly in the creation of innovative business models and technical solutions in later tasks of the work package. By capturing the ecosystem's current state and pinpointing specific pain points, ReMuNet ensures that its solutions are practical and sustainable. Through this structured, collaborative process, ReMuNet sets a new standard for European multimodal transport, establishing an adaptable, value-driven platform ecosystem that supports the evolving requirements of the NSB and RD corridors, ultimately contributing to a more resilient and efficient transport network across Europe.

1.4 From Deliverable 1.1 to Deliverable 3.2

Analysing the role-specific pain points and needs of the actors in the European multimodal transport ecosystem and understanding their value creation contributions is essential for the development of digital building blocks within ReMuNet. This approach ensures the alignment of ReMuNet with the requirements of transport stakeholders and thus increases acceptance and applicability.

Deliverable 1.1 conducted an introductory analysis on the European multimodal freight transport ecosystem via explorative research. Building on the results from Deliverable 1.1, Deliverable 3.2 delves deeper into describing the value flows between key roles in the ecosystem. It sheds light on corridor-specific characteristics and summarises the most relevant pain points and challenges stakeholders encounter while managing transport disruptions. Distinguishing between different pain point categories, Deliverable 3.2 synthesises those pain points that can be addressed with digital solutions and derives corresponding requirements for ReMuNet modules. As Deliverable 1.1 provides the basis for this approach, the key findings of this deliverable about structuring pain points within the multimodal freight transport network are briefly reflected.

The analysis of disruptions and challenges within the transportation and logistics sector highlights the critical role of carriers and the interplay between physical and information layers. Challenges primarily originate from the information layer, characterised by technological deficits and reluctance to share data. Key challenges include information management, system interoperability, and information exchange, with technology emerging as the overarching category. Issues like data quality, system fragmentation, and outdated technologies complicate operations, while regulatory factors and capacity management further exacerbate these challenges. Addressing these issues to foster collaboration and improve disruption management requires advanced technologies, standardised protocols, and collaborative platforms to enhance data accuracy, system interoperability, and regulatory compliance (von Stamm et al. 2024, S. 109–111).

Deliverable 3.2 will build on these insights and add a detailed examination of the current state of multimodal transport networks with a specific focus on the TEN-T Rhine-Danube and North Sea-Baltic corridors. It provides a comprehensive overview of the system's pain points and the resulting requirements for improvement towards more resilience. These requirements act as foundation for the design of digital modules and services provided via the ReMuNet platform in subsequent work tasks.

1.5 Structure of Deliverable 3.2

This document offers a comprehensive overview of the ReMuNet project’s objectives and methodologies, examines the multimodal transport ecosystem's current state and challenges along the Rhine-Danube and North Sea-Baltic corridors, and outlines the resulting requirements for the ReMuNet solution.

Chapter two serves as a theoretical foundation for analysing the current structure and dynamics of the multimodal freight transport ecosystem. It describes the theoretical background and introduces underlying concepts e. g. value flow modelling for analysing business ecosystems and value creation or the Gassman framework for describing business models.

Chapter three builds on the theoretical background by detailing the research methodologies used to link theory with the realities of the multimodal transport ecosystem in the Rhine-Danube and North Sea-Baltic corridors. It outlines tools such as surveys, expert interviews, and workshops, selected to capture diverse stakeholder perspectives and accurately reflect the ecosystem’s conditions through theoretical models.

Chapter four analyses the ecosystem of the Rhine-Danube and North Sea-Baltic corridors, outlining each corridor, key stakeholders, and their business models. The ecosystem is systematically depicted by defining role archetypes and mapping value flows that represent the exchange of goods, information, and finances. Real-world examples of representative actors illustrate these models, highlighting unique features and subtle differences between both TEN-T corridors.

Chapter five examines the pain points within the ecosystem, derived from D1.1 and the research findings in D3.2. It presents a new categorisation of pain points, highlighting various dimensions. Expert insights from both focus corridors support these findings. The chapter also discusses the transformation drivers behind these pain points and introduces a pain point analysis tool.

Chapter six outlines the requirements for the ReMuNet platform to address the pain points discussed in the previous chapter, offering initial ideas for potential solution ways. It categorizes the key areas ReMuNet must focus on in future deliverables and presents a framework to guide the project's future progress.

Chapter seven closes with a conclusion of the deliverable and an outlook towards future research contributions.

2 Theoretical Background

Analysing the current multimodal freight transport ecosystem requires a solid theoretical foundation for understanding and methodologies for describing business ecosystems and business models. Key actors operating in the two analysed TEN-T corridors may highlight structural or organisational differences and similarities within the two corridors by having different business models and value creation systems based on their role in the network.

Following an introduction to basic value creation systems and their characteristics, the business ecosystem, the primary value creation system for this deliverable, is examined in detail.

The next subchapter introduces methodologies to describe and visualise business models highlighting the approach of Osterwalder und Pigneur (2010) and Gassmann et al. (2014).

To conclude the theoretical background, the value flow model approach of den Ouden (2012) is presented as an instrument for mapping the status quo of the multimodal freight transport network, displaying the various value streams connecting the relevant roles within the ecosystem.

2.1 Value Creation System

This section explores the concept of Value Creation Systems (VCS), including its archetypes such as business ecosystems, clusters, and value networks. Emphasis is placed on the business ecosystem as the central VCS archetype relevant to ReMuNet.

2.1.1 Concept Definition

A VCS is a network of diverse actors who engage in interactions characterised by cooperation, competition, and co-opetition[1], all with the shared goal of generating monetary profit while driving innovation (Parolini 1999). Central to the effectiveness of a VCS is its ability to manage the inherent complexity and dynamism of the value creation process, ensuring the seamless flow and exchange of resources among its participants (Lusch und Vargo 2014). The roles assigned to each actor within the system define their specific contributions to the overall value creation process, making the interplay of these roles crucial for the system's success (Parolini 1999).

[1] The concept of "**co-opetition**" describes a situation in which two or more businesses engage in simultaneous *cooperation* for the purpose of value creation, while simultaneously engaging in *competition* with the goal of maximizing individual value capture Brandenburger und Nalebuff 1997.

Within a VCS, a broad spectrum of entities – including companies, public institutions, families, and non-profit organisations – contribute to value-creating activities (Parolini 1999). These entities interact through the exchange of both tangible and intangible resources, such as financial capital, information, and relational networks. The efficiency and output of the system are directly influenced by the nature and quality of these exchanges (Parolini 1999). Moreover, the regulation of value-creating activities within a VCS is often facilitated by a combination of hierarchical organisational structures and networked cooperation, which together accommodate the diverse entities involved and enable a variety of value-creating processes (Parolini 1999).

Building on this foundational understanding, the ReMuNet project adopts the concept of a VCS as a key framework for analysing and enhancing the European freight transport ecosystem. Specifically, the project places the business ecosystem archetype at the core of its investigation, where the focus is on how multiple actors collaborate to improve transportation efficiency, reduce greenhouse gas emissions and address industry challenges. This tailored definition underscores the importance of comprehending role-specific contributions and the dynamics of value exchange within this ecosystem, which are essential for achieving the project's objectives.

2.1.2 Value Creation System Archetypes

Building on this conceptual foundation, the next section compares VCS archetypes, including business ecosystems, clusters, and value networks. The analysis highlights their distinctive characteristics and advantages, with a focus on business ecosystems as most relevant to the ReMuNet project's objectives.

Clusters are geographically concentrated groups of interconnected companies and institutions within a specific field. This proximity fosters intense competition and collaboration, driving innovation and facilitating knowledge exchange (Porter 2000; Porter 1990). The localised nature of clusters means that actors are often deeply embedded in a community-based cooperative environment, where rivalry stimulates continuous improvement and innovation.

Value Networks (VN), in contrast, are not confined by geographic boundaries and can operate on a global scale. These networks involve a variety of industries, creating multidimensional flows of resources, information, and value across different sectors (Allee 2000; Peltoniemi 2004). Unlike clusters, VNs emphasise both competition and collaboration, allowing for dynamic interactions among diverse actors, which enhances adaptability and innovation (Peltoniemi 2004) .

Business Ecosystems (BE) stand out as complex, cross-industry economic communities where organisations and individuals collaborate to produce valuable goods and services (Moore 1993). Unlike clusters, which are industry-specific, and value networks, which focus on cooperative interactions, business ecosystems are characterised by their capacity for co-evolution and coopetition. This means that the actors within business ecosystems continuously adapt and evolve, not only due to internal dynamics but also to changes in the external environment. Business ecosystems are not limited by geographical proximity or industry sectors, allowing them to span across multiple industries and regions, facilitating broader knowledge creation and innovation (Iansiti und Levien 2004; Peltoniemi 2004).

Several key aspects distinctively differentiate these archetypes of VCS, shaping their overall functionality:

Actor behaviour is a fundamental distinguishing factor. Clusters thrive on community-based cooperation, where local collaboration drives success. In contrast, value networks leverage cooperative interactions across industries, while business ecosystems integrate both competitive and cooperative elements, fostering co-evolution and coopetition within and across industries (Peltoniemi 2004).

Industry boundaries also play a crucial role in differentiating these systems. Clusters typically focus on a single industry, allowing for deep specialisation within that field. In contrast, value networks and business ecosystems operate beyond industry-specific limits, with business ecosystems particularly noted for their cross-industry co-evolutionary dynamics (Peltoniemi 2004).

The **exchange of information and knowledge** varies significantly between these systems as well. In clusters, high competition drives intensive information exchange. Value networks, often supported by information and communication technology (ICT), foster cooperative knowledge sharing across industries. Business ecosystems emphasise co-evolution, heavily relying on ICT to facilitate the continuous exchange and creation of knowledge (Iansiti und Levien 2004).

Finally, **power distribution** within these systems also varies considerably. In clusters, power is generally decentralised, with no single actor dominating. In value networks, there may be a dominant actor who exercises some degree of control, though this control is typically less pronounced. Business ecosystems also feature decentralised control, often with one or a few dominant actors guiding the overall direction of the ecosystem (Peltoniemi 2004)

Table 1 provides an overview of key aspects differentiating the VCS discussed above.

Table 1: Comparison of different VCS

Aspect	Clusters	Value Networks	Business Ecosystems
Geographical Scope	Geographically concentrated	Not geographically bound, operates globally	Not geographically bound; spans across industries
Industry Focus	Focused within a single industry	Cross-industry collaborations	Cross-industry, co-evolutionary dynamics
Actor Behaviour	High competition with community-based cooperation	Emphasises cooperation with competition and collaboration	Integrates competitive and cooperative interactions
Roles of Actors	Defined by local context, often fixed	Flexible, spanning multiple industries	Complex and adaptive, promoting co-evolution

Resource Exchange	High levels of resource and knowledge exchange due to competition	Multidimensional resource flows across sectors	Extensive exchange of resources, driven by co-evolution
Power Control	Decentralised, no actor in control	Often a dominant actor with some level of control	Decentralised, often with one or few dominant actors
Information and Knowledge Exchange	Intensive due to competition	Cooperative, often enabled by ICT	Relies heavily on ICT, with a focus on co-evolution
Innovation and Adaptation	Driven by rivalry within a localised area	Enabled by cross-industry cooperation	Focused on continuous adaptation and innovation

2.2 Business Ecosystems

The concept of Business Ecosystems (BE) is crucial for the ReMuNet project, as it provides a strategic framework for the platform to foster collaboration within a competitive landscape. By adopting this approach, the project aims to promote data-sharing among diverse participants by developing tailored incentive systems that align with the unique needs of actors within the ecosystem. Furthermore, establishing a robust governance structure and identifying an accepted operator will safeguard equitable participation, ensuring no stakeholder is disadvantaged. This comprehensive platform and ecosystem design will not only address key stakeholder requirements but also secure a sustainable business model and governance framework for both operator and participants of the ReMuNet platform.

2.2.1 Concept Origin and Definition

The concept of Business Ecosystems was first introduced by James F. Moore in his influential 1993 publication "Predators and Prey: A New Ecology of Competition." In this work, Moore employed the metaphor of a biological ecosystem to describe the complex interactions and co-evolution of companies in the business world. According to Moore, BEs emerge from the convergence of key drivers such as capital, customer interest, talent, and innovation. These drivers collectively lead to the co-evolution of companies that collaborate to create value and achieve competitive advantages within the market (Moore 1993).

Since Moore's introduction in 1993, the concept has become increasingly influential in both academic research and practical strategy discussions. Based on initial works (Moore 1993; Moore 1996), a multitude of research streams on the analysis of ecosystems has emerged. Scholars identified eight ecosystem types called *business ecosystem*, *innovation ecosystem*, *platform ecosystem*, *knowledge ecosystem*, *entrepreneurial ecosystem*, *technology ecosystem*, *industry ecosystem, and circular ecosystem* (Jacobides et al. 2018; Aarikka-Stenroos et al. 2021; Autio 2021). The resulting multitude of definitions, broad scope, and unclear boundaries of the concept pose challenges to researchers and practitioners with respect to a uniform understanding of the concept (Oh et al. 2016; Ritala und Almpanopoulou 2017).

Adner provides an approach to describe ecosystems with the concept of *ecosystem-as-structure* and addresses the existing critique of the ecosystem concept (Hou und Shi 2021). Established approaches – referred to as *ecosystem-as-affiliation* (Adner 2017)– view the ecosystem as a community of connected actors, defined by networks and platform affiliation (Moore 1993; Moore 1996; Autio und Thomas 2014; Jacobides et al. 2015; Rong und Shi 2014). The structuralist approach sees ecosystems as a configuration of activities and actors to fulfil a defined value proposition (Adner 2017).

The ReMuNet project draws on the structural approach to ecosystems, as conveyed by Adner and Jacobides et al.:

*“A [business] **ecosystem** is a dynamic structure of different interdependent yet autonomous actors, who coordinate their complementary activities towards a shared purpose to co-create value.”* (Betz und Jung 2021)

This definition captures the essence of business ecosystems as evolving networks that thrive on collaboration, innovation, and the continuous adaptation of their participants to achieve sustainable success. It is therefore particularly appropriate for ReMuNet, as the project aims to foster a dynamic and collaborative environment where diverse stakeholders can co-create value, continuously innovate, and adapt to the ever-changing demands of the European freight transport sector.

2.2.2 Business Ecosystems Characteristics

BEs are defined by a set of interconnected characteristics that enable them to function as dynamic, adaptive networks of collaboration and innovation. Central to their operation is a shared purpose and vision that binds the ecosystem's participants together. Ecosystems typically develop around a collective vision of what they aim to achieve, providing a common reference point that guides the individual roles and contributions of each actor (Han et al. 2022; Betz und Jung 2021). This shared vision is crucial for aligning the efforts of all participants toward a unified goal, ensuring coherence and coordination within the ecosystem.

A defining feature of BEs is the emphasis on co-creation among all actors. In these ecosystems, every actor is actively involved in the value creation process, contributing their unique insights, resources, and expertise. This collaborative approach often includes the integration of customer feedback and contributions into product development, ensuring that the solutions provided by the ecosystem are closely aligned with market needs (Conrad et al. 2022; Thomas und Autio 2020)

The solutions developed within a Business Ecosystem are often modular and complementary in nature. Modular architecture allows customers to tailor products and services to their specific requirements, providing flexibility and customisation. The standardisation of interfaces, such as APIs, ensures that these modular components are interchangeable, facilitating seamless integration and interoperability within the ecosystem (Thomas und Autio 2020; Jacobides et al. 2018).

Multilateral relationships form the backbone of BEs, characterised by a high degree of interdependence among participants. Unlike traditional one-sided interactions, these relationships involve multiple actors who collaborate and exchange resources in a networked structure. This interconnectedness creates a complex web of dependencies that enhances the ecosystem's resilience and adaptability (Betz und Jung 2021; Adner 2017; Jacobides et al. 2018). The multilateral interdependence within the ecosystem facilitates the exchange of components and materials, enabling a more efficient and cohesive operation (Hofmann Trevisan et al. 2022)

Despite the high level of coordination, the actors within a Business Ecosystem maintain a significant degree of autonomy. No single actor exerts control over the entire ecosystem; instead, coordination is achieved through incentive systems established by a central actor, which encourages cooperation without imposing strict hierarchical control (Jacobides et al. 2018; Williamson und Meyer 2012).

Information-based value creation is another critical characteristic of BEs. The ecosystem relies on shared rules and infrastructures that facilitate the exchange of information, which in turn supports the exchange of products and services. This information flow is foundational to the value creation process, enabling participants to coordinate their activities and optimise their contributions to the ecosystem (Berentzen et al. 2021; Conrad et al. 2022; Jacobides et al. 2018; Thomas und Autio 2020).

The shared values within a BE further influence the interactions and behaviour of its participants. Core values such as sustainability and an entrepreneurial mindset are commonly held by all actors, guiding their actions and fostering a collaborative environment. These shared values are integral to maintaining trust and alignment within the ecosystem, ensuring that all participants are working towards common goals (Betz und Jung 2021; Conrad et al. 2022).

A joint technological infrastructure underpins the operations of a BE, with platforms and standardised interfaces like APIs playing a crucial role in facilitating interaction among actors. This infrastructure allows for the modular addition of new solutions, enabling the ecosystem to evolve and expand without requiring extensive prior coordination (Hoeborn et al. 2022; Thomas und Autio 2020). The presence of a robust technological backbone is essential for maintaining the ecosystem's flexibility and scalability.

Network effects are a key driver of growth within BEs, where positive feedback loops allow the ecosystem to scale rapidly as more participants join and contribute to the value creation process (Conrad et al. 2022). The relationships between actors in the ecosystem are often characterised by complementarities, where the value of one element is enhanced by the presence of another. These complementarities can be unique, supermodular, or generic, contributing to the overall cohesion and efficiency of the ecosystem (Hofmann Trevisan et al. 2022; Jacobides et al. 2018).

In summary, the characteristics of BEs – shared purpose, co-creation, modular solutions, multilateral relationships, autonomy, information-based value creation, shared values, technological infrastructure, network effects, and BEs – work together to create a dynamic and adaptive environment as depicted in Figure 1. This enables ecosystems to thrive in complex and competitive markets, driving innovation and sustained success.

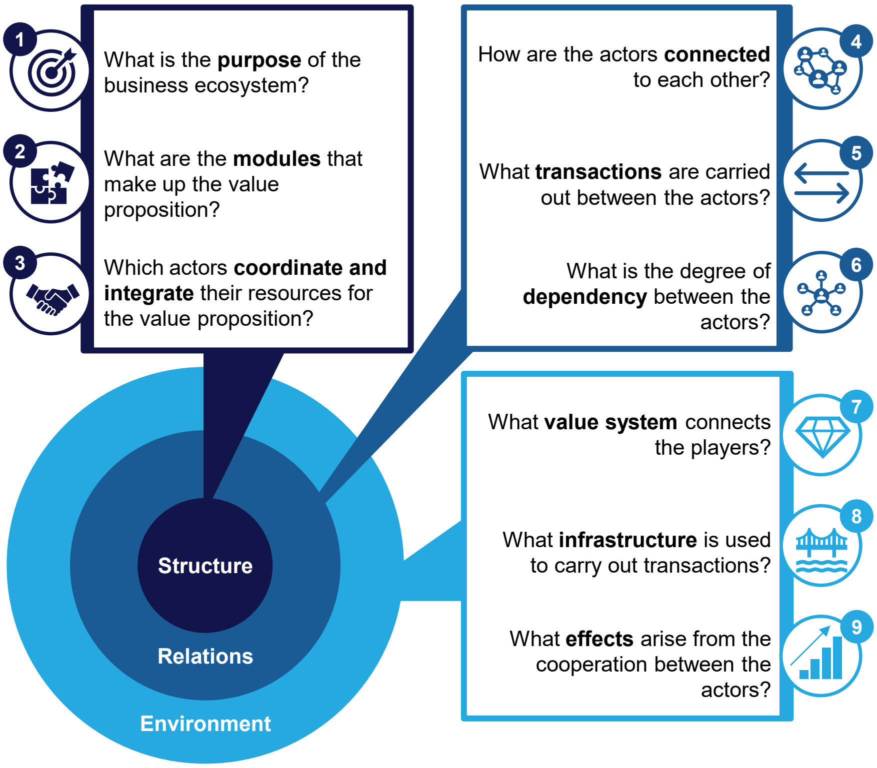

Figure 1: Ecosystem characteristics based on Conrad et al. (2022)

2.2.3 Strategic Role Models

Adner's (2017) Ecosystem-as-Structure approach provides a comprehensive framework for understanding the intricate dynamics of business ecosystems (BEs). Central to this approach are four key elements: activities, actors, positions, and links.

Activities refer to the discrete actions necessary to realise the ecosystem's focal value proposition (VP). **Actors** are the entities responsible for carrying out these activities, contributing their unique resources and capabilities. **Positions** define the roles and locations of these actors within the flow of ecosystem activities, determining how they interact with one another. Finally, **links** describe the connections between actors, facilitating the transfer of information, materials, and other resources within the ecosystem (Adner 2017).

Within this structural framework, the roles of actors in a business ecosystem become crucial for the system's overall functionality and success. Strategic Role Models (SRMs) are instrumental in this context, as they provide a structured way of analysing how different roles contribute to value creation and ecosystem sustainability. SRMs are essentially constellations of roles within a Value Creation System (VCS), offering insights into the characteristic behaviours and activities of ecosystem actors and explaining how these contribute to the viability of the ecosystem as a whole (Burkhalter et al. 2021; Dedehayir et al. 2018). In business ecosystems, roles can vary widely but generally fall into a few key categories.

Leaders are actors who drive the ecosystem forward, often holding central and influential positions. These leaders guide the ecosystem's strategic direction and often set the tone for innovation and collaboration (Moore 1993; Moore 1996; Iansiti und Levien 2004).

Niche players ensure the ecosystem's functionality by providing complementary products or services essential for value creation. They may not hold central positions but are critical for the ecosystem's health and sustainability (Iansiti und Levien 2004).

Value creation intermediaries include roles such as customers, suppliers, and assemblers, who are vital to the ecosystem's value creation process. These actors may not lead the ecosystem, but their contributions are indispensable, as they help in refining and delivering the final value proposition (Hoeborn und Gonzalez 2023).

Another critical role is that of **keystone players** - central figures who maintain the ecosystem's overall health by fostering innovation and ensuring that all actors benefit from the ecosystem's activities. Rather than exercising direct control, keystones provide indirect leadership, guiding the ecosystem's evolution through incentives and strategic influence (Iansiti und Levien 2004; David J. Teece 2017; Adner 2017).

An overview of strategic role models can be found in Table 2:

Table 2: Overview of strategic roles (Hoeborn und Gonzalez 2023)

<table>
<tr><th>Strategic Role Models</th><th colspan="6">Roles</th></tr>
<tr><td>Moore (1993, 1996)</td><td>Leader</td><td>Follower</td><td colspan="2">Outsider</td><td colspan="2">Customer</td></tr>
<tr><td rowspan="2">Iansiti & Levien (2004)</td><td colspan="2" rowspan="2">Keystone</td><td colspan="2" rowspan="2">Niche Player</td><td colspan="2">Dominator</td></tr>
<tr><td>Physical</td><td>Value</td></tr>
<tr><td>Adner (2006, 2017)</td><td colspan="2">Leader</td><td>Follower</td><td>Complementor</td><td colspan="2">Intermediaries</td></tr>
<tr><td>Gawer & Cusumano (2008, 2014)</td><td colspan="2">Platform Leader</td><td colspan="2">Complementor</td><td colspan="2">Platform leader-wannabe</td></tr>
<tr><td rowspan="2">Kastalli & Neely (2013)</td><td colspan="2">Architects</td><td>Solvers</td><td>Constructors</td><td colspan="2">Resources</td></tr>
<tr><td>Hub-Influencer</td><td>Scales – Niches Innovators</td><td colspan="2">Connectors and Integrators
Facilitators – representatives – promoters
Infrastructure</td><td colspan="2">Talent & Knowledge Capital</td></tr>
<tr><td>Jacobides et al. (2018)</td><td colspan="2">Hub</td><td colspan="2">Complementor</td><td colspan="2">Customer</td></tr>
<tr><td rowspan="2">Dedehayir et al. (2018)</td><td>Leadership Roles</td><td>Direct Value Creation</td><td colspan="2">Value Support</td><td colspan="2">Entrepreneurial</td></tr>
<tr><td colspan="2">Ecosystem Leader – Dominator</td><td>Supplier – Assembler
Complementor – User</td><td>Expert – Champion</td><td colspan="2">Entrepreneur – Sponsor
Regulator</td></tr>
</table>

Understanding these roles is vital for comprehending how BEs function and thrive. Each role, whether central or peripheral, contributes to the ecosystem's ability to create and sustain value. SRMs help clarify these contributions, allowing actors within the ecosystem to align their strategies and activities more effectively with the collective goals of the ecosystem. Moreover, the adaptability of roles within an ecosystem is crucial as actors often hold multiple roles or switch roles based on situational needs, enhancing the ecosystem's flexibility and resilience in a dynamic market environment (Kastalli und Neely 2013; Burkhalter et al. 2021)

2.3 Business Models

A Business Model (BM) is a strategic blueprint that shows how a company or organisation plans to create, deliver and capture value. It includes key resources, activities and partnerships (Osterwalder und Pigneur 2010). In addition, it entails information about their services, products, markets and cost structure. Furthermore, its value proposition explains what distinguishes this offering from other existing products on the market and what makes it particularly appealing to the target customer (Nielsen et al. 2018). Every new company or organisation, regardless of its industry or maturity level, needs a business model to create an understanding of its business operations and strategic direction (Nielsen et al. 2018). In addition, these models help companies to secure investments, attract new talent and increase the motivation of existing employees. Today, many companies and organisations use multiple business models rather than relying on just one. Given current trends and challenges, business models should be regularly evaluated and adjusted if necessary (Osterwalder und Pigneur 2010).

Gassmann et al. describe the importance of a business model as a holistic picture of how a company creates and captures value. The business model should therefore capture and define the who, what, how and why of a company. When innovating a business model, at least two of its dimensions need to be changed (Gassmann et al. 2014). Figure 2 shows how business models can be presented in the form of a "magic triangle". This framework illustrates the core components of a business model and their interrelations. It highlights how a company creates value, delivers it to customers, and ensures profitability.

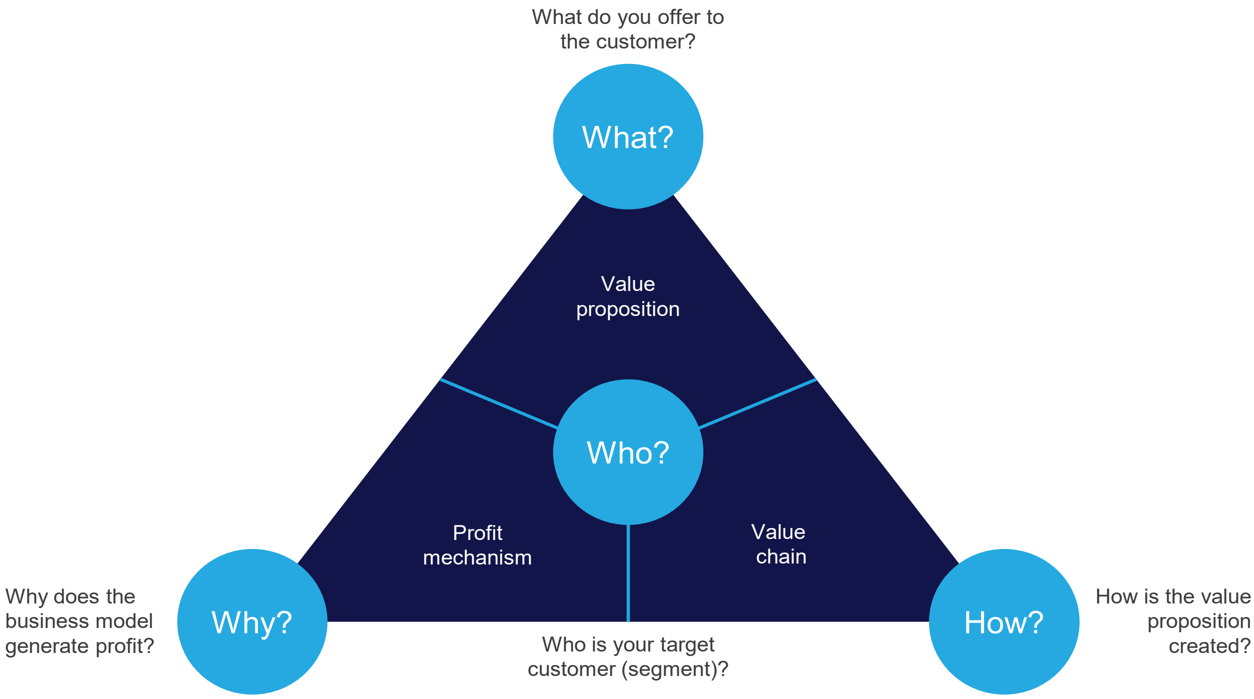

Figure 2: Business model as magic triangle (Gassmann et al. 2014)

Target Customers (Who?)

The initial dimension, centred in the triangle, pertains to the customer base, particularly the target customers that the business aims to serve. It involves understanding the specific audience that requires or values the offered product or service.

Value Proposition (What?)

The top dimension is concerned with the value proposition. In other words, it demonstrates the products and services that the company offers to its customers. It reflects the combination of functionality, benefits and solutions that the company provides to solve customer problems or fulfil their needs.

Value Chain (How?)

The value chain functions as a third dimension, with the primary focus being on the creation of the value proposition. This entails the various activities, processes, resources, and capabilities that function collectively to produce the desired value, all coordinated within the company's operational framework.

Profit Mechanism (Why?)

The fourth and final dimension is the profit mechanism, which addresses the question of why the business model generates earnings. It demonstrates how the model is economically sustainable through encompassing factors like cost structures and revenue streams, thereby clarifying the financial viability of the business.

2.4 Value Flow Modelling

The Value Flow Model according to (den Ouden 2012) is a methodical approach for analysing and designing value flows in complex systems, particularly in the context of innovation processes. It focusses on how value is created, transformed and exchanged by different actors in an ecosystem.

Value itself is defined as an adequate equivalent, a material or monetary worth or just generally worthiness. Stemming from the Latin word 'valere', something with value was considered as something strong or worthy (den Ouden 2012). Value as a conceptual idea has a different motivation and meaning on different levels and sections within the ecosystem Figure 3. As for ecosystems the economic value is determined by stability and profits from all involved and participating stakeholders. The psychological value of the ecosystem for the stakeholders relies on shared drivers and core values. Shared drivers can be individual motivations or the overall objective of the ecosystem. In terms of societal aspects within the ecosystem, value is generated through reciprocal relationships and transactions. The ecological value of the ecosystem is generated by having a sustainable network (den Ouden 2012).

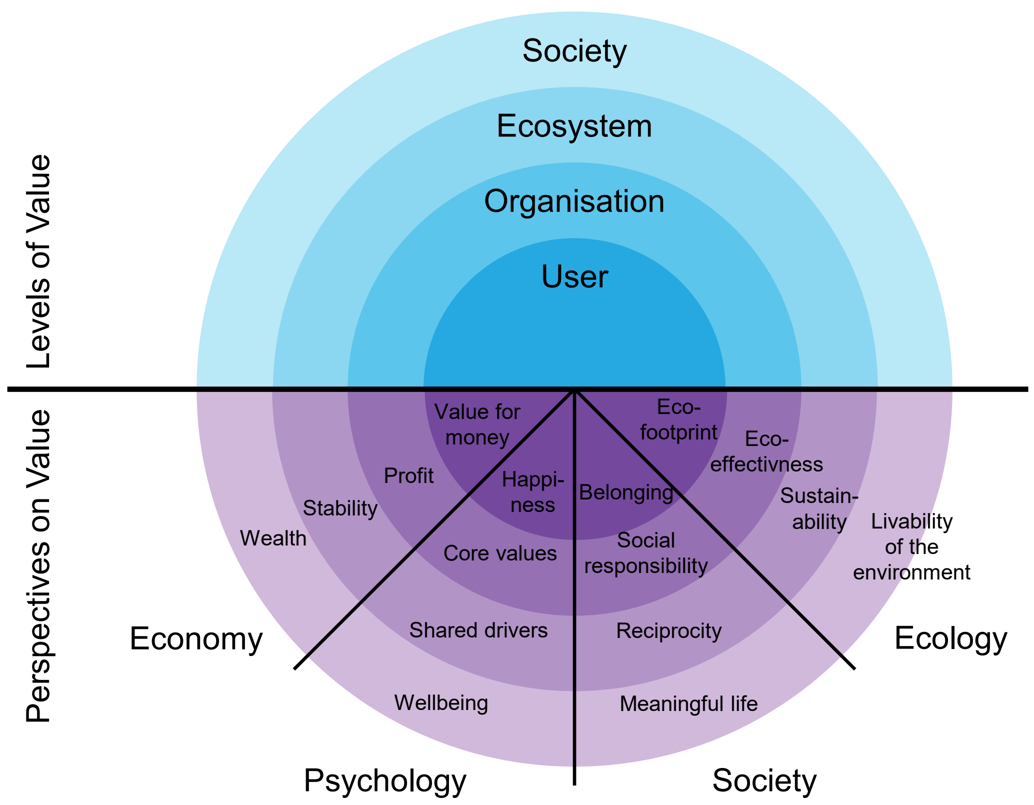

Figure 3: The value framework (den Ouden 2012)

2.4.1 Elements of the Value Flow Model

Value flow models after den Ouden (2012) differentiate nine distinct elements. The first element comprises the **actors**, i.e. relevant stakeholders and roles within the multimodal transportation ecosystem. **Motivations** are closely related to the actors and reflect the beliefs and interests within the network. Thirdly, **compatibility and influence** describe the relationship between the actors' motivations and their value proposition. **Investments and throughput time** comprise monetary and time requirements within the network so that actors can develop further. **transactions** are the flow of values between actors. In terms of mapping the value flows, **core value proposition**, **complementary offerings** and **supplying and enabling network** indicate the different areas of the network that make up the ecosystem to be described. Finally, **other stakeholders** describe actors outside the network who nevertheless have an influence on value creation (den Ouden 2012).

Selected elements are presented in detail below. These are used in this deliverable to create the value flow models. The other elements are not used further, as they are not sufficiently relevant for the analysis of the ecosystems in the context of ReMuNet and the creation of a catalogue of requirements for a digital platform.

Ecosystem Roles and Actors

Roles do not represent specific companies but embody skills and characteristics that are required for the ecosystem. Different roles differ in these and are thus clearly separated from each other. The interaction of all roles and actors enables value creation in the ecosystem (den Ouden 2012). The identification of relevant roles for the European freight transport ecosystem has already been part of D1.1 and is briefly summarised in chapter 4.1.

Core Value Proposition, Offerings, and Networks

The core value proposition describes what creates value to a customer and what a company is being paid and recognised for. Without a core value proposition there would be no value at all. Complementary offering might increase attractiveness of the core value proposition to the customer or address additional markets not satisfied with the core value proposition alone. The supplying and enabling network both encompass all actors necessary for offering the core value proposition like suppliers or other relevant enablers. Other actors might also be important to the ecosystem without directly affecting the core value proposition. Society at large for example is a role which might be considered additional (den Ouden 2012).

Transactions

Transactions within an ecosystem can be distinguished into four types of value (den Ouden 2012):

Table 3: Transactions of the value flow model (based on den Ouden 2012)

Goods and services	Produced products or offered services from a supplier, manufacturer or service provider for customers. Sometimes, multiple goods and services can be intertwined and thus summed up for simplicity.
Money and credits	Money includes all monetary streams between two actors including payments, contracts and invoices. Credits on the other hand might also be virtual such as bonus programs or loyalty bonuses.
Information	This covers a broad field of all kinds of information and data generated or exchanged between stakeholders. They might aim to monitor, to educate, to inform or to create knowledge.
Intangibles	Everything that cannot be described as one of the above categories is described as intangible. Notable difference to the other types is that intangibles never change when exchanged between actors.

The identification of transactions between actors of the European freight transport ecosystem is a central part of the online survey, expert interviews and workshops attended by relevant actors of the multimodal transportation sector.

2.4.2 Value Flow Mapping

Corresponding models are developed from the relevant elements of the value flow model. The sequential process can be structured in the following steps (den Ouden 2012):

1. **Identifying key roles of the ecosystem**

   Building on the findings from D1.1, for each role its core value proposition will be identified and concluded into business model frameworks following the fundamentals presented in chapter 2.3.

2. **Mapping of actors according to their business model**

   Based on the business model insights relevant actors will be arranged according to the core value proposition, the complementary offerings, and supplying and enabling network of the European multimodal freight transport network as a status-quo mapping of the current ecosystem.

3. **Mapping of transactions to value flow model**

   At last, the identified value streams are visualised connecting the relevant actors of the ecosystem resulting in a value stream model mapping an ecosystem in its desired state. Transactions and the overall flow of value has been identified using desk research, expert interviews and workshops with ecosystem stakeholders.

According to the purpose of this Deliverable the created value flow model will map the current status-quo of the European multimodal freight transport ecosystem with all relevant roles and stakeholders building on the findings of D1.1. This status-quo model forms the basis for D3.3 containing the design of a multimodal freight transport ecosystem orchestrated by the digital ReMuNet platform.

3 Research Design and Data Collection

A status quo analysis of the European multimodal freight transport ecosystem requires a detailed understanding of stakeholders, their business models, processes, information exchanges, information systems, and transport procedures. Building on insights from Deliverable 1.1, which outlined stakeholder roles and relationships, this deliverable focuses on mapping value streams and defining business models for key actors within the two focus corridors of the ReMuNet project.

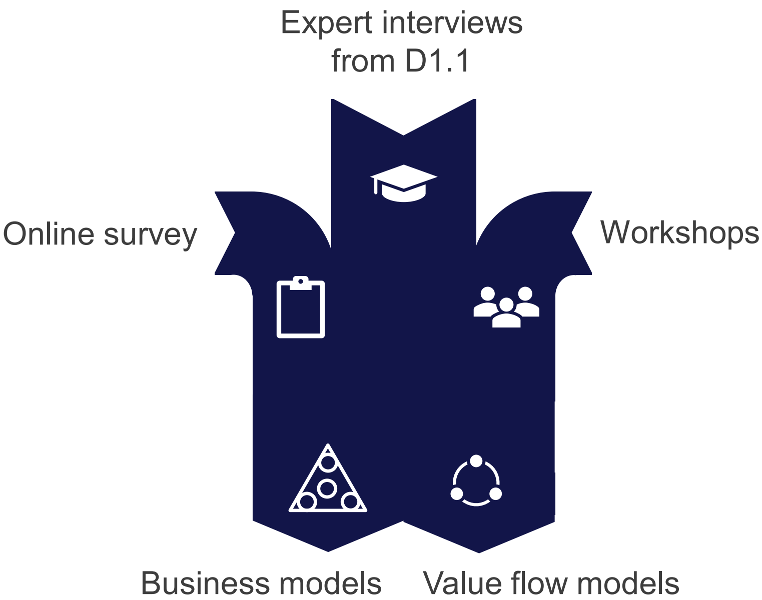

Figure 4: Framework for the research design and data collection

Insights from expert interviews conducted for the previous deliverable, which detailed processes, information exchanges, and stakeholder challenges, serve as the foundation for developing business models and value flow models. These insights are further enriched with data from a quantitative online survey and multiple workshops involving industry experts from the European multimodal freight ecosystem.

3.1 Expert Interviews

24 semi-structured interviews with industry experts from the European freight transport ecosystem were conducted during the preparation of Deliverable 1.1. Using a standardised interview framework and a digital whiteboard, these interviews provided detailed, high-quality insights into the unique demands and processes of the industry, enhancing the ecosystem analysis. Combined with a survey and expert workshops, these methods ensure comprehensive coverage of the study area and a representative analysis of the ecosystem. The interviews were structured around six key questions designed to capture stakeholders' perspectives on business models, value flows, and the characteristics of the European freight transport ecosystem:

1. What are the main activities of the company and what are its economic key value propositions?
2. Which customer segments does the company serve and what data is exchanged?
3. What contribution does the company make to sustainability in day-to-day business, but also regarding incidents?
4. What are the main challenges that the company faces in its operations and how have they been addressed so far?
5. Which disruptions affect the company the most or most frequently and what challenges does it face in overcoming them?
6. How can digital solutions contribute to better disruption management and what has hindered implementation so far?

While expert interviews offer valuable insights into the multimodal freight transport ecosystem, several limitations must be acknowledged. Responses may be influenced by subjectivity and bias, as experts' perspectives are shaped by personal experiences and institutional affiliations. This can result in biased interpretations. Additionally, the limited sample size restricts generalisability, as the findings may not fully represent the broader industry or capture diverse regional and sectoral perspectives. The scope of expert interviews may also exclude critical topics, as discussions often focus on the interviewees' specific expertise or interests.

However, combining the interviews with an online survey mitigates these limitations, ensuring more representative and reliable findings for mapping the status quo of the multimodal freight transport ecosystem.

3.2 Quantitative Survey Research

Surveys, widely used as an exploratory research instrument (Mummendey und Grau 2014), enable generalisation to larger groups by collecting data from representative system samples. They facilitate the examination of multiple variables in a short timeframe, yielding numerous findings with relatively low effort. Standardised answer options allow for easy quantification of key insights, aiding in the measurement of complex contexts such as stakeholder relationships or value streams within ecosystems (Glasow 2005). Survey data can be efficiently analysed using descriptive and inferential statistical methods, ensuring valid and reliable results (Mummendey und Grau 2014).

An online survey was conducted to collect data and information for mapping the current transport ecosystem. The survey focuses on three key research areas essential for analysing the status quo of the European freight transport ecosystem:

- Detailed characterisation of multimodal supply chain actors across a broad range of variables.

  A clearer understanding of roles, particularly their functions within the transport network, is crucial for identifying relationships and exchanges between them. This understanding supports mapping the current multimodal transport ecosystem for the Rhine-Danube and North Sea-Baltic corridors. The collected data will inform the development of role-specific characteristics, common business models, and exchanged value flows within the transport sector.

- Assessment of whether actors view ReMuNet as a viable solution for improving transportation efficiency and addressing industry needs and challenges.

  Identifying role-specific shortcomings, pain points, and needs is essential for developing a trusted digital platform solution like ReMuNet.

- Exploration of requirements and concerns related to ReMuNet as a digital platform.

  Building on the identified needs and challenges, a requirements catalogue must be developed to address these shortcomings and deliver an effective, robust solution.

The survey builds on insights from Deliverable 1.1 and aims to identify role-specific shortcomings, pain points, and needs, as well as exchange relationships within the transport ecosystem. The outcomes include role-specific profiles detailing inter-role relationships, common business models characterising the multimodal transport ecosystem, and requirements catalogue for designing the ReMuNet digital platform.

To achieve these objectives, the questionnaire is structured into six main topics, incorporating various question formats such as free text, single choice, multiple choice, rankings, and Likert scales:

1. **Logistics:** General questions about order handling and transportation processes in logistics companies to enhance role understanding.
2. **Corridor:** Identification of key TEN-T corridor actors and mapping of intermodal ecosystems specific to the focused corridors.
3. **Business models:** Identification of relevant business models of logistics stakeholders to enhance role understanding.

4. **Digital platforms:** Collecting insights on information flows, exchange relationships between roles, stakeholders' use of digital platforms, and identifying requirements for the ReMuNet platform.
5. **Needs:** Confirming identified needs and evaluating the potential of ReMuNet to address them effectively.
6. **General information:** Collecting general demographic information about stakeholders and their companies.

A complete catalogue of all questions from the online survey is included in Annex I. The survey design supports the creation of business model canvases based on Osterwalder und Pigneur (2010) and Gassmann et al. (2014) for relevant stakeholders and key roles in the multimodal transport ecosystem. This effort contributes to the design of the ReMuNet ecosystem, to be developed in Deliverable 3.3.

The survey questions were developed iteratively through multiple brainstorming sessions, drawing on insights and experiences from the survey conducted for Deliverable 1.1. Certain aspects were validated by consortium partners and enhanced with input from corridor experts, particularly for questions concerning key actors in the TEN-T corridors. Dissemination began on August 1st through online platforms such as LinkedIn and email, targeting approximately 450 European freight transport experts. The survey, open until November 15th, received 54 responses.

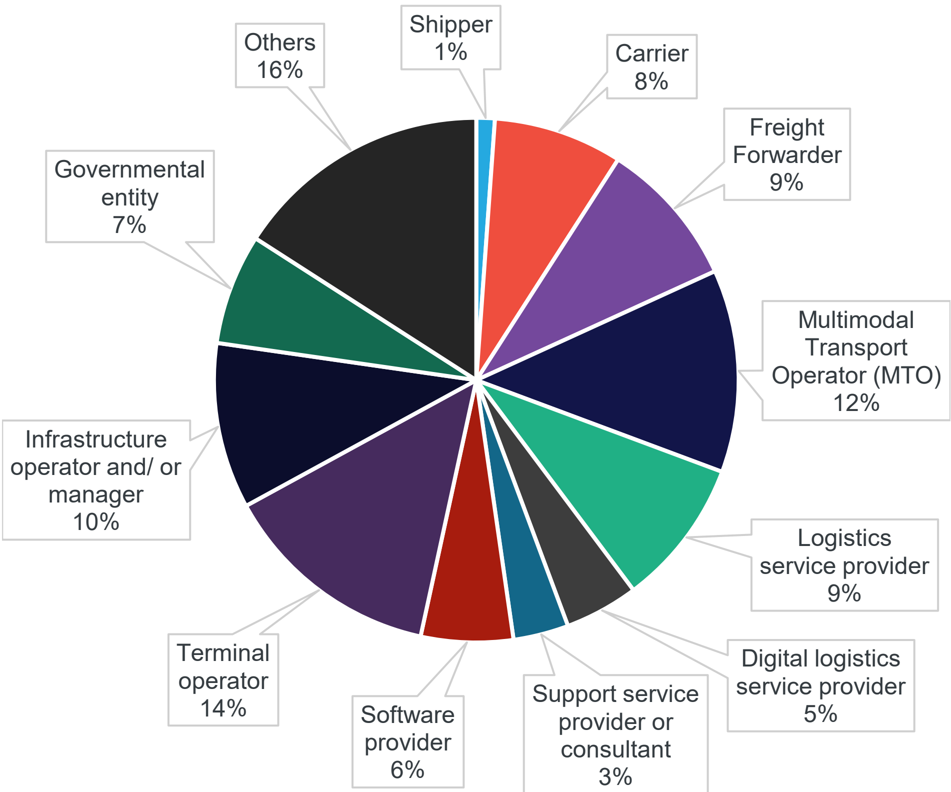

Figure 5: Distribution of survey participants by role

The survey reached a broad range of actors from both corridors, as illustrated in Figure 5. The roles within the multimodal transport ecosystem, which are going to be defined during the ecosystem mapping, are well-represented in the survey results. However, categorising some companies into a single role is challenging due to overlapping activities. Notably, only 11% of respondents are companies focused on digital solutions, such as digital logistics service providers and software providers. In contrast, other categories are well-distributed, covering all key areas and activities of the transport ecosystem.

Around 50% of surveyed companies report annual revenues exceeding €50 million and employ over 250 people (see Figure 6). Smaller enterprises are also well-represented, with 25% reporting revenues below €2 million and 17% employing fewer than 10 people. This diverse mix of participants highlights the broad spectrum of contributors to the transport ecosystem captured in the survey.

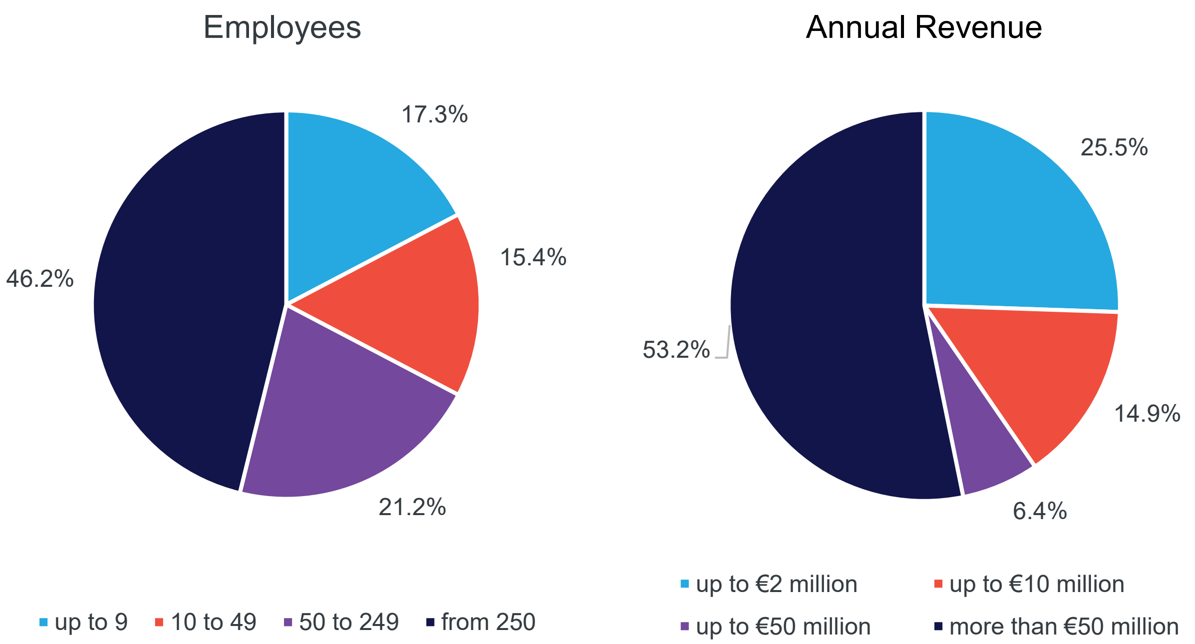

Figure 6: Proportion of SMEs among the participants

An online survey can only reveal associations between variables, not causation, and its level of detail is limited, providing estimates rather than precise measurements. To address these limitations, expert interviews and workshops were conducted to validate the survey findings and enrich them with detailed insights, creating a clearer and more comprehensive understanding of the multimodal freight transport ecosystem.

3.3 Workshops

To develop a comprehensive understanding of the multimodal freight transport ecosystem and establish a shared foundation for stakeholder discussions, a series of structured workshops was organised. These workshops built on insights from expert interviews, which provided an initial framework for describing the ecosystem's components and flows. The sessions were instrumental in identifying pain points and defining the requirements for the ReMuNet solution in a structured and complete manner.

A key focus of this deliverable is detailing the various aspects of the multimodal freight transport ecosystem. This inherently complex system involves multiple interconnected flows, including the movement of physical goods, information exchanges, and financial transactions among diverse stakeholders and processes. Describing these flows fosters a shared understanding, improving communication and collaboration among stakeholders.

To facilitate visualisation and discussion, a Business Process Model and Notation (BPMN) tool was employed. Initial findings from desk research and expert interviews on multimodal transport processes were prepared using BPMN, presented in a clear and standardised visual format. During the workshops, experts from various segments of the transport process participated in interactive sessions via video calls with screen sharing. Participants were selected for workshops with different focal points based on the following criteria:

- The specific part of the process targeted in the workshop, such as the first and last legs, the main leg, information flows, or requirements
- Participants who can provide insights on the same focus area but represent different roles within the business ecosystem
- Participants' level of familiarity with the ReMuNet project, ranging from consortium members to those familiar with or new to the project

During the workshops on process and flow mapping, participants were guided through visualised transport processes, with each action and decision point explained in detail. This collaborative walkthrough facilitated real-time discussion, correction, and validation of the models. Participants contributed expertise-based insights, leading to iterative adjustments and improvements to the process models after each session.

Building on the pain points identified in Deliverable 1.1, the workshops also aimed to integrate these issues into the process models while uncovering additional challenges. By systematically analysing each step of the transport process, participants identified specific locations of inefficiencies, delays, and communication breakdowns. This approach localised pain points within the visualised processes, providing stakeholders with the context needed to consider targeted solutions. In subsequent workshops, the requirements identified from earlier sessions were presented for stakeholder review and critique. This collaborative setting fostered open dialogue, enabling participants to challenge assumptions, propose modifications, and validate the feasibility of each requirement. New pain points and requirements emerged through these discussions and were incorporated into an evolving and comprehensive list of stakeholder needs.

The workshops were a key component of the methodology for this deliverable. By engaging stakeholders in process visualisation, pain point identification, information flow analysis, and requirement definition, the findings were firmly grounded in practical industry experience. This ensured alignment with real-world needs. However, some limitations of this approach must be acknowledged. Workshop findings have limited generalisability, as insights from a specific participant group may not represent the broader industry or reflect diverse regional and sectoral perspectives. Additionally, the virtual workshop format may have affected participant interaction dynamics compared to in-person sessions.

Despite these limitations, combining workshops with other methods, such as expert interviews and surveys, mitigated these challenges. The collaborative approach yielded a validated, detailed description of transport processes, a clearer understanding of pain point locations, and a well-defined set of requirements for developing the ReMuNet solution. This comprehensive methodology ensured representative and reliable findings, effectively mapping the status quo of the multimodal freight transport ecosystem.

4 Mapping the multimodal transport network

Multimodal transport networks form a complex and dynamic ecosystem that is essential to global trade and markets. These networks coordinate various transportation modes - such as road, rail, and waterways - to move goods efficiently from origin to destination. At their core, multimodal transport ecosystems comprise interconnected stakeholders, infrastructure, technologies, and regulations that collectively enable seamless transitions between transport modes.

This ecosystem is marked by intricate relationships, high interdependence, and a strong need for coordination to optimise performance and meet the demands of global supply chains. It operates through a web of interactions, balancing cooperation and competition among participants to achieve efficiency and reliability:

- **Horizontal Collaboration**: Partnerships between companies at the same level, such as carrier alliances, to share resources and optimise capacity utilisation. Horizontal cooperation – when well conducted - benefits the customer experience (Cruijssen et al. 2007).
- **Vertical Collaboration**: Coordination between different levels of the supply chain, such as between shippers and orchestrators, to enhance service quality and efficiency (Barratt 2004).

Collaboration and competition among actors in the multimodal transport ecosystem occur across multiple layers and through various modes of interaction. This chapter aims to clarify these dynamics by first defining and conceptualising the roles within the ecosystem as nodes in the system, building on the findings and descriptions from Deliverable 1.1. Subsequently, the interfaces between the different modes of interaction are analysed and detailed.

4.1 Ecosystem Roles

The previous deliverables, D1.1 and D1.2, identified key roles within the multimodal freight transport network (von Stamm et al. 2024; see Feyen und Penet 2024). Understanding and characterising these central roles is essential for analysing the ecosystem according to the Value Flow Model outlined by den Ouden (2012) (see section 2.4). Since individual actors are critical to realising the ecosystem's value proposition (Adner 2017), a detailed analysis of their value creation logics and business models is required. The role profiles in subsections 4.1.1 to 4.1.12 are structured based on the four-component framework by Gassmann et al. (2014). Additionally, key activities for each role, derived from survey results, are presented in diagrams. These visualisations illustrate the number of actors within each role engaging in specific activities, providing a clear overview of their operational patterns.

The role profiles described form the foundation for developing the ReMuNet ecosystem in Deliverable 3.3, integrating digital innovations introduced by the ReMuNet consortium. Figure 7 illustrates the essential roles within the ecosystem, serving as the basis for the value flow model developed in this deliverable. In the following chapters, the flows of goods and services, information, and finances are visualised using this diagram and are ultimately presented in a consolidated format.

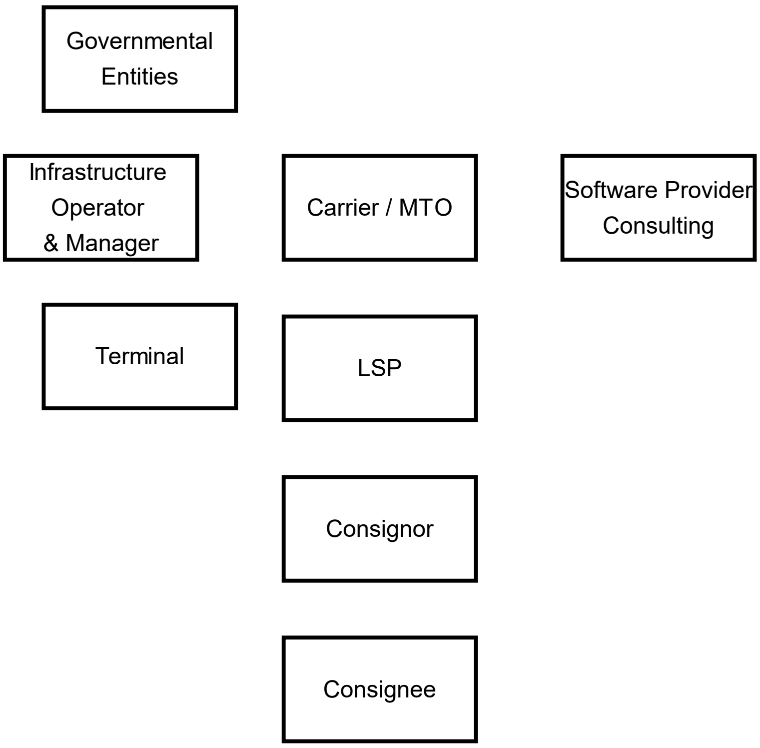

Figure 7: Roles in the European multimodal freight transport ecosystem

4.1.1 Consignor

The consignor, or shipper, initiates the transport process by supplying goods for shipment and typically contracting freight forwarders or multimodal transport operators. While direct transport management is possible, it is uncommon due to the complexities of international supply chains. As the initial owner of the goods, the consignor primarily serves consignees

- businesses or final consumers - by preparing shipments, ensuring proper loading and packaging, and managing freight data (see Table 4).

Table 4: Business model of the Consignor

Role	Who?	What?	How?	Why?
Consignor	Consignees (Business or final consumer)	Goods, including stuffing and packaging, are items required by customers for specific purposes. These goods must be transported to consignees in a predictable manner, enabling them to plan production processes or personal use effectively.	Key activities include planning production and transportation while ensuring the accuracy of static freight data. This involves coordinating and managing transportation arrangements and, in some cases, preparing packaging. These tasks are often carried out in collaboration with partners within the transport network.	Most consignors differentiate themselves through unique selling points such as quality, price, or niche products, making them attractive to customers. Expanding market accessibility by shipping to distant locations meets the demands of a broader customer base. While this incurs additional supply chain costs, most customers are willing to bear these costs due to the value offered, ultimately increasing revenue for consignors.

Consignors play a critical role in the multimodal transport ecosystem by arranging transportation and keeping consignees informed about delivery timelines. Through collaboration with freight forwarders, carriers, and terminal operators, consignors gain access to broader markets, efficiently reaching distant customers. This expansion generates new revenue streams and strengthens supply chains. The interconnected nature of the ecosystem allows consignors to reduce shipping costs and improve delivery times, creating value for their customers while benefiting from enhanced logistical efficiency (von Stamm et al. 2024; Feyen und Penet 2024).

4.1.2 Consignee

The consignee, or receiver, initiates the consignment process by placing an order with the consignor and is entitled to receive the goods as specified in the transport documents. Consignees also hold rights under the transportation contract, including specifying the delivery location and providing instructions to the carrier (von Stamm et al. 2024). The typical business model for consignees following the structure of Gassmann et al. is depicted below in Table 5.

Table 5: Business model of the Consignee

Role	Who?	What?	How?	Why?
Consignee	No further customer	Manufactured goods are produced using received freight and supplied to other companies to meet their specific demands. The services provided	Ordering goods and specifying requirements are essential for manufacturing products or delivering services. Key activities include planning operations	Consignees leverage their knowledge to create new value from the goods received, producing offerings that customers are willing

		can range from highly flexible and rapid responses over short-term needs to long-term, regular operations.	and defining transportation requirements, such as timelines, regularity, and costs, to ensure efficient integration into the production or service process.	to purchase. However, ordering goods involves risks related to time and cost planning, particularly in the event of disruptions.

In the multimodal transport ecosystem, the consignee serves as the endpoint for goods, whether as end consumer or business acquiring products for resale or further processing. The consignee's role includes ordering goods, defining requirements, and taking responsibility for deliveries upon receipt.

4.1.3 Logistics Service Provider

Logistics Service Providers (LSPs) play a vital role in supply chains, offering various services such as warehousing, commissioning, packaging, and various value-added activities (von Stamm et al. 2024; Feyen und Penet 2024). With technological advancements, Digital Logistic Service Providers (DLSPs) have emerged, specialising in digital solutions like business analytics, route planning, fleet management, and supply chain optimisation, predominantly operating without physical assets. LSPs are categorised as "nth Party Logistics Providers" (nPLs). Third-Party Logistics Providers (3PLs), mainly freight forwarders, handle core logistics activities and coordinate among consignors, carriers and further service providers, while Fourth-Party Logistics Providers (4PLs) focus on strategic supply chain development and optimisation, typically without owning physical assets (see Table 6).

Table 6: Characterisation of logistics service providers (von Stamm et al. 2024)

SERVICE CHARACTERISTICS OF LSPs	1PL	2PL	3PL	4PL	DLSP
Self-management of logistics function (own assets)	X	X			
Lease of own transportation (asset-based logistics services)		X	(X)		
Transportation and freight forwarding		(X)	X	X	(X)
Warehousing, including inventory management		(X)	X	X	
Picking, packing, and labelling		(X)	X	X	
Reverse logistics (returns), customer relationship management			X	X	X
Project management (PM), sourcing and negotiations				X	(X)
Consultancy function				X	X
End-to-end integration				X	(X)
Logistics planning and control				X	X

Table 6: Characterisation of logistics service providers (von Stamm et al. 2024)

SERVICE CHARACTERISTICS OF LSPs	1PL	2PL	3PL	4PL	DLSP
Transport management (3PL management)				X	X
Main activity: Provision of digital logistics services				(X)	X

4.1.4 Carrier

Carriers are responsible for transporting goods between supply chain nodes using various modes, with a focus on road, rail, inland waterways, and short sea shipping within the ReMuNet project. They may be contracted directly by consignors or through intermediaries such as freight forwarders, typically consolidating goods into intermodal transport units (ITUs). In intermodal transport, carriers operate between terminals or between terminals and consignors or consignees. Road transportation specialists, commonly known as "road haulers," are integral to the multimodal transport ecosystem. Carriers contribute by providing the physical assets required to move goods efficiently between consignors, terminals, and consignees. Their diverse customer base includes consignors, freight forwarders, multimodal transport operators, and digital logistics service providers. Carriers primarily offer transportation services across various modes, such as road, rail, and waterways. By owning and maintaining transportation assets, they ensure the efficient flow of goods across supply chain segments. They coordinate transport arrangements, manage exclusive contracts, and optimise delivery schedules to meet customer requirements effectively.

While all carriers provide the essential service of transporting goods, there are distinct differences based on the mode of transportation. Road carriers excel in providing flexible and speedy transport for small to medium-sized shipments over shorter distances. Railway carriers, on the other hand, are better suited for long-distance and large-volume shipments, focusing on cost efficiency but with less flexibility due to fixed schedules and routes. IWW (Inland Waterways) and Short Sea carriers prioritise cost-effective solutions for transporting bulky cargo over long distances but are slower and more dependent on weather conditions, e. g. water levels. Together, these carriers create a versatile network that enhances the overall efficiency of the multimodal ecosystem by offering tailored solutions for different logistical needs. (von Stamm et al. 2024; Feyen und Penet 2024). The business model evaluated by the Gassmann model is visible in Table 7.

Table 7: Business model of the Carrier

Role	Who?	What?	How?	Why?
Carrier Road	Freight forwarders, MTO, DLSP. Often there are long time -contracts with these customers. The concrete needs of the same customer can vary from time to time depending on the market needs.	Transportation of goods using the corresponding mode, depending on the customers' needs so they can sell their own services. Reliability of transportation and the region of operation for the specific mode differs the company from other companies with similar services.	The key values are owning and maintaining transportation assets and vehicles. Mainly transporting between consignor/ terminal or terminal/consignee, sometimes terminal/terminal. The communication with customers and flexibility of the service can differ between companies depending on the customer and its needs.	The customer needs a fast and flexible transportation. Therefore, the value proposition is reliable and flexible transport of goods. The income is generated by regular and spontaneous (more expensive) transportation operations, ideal for small to medium-sized shipments and last miles. Risks are high transport costs and weather conditions impairing road transport.
Carrier Railway undertaking				Customers require fast, cost-effective transportation that can be planned well in advance. Railways offer an energy-efficient and low-emission option for transporting large volumes of cargo, enabling reduced transportation costs. However, risks include the vulnerability of rail infrastructure to disruptions and the need to adhere to pre-booked timeslots, which require careful planning and strict compliance.
Carrier IWW and Short Sea				Customers seeking cost-effective and scalable transportation often choose waterways, which enable energy-efficient movement of large cargo volumes. Revenue is maximised through regular shipments and fully loaded barges. However, risks include water level fluctuations, limitations in harbour terminal infrastructure, and a lack of flexibility. Long waiting times at busy harbours, depending on traffic conditions, can further impact efficiency.

Key activities of carriers in the freight transportation resulting from the survey conducted are transportation management, customer relationship management and scheduling and coordination (see Figure 8).

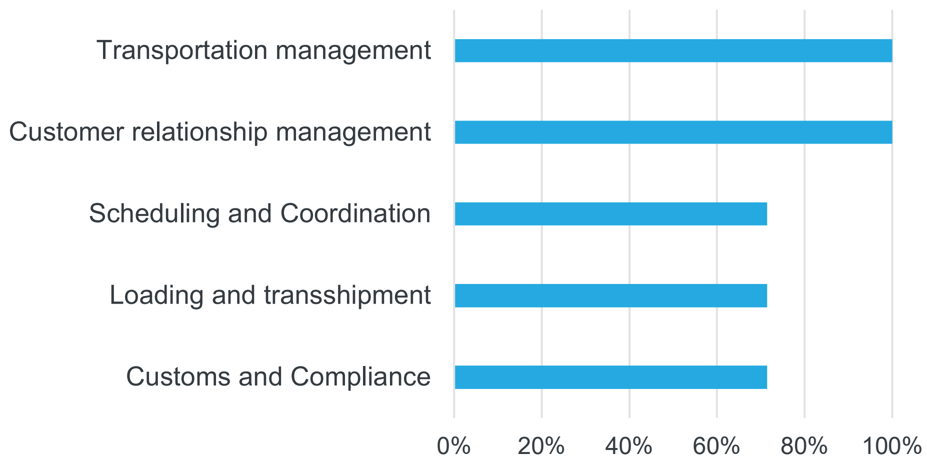

Figure 8: Survey results on the key activities of carriers in freight transportation

Transportation management involves overseeing and executing the physical movement of goods across multiple transport modes. Customer relationship management focuses on building and maintaining strong customer relationships to ensure satisfaction and encourage repeat business. Scheduling and coordination entail managing shipment schedules to maximise throughput and minimise downtime.

4.1.5 Freight Forwarder

Freight forwarders act as intermediaries in logistics, organising shipments for consignors to ensure efficient delivery. They manage tasks such as contracting carriers, overseeing transit, and providing value-added services like warehousing, documentation, and packaging.

Asset-owning freight forwarders use in-house resources, such as transport assets and warehouses, to control the logistics process. This enables precise scheduling, efficient route management, and cost optimisation by prioritising their own assets. While this ensures consistent service quality, it may limit flexibility in scaling operations to meet market demand. These forwarders contribute to the multimodal ecosystem by offering reliable, end-to-end logistics services (von Stamm et al. 2024).

Asset-light freight forwarders, on the other hand, focus on coordinating logistics by contracting third-party carriers and service providers. This model allows flexibility to adapt to market changes and provide diverse transport options. By outsourcing warehousing and transport services, they reduce costs and enhance efficiency for clients. However, dependence on external partners can impact control over service quality. The business model, analysed using the Gassmann framework, is detailed in Table 8.

Table 8: Business model of the Freight Forwarder

Role	Who?	What?	How?	Why?
Freight Forwarder - with own assets (2PL/3PL)	Primarily consignors, though other freight forwarders or multimodal transport operators may also be involved.	The service involves organising freight transports between two locations, either with own or third-party assets sometimes including warehousing, packaging, and insurance arrangements.	Freight forwarders manage tendering and contracting with carriers, terminals, and infrastructure operators, while monitoring transit movements. When owning transport assets, these are prioritised for use before outsourcing to external providers. Additional services, such as insurance contracts, documentation, and warehousing, are sometimes offered.	Customers often lack the capacity to orchestrate transportation independently. Partnering with a freight forwarder increases efficiency, as they leverage subcontracted LSPs, expertise in governance, route infrastructures, and the broader ecosystem. This collaboration reduces delivery costs and time. Freight forwarders gain greater operational control by utilising their own fleets (when

Freight Forwarder - without own assets (3PL)	Consignors	Customers outsource transportation management and associated bureaucracy to the freight forwarder.	Freight forwarders handle tendering and contracting with external carriers, terminals, and infrastructure operators while monitoring transit movements. To meet customer requests, they may also establish additional contracts with service providers offering warehousing and other logistics solutions.	available) to minimise costs while outsourcing irregular or high-volume demands. This model generates revenue, as freight forwarders can offer transportation services at a lower cost than customers would incur managing logistics in-house.

Key activities of freight forwarders identified in the survey are summarised in Figure 9. These include core transport-related functions such as transportation management, which serves as their primary value proposition, along with scheduling, coordination, and customs and compliance management.

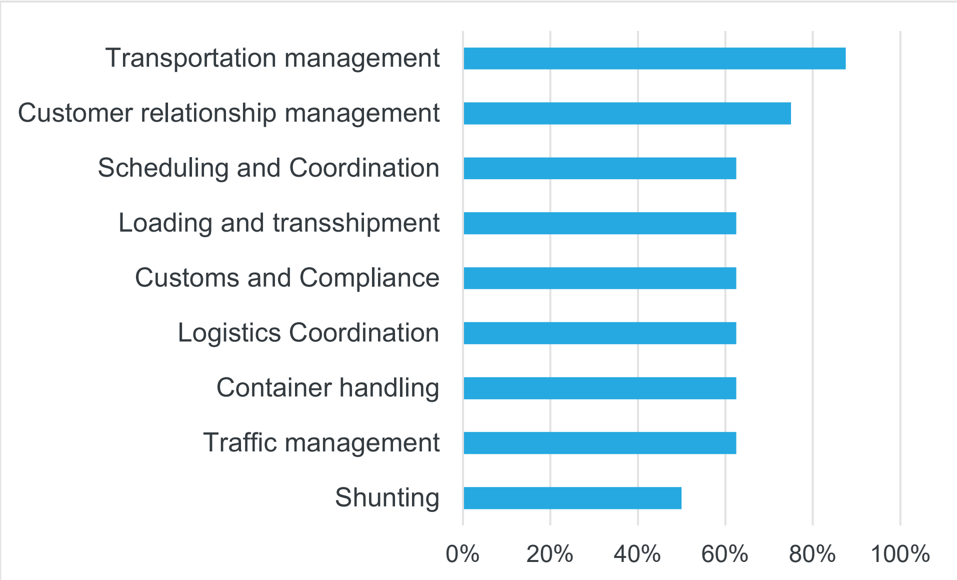

Figure 9: Survey results on the key activities of freight forwarders in freight transportation

Customer relationship management is a significant aspect of freight forwarders' daily operations. This involves maintaining effective communication with customers and providing regular updates on freight status. Activities such as logistics coordination, loading and transshipment, and storage and warehousing are also notable but typically require the use of in-house assets. Additionally, some freight forwarders invest in new technologies, including data analytics services, traffic management, and technology development.

4.1.6 Multimodal Transport Operator

A Multimodal Transport Operator (MTO), also known as an intermodal or combined transport operator, integrates multiple transportation modes under a single contractual framework. MTOs coordinate end-to-end transport processes using combinations of road, rail, and sea to move goods efficiently from origin to destination. By owning and managing networks of carriers, assets, and partners, they simplify the logistics chain for consignors and freight forwarders.

Unlike traditional freight forwarders, MTOs operate specific assets such as wagons, trucks, trains, ships, and terminals, enabling greater control over the supply chain. This allows them to optimise transport routes, reduce handling times, and streamline administrative tasks. By offering flexibility and minimising bureaucratic hurdles, MTOs enhance multimodal transport efficiency, support seamless cross-border logistics, and ensure timely deliveries for clients (von Stamm et al. 2024; Feyen und Penet 2024). The business model evaluated by the Gassmann model is visible in Table 9.

Table 9: Business model of the Multimodal Transport Operator

Role	Who?	What?	How?	Why?
Multi-modal Transport Operator (3PL/4PL)	Con-signors, freight for-warders	Service of trans-portation within a single contract. Organisation of the transport to reach the final ter-minal in the range of the operator by using multiple modes, leading to a simpler trans-portation process.	Owning and maintaining networks of carriers, partners and own assets across multiple modes of transportation are key activities needed. Some-times additionally or-chestrating the commu-nication and contracts with other partners, while also managing the supply chain are the competencies.	Giving the possibility to transport goods with a low amount of bureaucracy for comparably complex tasks is a unique selling point. The maintenance of such a com-plex network can be chal-lenging and need a lot of dif-ferent competences. Com-bining these makes it possi-ble to use a combination of different modes and makes the transportation more effi-cient, leading to revenue.

Figure 10 shows the survey's distribution of MTO key activities. Core functions include transportation management, loading and transshipment, customer relationship management, traffic management, logistics coordination, and scheduling. Transportation management oversees goods movement across modes, while loading and transshipment handle cargo transfer between modes.

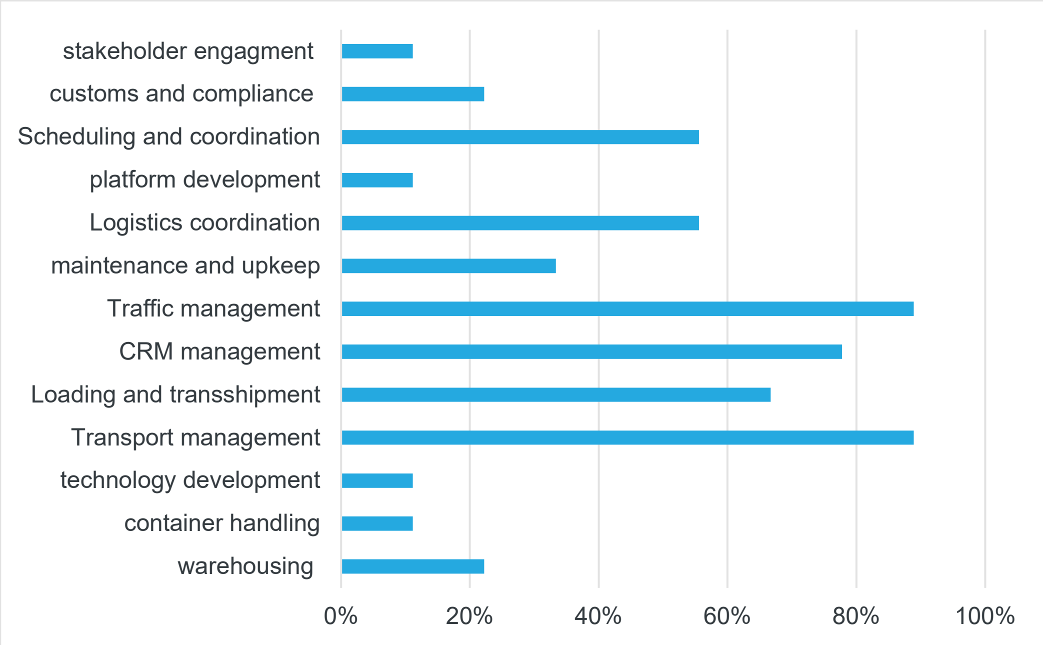

Figure 10: Survey results on the key activities of Multimodal Transport Operators in freight transportation

Customer Relationship Management builds strong relationships to ensure satisfaction and loyalty. Traffic management optimises routes and reduces congestion by planning and controlling vehicle flows. Logistics coordination handles all shipping aspects, including route selection and carrier contracting. Scheduling and coordination manage shipments to maximise throughput and minimise downtime.

4.1.7 Digital Logistics Service Provider

Digital Logistics Service Providers (DLSPs) play a pivotal role in the multimodal transport ecosystem, specialising in orchestrating logistics operations using advanced digital solutions, without owning physical assets. Their business model relies on technologies such as cloud computing, digital twins, Internet of Things (IoT), big data analytics, and blockchain to manage and optimise transport assignments. These tools enable DLSPs to streamline processes, improve supply chain visibility, and address inefficiencies, particularly within complex logistics networks.

Unlike traditional logistics providers, DLSPs focus on integrating and orchestrating data to enhance coordination among consignors, carriers, terminal operators, and other stakeholders. The business model, analysed using the Gassmann framework, is detailed in Table 10.

Table 10: Business model of the Digital Logistics Service Provider

Role	Who?	What?	How?	Why?
Digital Logistics Service Provider	Consignor and freight forwarder	Digital Logistics Service Providers (DLSPs) offer solutions for orchestrating and managing transport assignments. Consignors can fully outsource transportation needs to DLSPs, benefiting from modern, highly efficient digital systems. Freight forwarders can also collaborate with DLSPs to enhance their transport processes.	DLSPs leverage cloud computing, digital twins, IoT, and big data analytics to gain insights into the transport ecosystem. Using these tools, they orchestrate goods transport without owning assets, relying on partnerships with asset owners. Developing and implementing these digital solutions and maintaining a robust network are among their key activities.	By managing and orchestrating processes with modern digital tools, DLSPs achieve higher efficiency through advanced technology use, offering greater possibilities and scalability in their service offerings compared to other actors. The ability to customise service portfolios to meet specific customer needs enhances their appeal. Additionally, DLSPs reduce costs by operating without physical assets, relying instead on partnerships with asset owners. While navigating the complex ecosystem is challenging, the efficiency gains, economies of scale, and flexibility they provide drive significant benefits, forming the basis of their value proposition and revenue generation.

DLSPs enhance the ecosystem by delivering software-based solutions that automate and optimise logistics workflows, reducing administrative burdens and boosting overall efficiency. They play a key role in modernising transport systems, enabling faster and more accurate decision-making while driving cost-effective logistics solutions in an increasingly complex environment. (von Stamm et al. 2024).

4.1.8 Software Provider

Software providers in the multimodal transport ecosystem support logistics service providers, carriers, terminals, and freight forwarders by offering advanced software solutions. Leveraging technologies such as cloud computing, digital twins, IoT, and blockchain, they optimise freight orchestration and enhance operational efficiency Table 11.

Table 11: Business model of Software Providers

Role	Who?	What?	How?	Why?
Software Provider	Logistic service providers (DLSP, carrier, terminals, multimodal transport operators, freight forwarder)	Software solutions for orchestrating freight transport are developed and implemented by providers, enabling actors to operate more efficiently and scale their operations effectively.	Leveraging cloud computing, digital twins, IoT, big data analytics, and blockchain, software providers structure and analyse the ecosystem. Their main value proposition lies in developing and implementing tailored software solutions, which can vary significantly across companies and actors.	By leveraging their software development expertise, providers assist other stakeholders in managing and orchestrating transport processes more efficiently. Income is generated through service models such as SaaS or subscription plans. The improved efficiency translates into higher income for customers, forming the basis of the value they pay for.

Software providers in the multimodal transport ecosystem serve logistics service providers, carriers, terminals, and freight forwarders by offering advanced software solutions. Using technologies such as cloud computing, digital twins, IoT, and blockchain, they optimise freight orchestration while enhancing visibility, efficiency, and coordination across the supply chain. Their business model centres on empowering logistics operators to streamline processes, reduce costs and risks, and drive digital transformation in transport management. They usually offer their software as a service (SaaS) or similar pricing models.

4.1.9 Support Services and Consulting

Logistics service providers have adapted their support and consulting services to meet evolving market demands and leverage technological advancements in the freight transport sector (see Table 12).

Table 12: Business model of Support Services and Consulting

Role	Who?	What?	How?	Why?
Support Services and Consulting	Other logistic service providers	Customers present unique needs for optimising their freight transportation processes. These are addressed with tailored concepts, leading to customised solutions.	Leveraging their logistics expertise, providers offer tailored solutions through data-driven analysis to help companies address and resolve challenges effectively. A key activity is maintaining up-to-date knowledge of the ecosystem.	When customers lack the resources or expertise to address challenges or explore new opportunities internally, consulting companies provide support. This generates revenue, often through daily rates or master agreements.

Support and consulting services in the freight transport sector have evolved with changing market dynamics and technological advancements. Traditionally, industrial distributors served as full-service intermediaries, providing comprehensive support services. However, this model has faced competition from functional specialists focusing on specific logistics activities. In response, specialised support and consulting firms have emerged, offering tailored models to address the unique challenges of freight transport operations (von Stamm et al. 2024).

4.1.10 Terminal Operator

Terminals, also known as nodes or hubs, are vital to the transportation network, supporting shunting and transshipment processes that enable modal shifts essential for intermodal transport. Their customers include a variety of logistics service providers, such as carriers, freight forwarders, and transport operators.

Terminals are categorised by their infrastructure and transport mode connections: bimodal terminals link two modes (e.g., road and rail), trimodal terminals connect three (road, rail, and waterway), and unimodal terminals serve a single mode. Shunting, involving the arrangement of train wagons, and transshipment, which transfers freight between modes either vertically (using cranes or forklifts) or horizontally (for non-craneable units like semi-trailers), are key terminal operations (see Table 13).

Table 13: Business model of the Terminal Operator

Role	Who?	What?	How?	Why?
Terminal Operator	Carriers, freight forwarder, transport operators	Enabling the switching of modes of transportation, including warehousing during the process, is a key terminal function. Additional services, such as commissioning, emergency support, repair and maintenance, licensing, and customs handling, are often provided. Modal shifts enhance supply chain efficiency and play a crucial role in distribution.	Terminals provide the infrastructure and logistics required for transshipping goods from different transporters, forming their core value proposition. As a result, terminal and infrastructure management is a critical activity that must be consistently maintained.	Terminals are essential for multimodal transport operations, enabling the use of multiple modes to enhance supply chain efficiency and support last-mile transportation. Customers pay for terminal services, which often remain more cost-effective than relying on a single mode of transport.

In addition to these primary operations, terminals also handle various subprocesses to ensure functionality, including commissioning, emergency services, repair and maintenance, security, licensing, customs processing, warehousing, and documentation (von Stamm et al. 2024; Feyen und Penet 2024).

Figure 11 illustrates the activities most prominent in the daily operations of terminal operators and managers. Transport management and customer relationship management stand out as particularly significant, emphasising their critical roles in ensuring operational efficiency and well-functioning terminals.

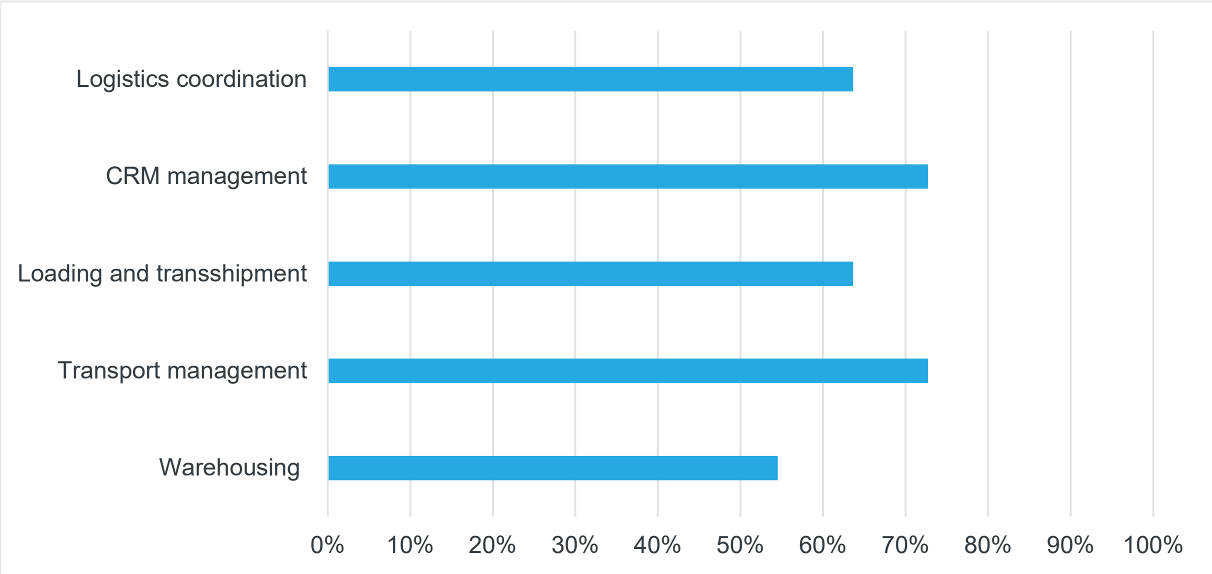

Figure 11: Survey results on the key activities of Terminal Operators in freight transportation

Loading and transshipment, involving the physical transfer of cargo between transport modes, is a core activity for terminals. Logistics coordination, crucial for organising shipping processes such as route planning and carrier selection, streamlines operations. Additionally, many operators provide warehousing services, including goods storage and inventory management for timely distribution.

4.1.11 Infrastructure Operator and Manager

Infrastructure operators and managers play a vital role in the multimodal transport ecosystem by developing, operating, and maintaining transport networks and facilities. They enable carriers and terminal operators to efficiently move goods, vehicles, and passengers along transport routes. By managing real estate, planning, and maintaining transport facilities, infrastructure operators ensure seamless connectivity between terminals and reliable long-term transport routes (Table 14).

Table 14: Business model of the Infrastructure Operator and Manager

Role	Who?	What?	How?	Why?
Infrastructure Operator and Manager	Carriers, Terminal operators	Infrastructure operators and managers enable carriers to transport freight by providing and maintaining the infrastructure essential for the transportation process. This infrastructure must be well-maintained to ensure the safe and efficient movement of goods, vehicles, and passengers along routes. they connect various locations and terminals while supplying partners with critical information, particularly during disruptions.	Infrastructure operators create value by managing real estate in the form of physical transport infrastructure, as well as planning, constructing, and maintaining transport facilities. These activities demand a range of competencies, including engineering and slot management, backed by a broad network of partners and resources.	Carriers rely on operational infrastructure, while terminals must be connected to it. As a result, both pay for infrastructure usage, either on a pay-per-use basis or through flat rates, such as truck tolls or train path allocations. Maintenance, which is both costly and complex, represents the largest expense for infrastructure operators.

Their efforts prevent congestion, support smooth logistics flows, and minimise disruptions, optimising the overall supply chain. This role is essential for sustaining ecosystem efficiency and enabling the continuous movement of goods across multiple transport modes (von Stamm et al. 2024; Feyen und Penet 2024).

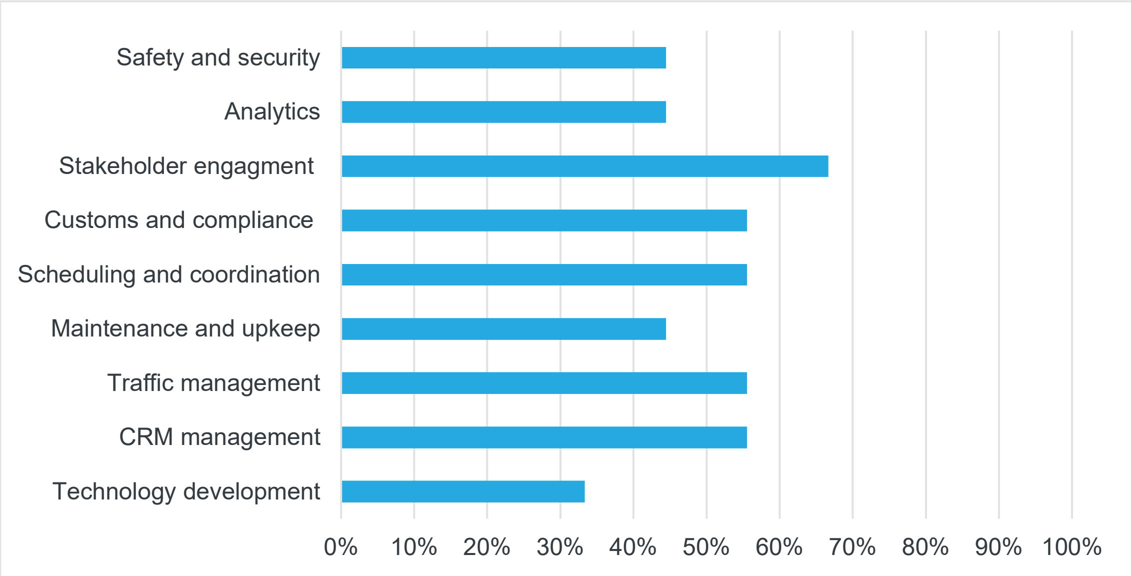

Figure 12: Survey results on the key activities of Infrastructure Operators and Managers

Infrastructure operators must prioritise customer relationship management and stakeholder engagement to ensure smooth and successful operations. Strong client connections and collaborative efforts with all involved parties are vital. Regular maintenance is equally critical to keep infrastructure and equipment in optimal condition, ensuring reliable daily functionality.

In the railway sector, efficient shunting operations, which organise rail cars to assemble or disassemble trains, are a core activity. Long-term capacity planning enables operators to anticipate future demand and expand infrastructure to meet evolving needs. Staying updated on technological advancements is essential, as digital solutions can streamline logistics and enhance overall efficiency.

Effective traffic management focuses on planning and controlling vehicle flows to optimise routes and reduce congestion. Additionally, precise scheduling and coordination are key to maintaining shipment timelines, maximising throughput, and minimising downtime.

4.1.12 Governmental Entities

The previous roles were described through their business models and key activities identified in the survey. However, as most governmental entities do not operate for profit, they lack a clear business model. Instead, representative entities are mentioned, with a brief explanation of their operations.

The **European Commission's Directorate-General for Mobility and Transport** (DG Move) primarily collaborates with infrastructure operators, managers, multimodal transport operators, and terminal providers on infrastructure plans and funding applications. It oversees the implementation of EU guidelines for the TEN-T network, evaluating funding documents such as applications and contracts under mechanisms like the Connecting Europe Facility (CEF). DG Move also certifies TEN-T infrastructure, ensuring eligibility for EU funding and alignment with strategic goals. It develops and implements EU transport policies, particularly for the TEN-T corridors, and monitors compliance with EU regulations and directives governing transport infrastructure. This oversight ensures consistency and adherence to high standards across the network.

The **EU-Rail Joint Undertaking** aims to transform and modernise Europe's rail system, enhancing efficiency, reliability, and interconnectedness while reinforcing its role in the EU's multimodal transport ecosystem. This initiative leverages technologies and best practices to boost rail capacity and appeal, ensuring its place as a cornerstone of sustainable mobility in Europe. A key focus of EU-Rail is the standardisation of rail systems across Europe, enabling seamless cross-border travel and freight movement.

The **European Union Agency for Railways** (ERA) oversees the harmonisation and interoperability of the rail network within the TEN-T framework. It collaborates with rail carriers and infrastructure operators, who must submit Technical Specification for Interoperability (TSI)-compliant certificates and technical reports. ERA facilitates the certification process, ensuring all rail vehicles meet technical specifications for interoperability and are authorised for cross-border operation. This work promotes the seamless integration of rail systems across the EU, enabling efficient and safe passenger and freight movement.

The **European Maritime Safety Agency** (EMSA) plays a crucial role in organising and regulating maritime transport within the TEN-T network. It collaborates with carriers and waterway terminals, which must submit safety certificates and transport documents to port authorities for compliance. EMSA ensures the monitoring and enforcement of maritime safety and environmental standards for European waterways within the TEN-T framework.

National Transport Authorities regulate and monitor freight transport at the national level, working with carriers across different modes to ensure compliance with transport authorisations required for cross-border traffic. They oversee the issuance and use of licences and driving cards, ensuring adherence to driving time regulations and proper authorisations. Their role is essential for maintaining safety standards and enabling seamless transport across national borders within the TEN-T network.

Customs Authorities regulate and control the cross-border movement of goods along TEN-T corridors and beyond. They collaborate with freight forwarders, carriers, consignors, and consignees to ensure the accurate preparation and submission of customs documents. Their responsibilities include inspecting goods for export to verify compliance with customs regulations, excluding prohibited items, and ensuring conformity with accompanying documentation. Inspections may occur at export points or consignee premises. Customs declarations for imports, exports, or transit must comply with national laws and can be submitted electronically or manually, accompanied by detailed documentation, such as CMR consignment notes. Freight forwarders typically handle these declarations to facilitate smooth processing.

4.2 Multimodal Transport process

Documenting the multimodal freight transport process aimed to establish a standardised view of current operational procedures. This structured approach serves as a foundation for systematically analysing inefficiencies and identifying opportunities for improvement. By gaining a comprehensive understanding of the process, bottlenecks can be identified, specific requirements evaluated, and areas for simplification and optimisation pinpointed. The objective is to develop a more efficient and coordinated system that meets the complex demands of multimodal freight transport.

Research Approach

The methodological approach to documenting and analysing the multimodal freight transport process involved two key steps. First, desk research was conducted to gather existing data and insights on current practices within the sector. This initial work led to the creation of a detailed version of the fundamental multimodal transport (MMT) process.

Second, a series of workshops was held with industry experts, including LSPs, MTOs, carriers, infrastructure and terminal operators, software providers, and consignors. During these workshops, essential steps relevant to ReMuNet were identified, and the process design was refined by removing irrelevant steps, simplifying the workflow.

This documentation established a standardised view of current operational procedures, providing a foundation for systematically analysing inefficiencies and identifying improvement opportunities. By comprehensively understanding the process, bottlenecks can be identified, specific requirements evaluated, and areas for simplification and optimisation pinpointed. The ultimate goal is to create a more efficient, coordinated system that meets the complex demands of multimodal freight transport.

Modelling Assumptions

Insights from the expert workshops led to the establishment of a list of core assumptions. These assumptions define key aspects of the multimodal freight transport process and serve as a foundation for simplifying and optimising its design.

a) Three-staged transport process

The multimodal transport process is divided into three primary stages: the first leg, the main leg, and the last leg. This division forms the basis for the process design, as it is widely recognised in both scientific and operational logistics frameworks. The following sections will examine each stage in detail to provide a comprehensive understanding of the multi-modal transport workflow.

b) Network-based planning

The network-based planning approach uses pre-booked capacities, such as trains and barges, as fixed inputs to optimise transport planning, aligning with ReMuNet's goal of building resilience and efficiency by connecting networks. In contrast, the order-based planning approach focuses on time-sensitive deliveries, prioritising scheduling around specific arrival times. The former maximises capacity utilisation, while the latter ensures delivery precision.

c) One-step planning approach

This assumption envisions the transport process being planned as a single, unified step rather than divided into separate segments. By contrast, segmented planning - where the main transport leg is planned independently and the first and last miles are treated as separate components - is common in intercontinental transport. However, holistic one-step planning is more suitable for shorter, Europe-focused networks like ReMuNet.

d) Standardised loading and unloading

The transport process follows a standardised approach for the on- and offloading of transport units. The main leg is structured as a repetitive sequence of “unloading,” “layover time,” and “loading.” This consistency aligns with ReMuNet’s goal of achieving smooth and simplified multimodal handovers. By standardising these steps, the main leg can be easily adjusted for varying distances, ensuring seamless operations across transport lengths.

e) Unification of carrier roles

Key roles in the transport process are derived from previous chapters and simplified where necessary. The carrier’s role encompasses transporting goods between supply chain nodes across various modes, including road, rail, inland waterways, and short sea shipping. As no significant process differences arise between these modes, they are consolidated into a single “carrier” role. This role also includes all forms PL from 1 to 4PL, cause if they appear as the transporting entity. Otherwise, they can be seen as part of the “Orchestrating entity”

f) Orchestrating entity

In the simplified modelling approach, it is assumed that the consignor delegates transport management to an orchestrating entity. This entity is responsible for overseeing the transport process and subcontracting necessary logistics partners. Within the model, the orchestrating entity is primarily represented by LSPs, such as freight forwarders and MTOs.

4.2.1 Transport Planning and Preparation

In the first leg of the process, the transport planning and preparation phase ensures that all foundational steps necessary to initiate and manage the order are completed before the physical transport process sets off (see Figure 13).

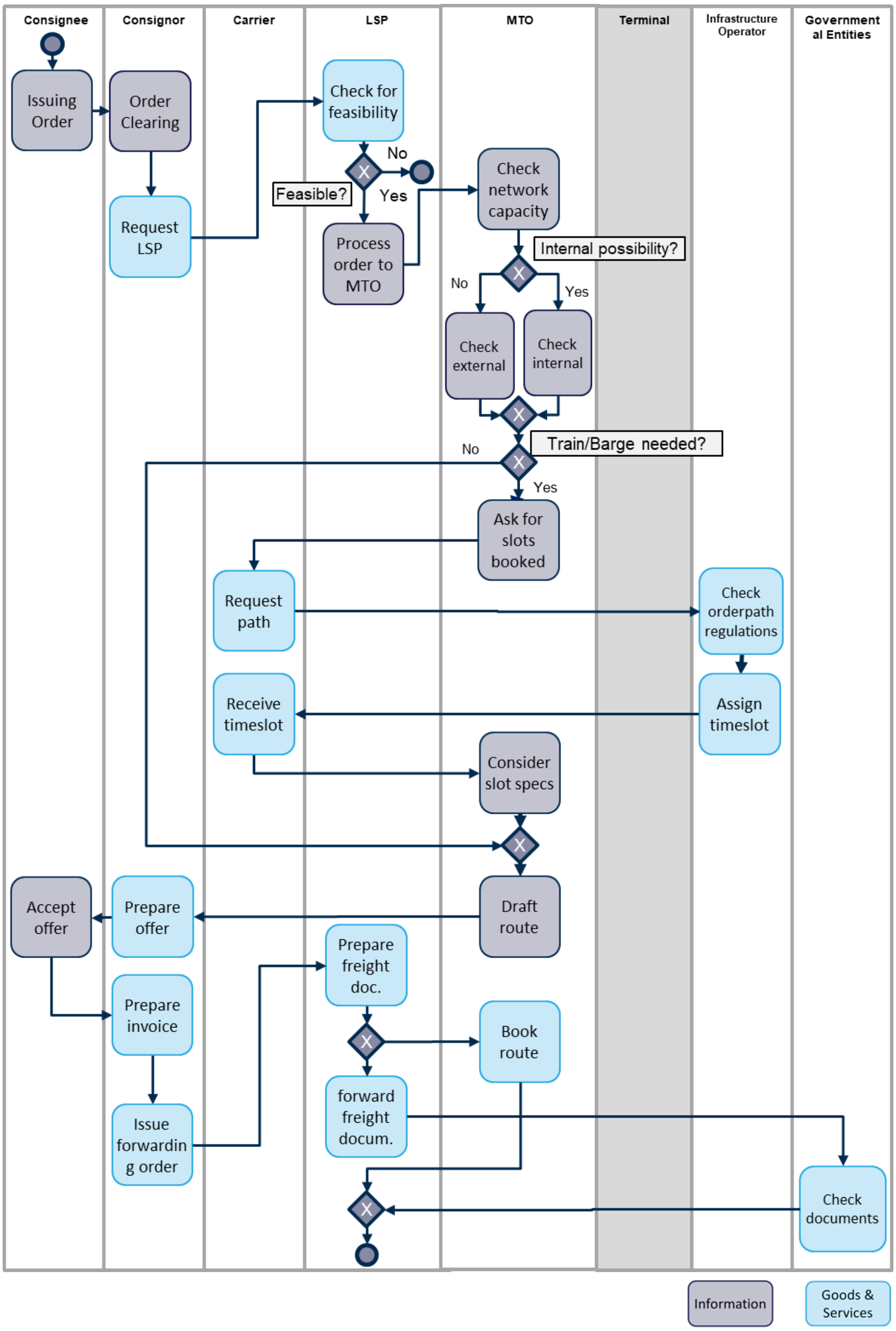

Figure 13: Transport Planning and Preparation Process

The process begins with the consignee issuing an order, which records the shipment's requirements. The consignor then clears the order, verifying it meets all necessary criteria. Once cleared, the consignor engages an LSP, such as a freight forwarder or MTO, to manage the transport as an orchestrating entity.

The orchestrating entity conducts a feasibility check to identify restricted or sensitive items within the shipment. If such items are detected, additional protocols may be required, potentially rendering the process unsuitable for ReMuNet due to the complexity of switching to alternative routes. Otherwise, the order proceeds under standard guidelines to the processing stage.

Next, a network capacity check determines whether the order can be accommodated internally or externally. This step may present challenges, as noted during interviews:

> *“I can already say that I plan as if there were unlimited capacities. But in reality, they may be limited. I might be able to plan better if these limitations were known to me.”* (IP 13)

If a train or barge is required, a confirmation for booked slots is needed. The carrier then secures the shipment’s route through a path request. A regulations check ensures compliance along the planned route, followed by assignment of a time slot, confirming a specific transport timeframe based on availability. The time slot details are reviewed to confirm alignment with broader scheduling requirements.

A route draft is then created, outlining a preliminary route with key stops and transfer points. The consignor prepares an offer for the consignee, including costs and transport details such as pickup time, destination, and involved parties. Upon the consignee’s acceptance, the consignor issues an Invoice reflecting the agreed terms.

Next, a forwarding order is issued to authorise the physical movement of goods, and freight documents are prepared to meet transport and regulatory requirements. These documents are forwarded to customs to ensure compliance with trade regulations.

Finally, the transport path is officially booked, reserving the necessary sequence of moves and facilities. With all preparation steps completed and verified, the shipment is ready for transport. Table 15 outlines the exchanged documents and the roles involved in the transport planning and preparation process.

Table 15: Exchanged documents in the transport planning and preparation process

Exchanged documents	Document path
Order	Consignee to Consignor
Order	Consignor to Orchestrating Entity (LSP, MTO)
Invoice	Consignor to Consignee
Forwarding Order	Consignor to Carrier
Freight documents	Orchestrating Entity (LSP, MTO) to Governmental Entity
Consignment Note	Orchestrating Entity (LSP, MTO) to Carrier

4.2.2 First Leg: Pick up and Transport

The "First Mile" refers to the initial stage of physical transport, where freight moves from the consignor to the first intermediate destination. This phase establishes the logistical and documentary groundwork necessary for efficient transfers in subsequent stages. It emphasises structured preparation, systematic coordination, and secure road transport (see Figure 14).

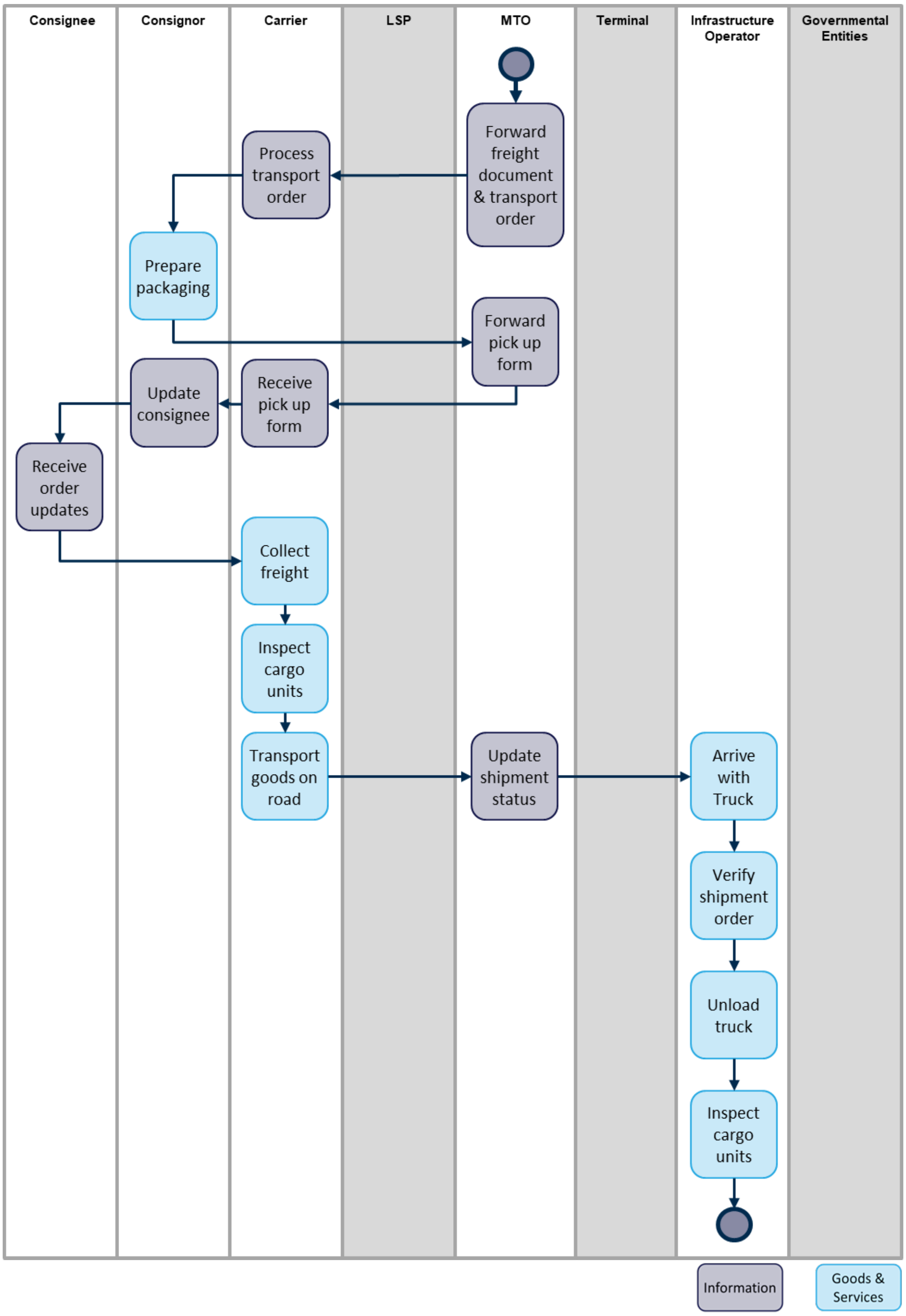

Figure 14: Pick-up and transport within the First Leg

The process begins with the orchestrating entity transferring freight documents and transport orders to the carrier, providing essential shipment details. The carrier processes the transport order while the consignor prepares the cargo for collection, including packaging. A pick-up form is then sent to the carrier to initiate the "First Mile" transport, and the consignee is updated with the order status and estimated time of arrival.

Once preparations are complete, the carrier collects the cargo from the consignor's location, marking the start of the First Mile. A handover inspection ensures the cargo matches the transport order and is in suitable condition. The goods are then transported by road to a designated logistics point, and the shipment status is updated.

At the destination, the truck undergoes a shipment verification to ensure the items match the records. The cargo is unloaded and prepared for the next transport stage. A final inspection confirms the condition and completeness of the goods, concluding the "First Mile" phase.

Table 16: Exchanged documents within pick-up and transport during the First Leg

Exchanged documents	Document path
Transport order	Orchestrating Entity (LSP, MTO) to Carrier
Pick up form	Orchestrating Entity (LSP, MTO) to Carrier
Handover Protocol	Terminal to Orchestrating Entity (LSP, MTO)
Consignment Note	Carrier to Terminal
Labelling	Carrier to Terminal

4.2.3 Main Leg

The main leg transport phase covers the primary distance freight travels between key supply chain nodes. It consists of four subprocesses: Unloading, Layover Time, Loading, and Transport. Loading procedures differ by transport mode - road, rail, or barge - based on operational needs. This phase is critical for ensuring efficient goods transfer and transit, serving as the core of multimodal logistics. Figure 15 illustrates the entire Main Leg transport process, with detailed explanations of its subprocesses provided in the following subsections.

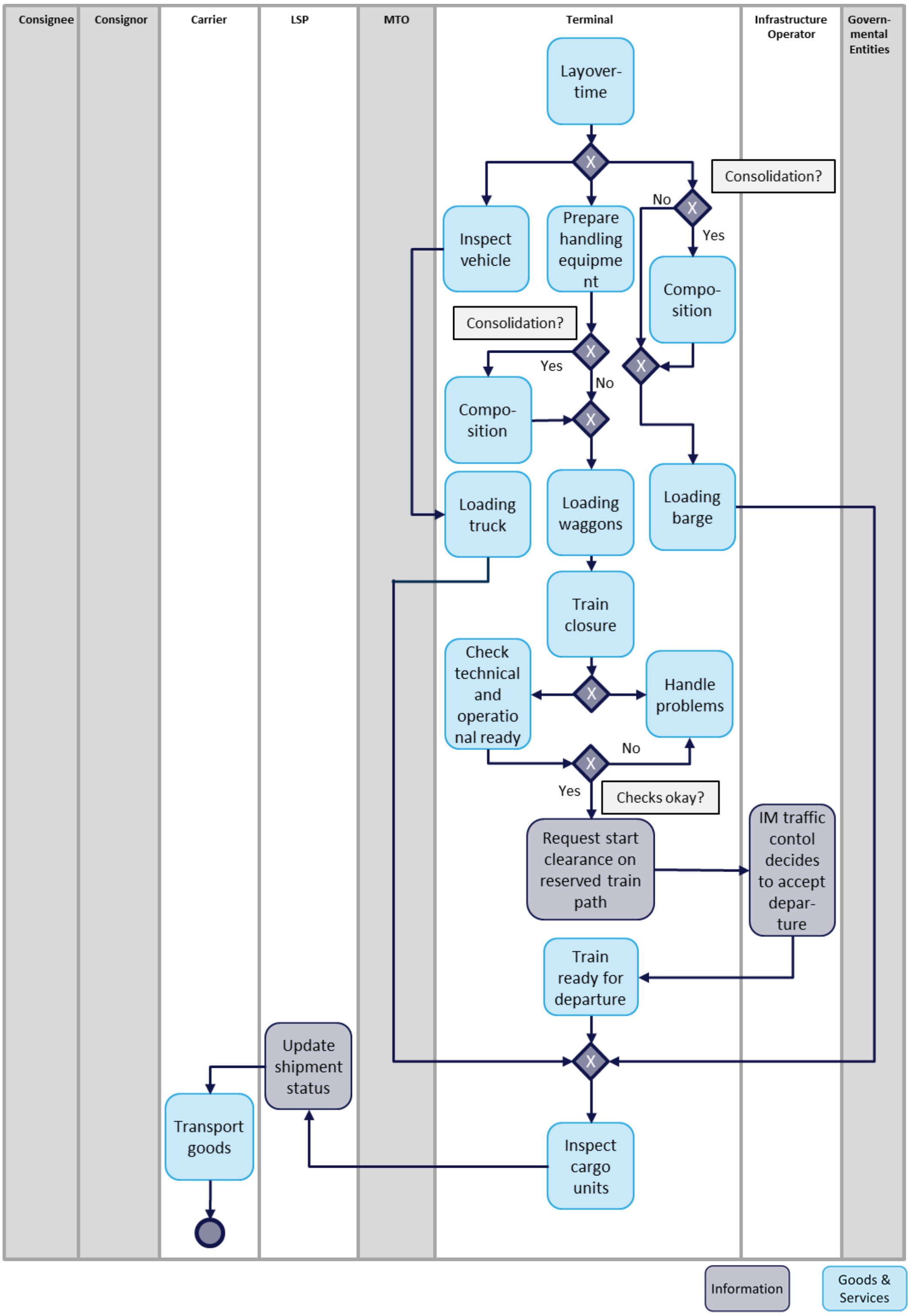

Figure 15: The Main Leg transport process

Unloading

Upon reaching the terminal, the carrier undergoes a series of entrance checks before being granted access. The process begins with identification of the transport unit, often via advanced camera systems at the terminal entrance, which automatically verify information such as truck license plates, train identification numbers, or ship names. The carrier's identity is also confirmed to ensure alignment with the scheduled and authorised movements within the facility. These initial checks are critical for minimising errors and ensuring safe, smooth terminal operations.

Once verified, the transport unit officially "arrives" at the terminal, entering the facility. For rail carriers, an additional vehicle inspection is conducted to confirm regulatory and safety compliance, including the mechanical condition and secure arrangement of cargo units.

Following the vehicle inspection, the carrier proceeds to the check-in phase. During check-in, essential transport and handling information is exchanged between the carrier and terminal authorities. This step ensures alignment on the specific requirements of the cargo, which may vary based on its nature and handling needs. Key details are documented on transport-related documents such as the consignment note, which specifies the cargo's origin, destination, and characteristics, as well as labels or identification plates on the transport assets. This step is sometimes challenging as mentioned by an expert:

„Some examples that we have encountered in the recent past have been theft or damage to the loading units or contents of the loading units. There have also been incidents or accidents." (IP 7)

Once the check-in phase is completed, the process advances to the physical unloading of goods. During unloading, freight and assets are removed from the transport unit while undergoing thorough checks for intactness and completeness. These inspections are vital for identifying any potential issues such as damage or discrepancies in the cargo before the goods proceed further within the terminal. If the goods are intended for temporary storage, they may be registered in the terminal's warehousing systems. Alternatively, the cargo may be transferred directly to the next transport unit for the subsequent leg of its journey, streamlining the transition and minimising the time spent within the terminal.

Regardless of the immediate handling pathway, there is typically a minimal layover time within the terminal. This short waiting period, termed "layover time," is inevitable due to the need for brief coordination. During this period, any necessary preparations for the next stage of transport can be finalised, whether that involves additional handling or confirming arrangements for the next carrier. As a result, the process continues with layover time as an integrated component.

Upon confirmation of the cargo's condition, handover protocols are documented. These protocols serve as formal records of the transfer, including details of the cargo's state and any observations or discrepancies noted during the inspection. The completed handover protocols are then forwarded to the orchestrating entity, ensuring that all relevant parties are informed of the cargo's status and ready for the next iteration in the transport chain. The exchanged documents are briefly outlined in Table 17.

Table 17: Documents exchanged in the unloading phase of the Main Leg

Exchanged documents	Document path
Consignment note	Carrier to Terminal
Labelling	Carrier to Terminal
Handover protocol	Terminal to Orchestrating Entity (LSP, MTO)

Layover time

Layover time refers to the period assets spend at a terminal awaiting the next transport stage. Unlike warehousing, layover time is minimised to avoid storage, ideally approaching zero. This phase also includes instances where trucks or goods are temporarily held, such as at parking facilities while waiting for connecting transport.

At the start of this phase, the orchestrating entity receives an update confirming the arrival and readiness of goods for the next stage. This update includes the handover protocol, initially detailed in the unloading phase which verifies that the goods are ready for pickup. This process ensures a smooth transition and minimises downtime in the multimodal transport workflow.

Loading

Due to elemental differences between the modes of transportation about the process unit of onloading, this unit will be explained for each mode separately.

a) Loading trucks

Before loading, trucks undergo a thorough inspection to ensure operational functionality, checking brakes, lights, tires, and other essential systems. Once cleared, the truck proceeds to the designated pick-up point within the terminal, where the cargo unit - whether a container, trailer, or other asset - is securely coupled to the truck. After coupling, a final inspection verifies that the cargo is properly secured, undamaged, and ready for transit, and that the unit is safely attached to the truck. Upon successful completion, handover protocols are created, documenting the cargo's condition, contents, and readiness. These protocols are transmitted to the orchestrating entity, formally notifying them that the goods are ready for the next transport leg.

b) Loading freight trains

Before loading a train, it is crucial to determine whether cargo composition requires specific sequencing, particularly for trains with multiple destinations or terminals unable to accommodate the train's full length. Time-sensitive shipments may require prioritised placement for efficient unloading. If sequencing is necessary, the terminal arranges and prepares assets in the required order to meet unloading needs at various destinations.

Once preparations are complete, the loading process begins. Following loading, a certified wagon inspector performs a "train closure," conducting a thorough technical and operational check of the engine and wagons to ensure they are safe and operable. Any issues identified are addressed immediately, with inspections repeated until the train meets compliance standards.

After passing inspection, the Infrastructure Operator is contacted to confirm the availability of the pre-reserved train path and grant final clearance for departure. Upon approval, the orchestrating entity is updated on the train's status, and the handover protocol detailing the cargo's condition and readiness is transmitted. This ensures all parties are informed, allowing the train to depart seamlessly on its scheduled route.

c) Loading barges

Before loading ships, handling equipment - primarily cranes and other lifting device - must be prepared and configured to ensure safe and efficient handling of the specific cargo type and weight. For barge transportation, precise composition and arrangement of freight units are crucial, as barges often travel long distances with multiple stops. Careful positioning of cargo aligns with intended destinations, minimising unnecessary handling and reducing time and effort at each stop.

After detailed planning and organisation of the cargo layout - accounting for weight distribution, stability, and the loading/unloading sequence - the loading process begins. This careful arrangement ensures smooth transit and optimised access for intermediate stops. Once final checks are completed and all units are secured, the vessel is ready to depart.

For all transport modes, it is essential for the actor responsible for transshipment to document the cargo's condition. This ensures seamless handling, prevents false insurance claims, and allows transparent tracing of responsibility for any damages (see Table 18).

Table 18: Documents exchanged during loading

Exchanged documents	Document path
Handover Protocol	Terminal to Orchestrating Entity (LSP, MTO)

Main Leg transport

After collecting goods from the consignor or completing the initial loading of transport assets, the designated carrier is responsible for moving the shipment to the next transit node. For ReMuNet's purposes, no critical differences exist between transport modes - road, rail, or water way - at this stage. Therefore, all three modes are consolidated into a single unified category for simplicity.

Each carrier operates under a standardised process to ensure consistency and efficiency in reaching the next handover point. This generalised approach reduces complexity, focuses on continuity and reliability across multimodal segments, and facilitates smoother transitions between modes. By applying a unified set of requirements and protocols, ReMuNet promotes seamless integration throughout the transport network.

4.2.4 Last Leg: Transport and Delivery

The final destination of cargo is usually a consignee-designated location, such as a warehouse, distribution centre, or retail outlet, rather than a terminal. Upon arrival at the final terminal in the multimodal transport chain, cargo is transferred to a truck for last mile delivery (see Figure 16). This begins with loading the cargo onto the truck, following the structured process outlined in the Main Leg subprocess. During this phase, the handover protocol, detailing the cargo's condition and readiness for delivery, is sent to the responsible orchestrator. This protocol officially transfers responsibility from the terminal to the last-mile carrier, allowing the truck to depart for the final destination.

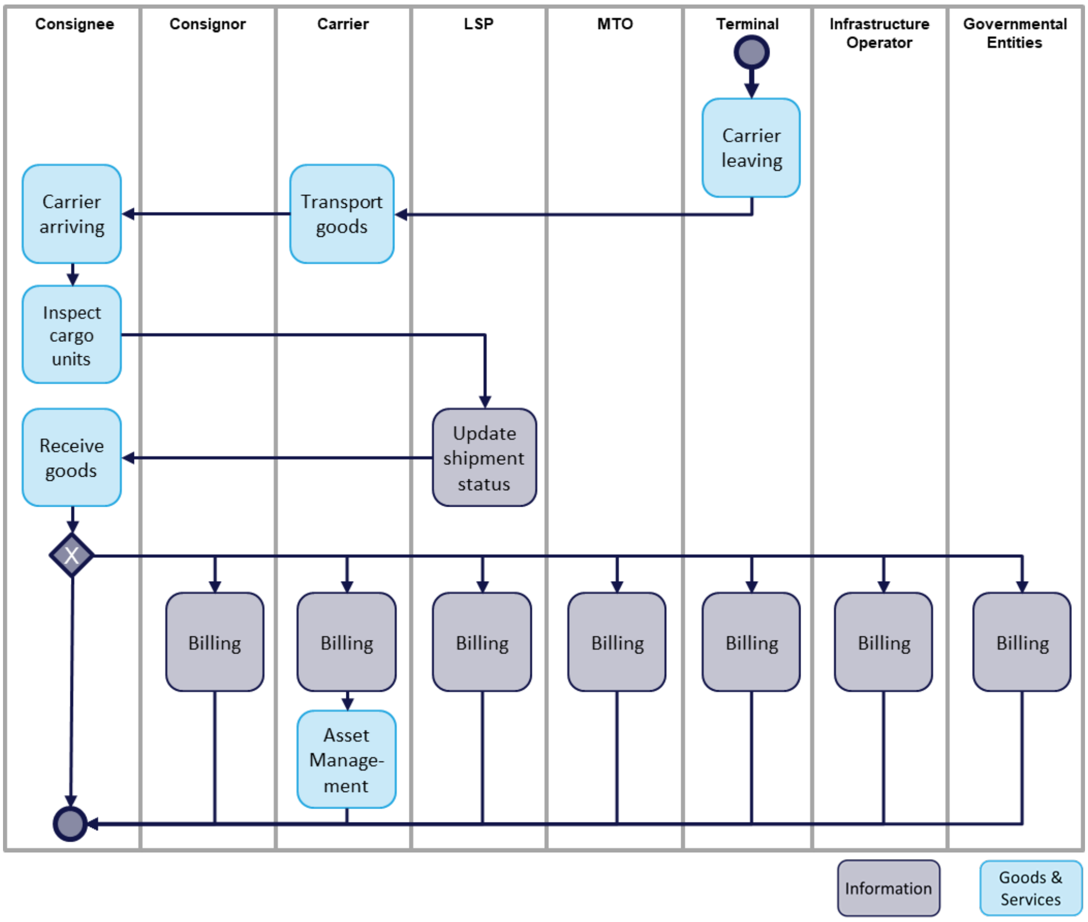

Figure 16: Final Leg transport and delivery process

At the destination, the truck is unloaded, and a final inspection confirms the cargo is intact and complete. Once verified, the consignee acknowledges receipt, and the orchestrating entity is notified of the completed delivery, concluding the transport cycle.

Following this update, the billing process is initiated, with each actor - whether providing logistics, storage, or transport - receiving invoices based on their contributions. Meanwhile, transport assets like containers and pallets are inspected, cleaned, and prepared for future use, ensuring readiness for the next shipment and maintaining logistics network efficiency. The documents exchanged during the Last Leg are briefly summarised in Table 19.

Table 19: Documents exchanged in the Last Leg transport process

Exchanged documents	Document path
Consignment Note	Carrier to Consignor
Labelling	Carrier to Consignor
Handover protocol	Consignor to Orchestrating Entity (LSP, MTO)

4.2.5 Process in the face of disruptions

The discussions and research to date describe the MMT process as functioning smoothly under normal conditions, without disruptions or rerouting. Nevertheless, the process is very fragile and vulnerable if there are any disruptions in the process. Typical disruptions and delays are caused by infrastructure problems of the railways, low water levels, lack of capacities, strikes, technical errors in terminals, natural disasters hindering the transportation, etc. Challenge is to minimise the number of disruptions which can occur throughout the whole process, while simultaneously handle them more efficient. But on the on hand, there is high pressure due to strong and complex demand; on the other hand, the industry finds it very difficult to network and cooperate and thus react quickly and agilely to these disruptions. The main reasons for this are long-established industry structures, lack of cooperation between different actors, but also a lack of standardised transport documents. This is particularly evident in the steps of transport preparation (routing or, in the event of a disruption, rerouting).

This and further several bottlenecks were revealed in the Workshops and interviews, underlined by these two quotes examples:

“It is the weakness of the terminals. There are currently no automated data streams with the railway companies at all. You have to switch between systems.” (IP 14)

“In many cases, you depend on an appointment to receive your cargo and be unloaded or loaded. That appointment needs to be scheduled in advance. How do you notify? There’s no standard for informing when and where you will arrive with the cargo. This lack of consistency results in wasted time and missed opportunities.” (IP 3)

These examples highlight the challenges of addressing disruptions and delays. Designing a process that accounts for every possible event and solution is impractical. The inefficiencies identified are closely tied to the ecosystem's pain points and operational dynamics. Chapter 5 will examine these pain points in greater detail and present them in a structured manner.

4.3 Value Flow Model of the multimodal Freight Transport Ecosystem

Chapter 4.3 forms the foundation for the ecosystem value map and highlights critical shortcomings and pain points during disruptive events. Applying the methodology of den Ouden

(2012) and insights from Chapters 4.1 and 4.2, this section explores the connections between the defined ecosystem roles. It begins by describing the flow of goods and services, followed by a detailed analysis of information exchange. Finally, it outlines the financial interactions that link the ecosystem actors.

4.3.1 Flow of Goods and Services

Figure 17 illustrates the flow of goods and services in the multimodal transport sector, highlighting relationships between roles and the standard progression of a transport order using arrows.

The flow starts with the consignor providing the goods, followed by the carrier or MTO handling the first mile of the first leg. In the main transport phase, one or more multimodal loops may occur, with terminals serving as transshipment points and the carrier or MTO managing transport between terminals. This section demonstrates the model's flexibility, accommodating various transport scenarios. The process concludes with the carrier or MTO handing over the goods to the consignee in the last leg.

This value flow model effectively represents the flow of physical goods and the interactions among roles in the logistics chain. It serves as a foundation for analysing and optimising transport processes, identifying bottlenecks, and enhancing efficiency within transport networks.

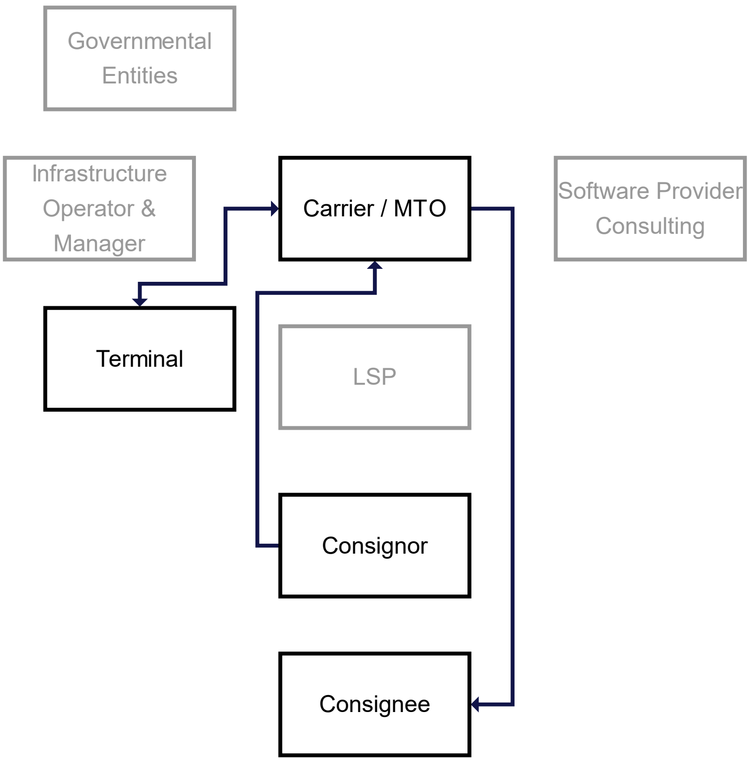

Figure 17: Visualisation of flow of goods during the multimodal transport

4.3.2Flow of Information

The interviews and workshops with stakeholders provided insights into the types of information exchanged in multimodal transport operations. A wide variety of documents are shared among participants, including orders, invoices, handover protocols, status reports, Global Positioning System (GPS) data, and transport orders. This diversity makes it difficult to create a unified view of information flows across the system.

Several factors contribute to this complexity. Document types and formats differ significantly based on the country, transport mode, stakeholder role, and contractual specifics. There is no widely accepted standard for document content, and mandatory information requirements vary across jurisdictions. These inconsistencies are further complicated by differing practices between transport modes. This issue was highlighted in one workshop:

“There are a lot of regulations. There are a lot of directives imposing, I think data sharing, but the minimum set of data are not defined so that that's one of the of the pain point because there we have a lot of discussion about […] unique standard to exchange that this will never happen[…], you have the railway world, you have the logistic world, and they are of course not defining the same data elements. They are not defining the same standards.” (WS 1)

The data types, handling systems, and tools used for information sharing vary widely among stakeholders, ranging from APIs and EDIs to emails and even fax. This diversity, combined with varying levels of digitalisation and unique operational demands across stakeholders, adds significant complexity. One interview quote highlighted this challenge:

“Because it quickly becomes clear that interface management in particular is a huge issue, not to mention our expertise on the one hand and a weak point in the entire transport process on the other.” (WS 2)

These factors combined make it highly challenging to fully understand the details of the information exchange process.

The survey results also confirm that the freight transport ecosystem uses several different data exchange formats for sharing information between stakeholders (see Figure 18).

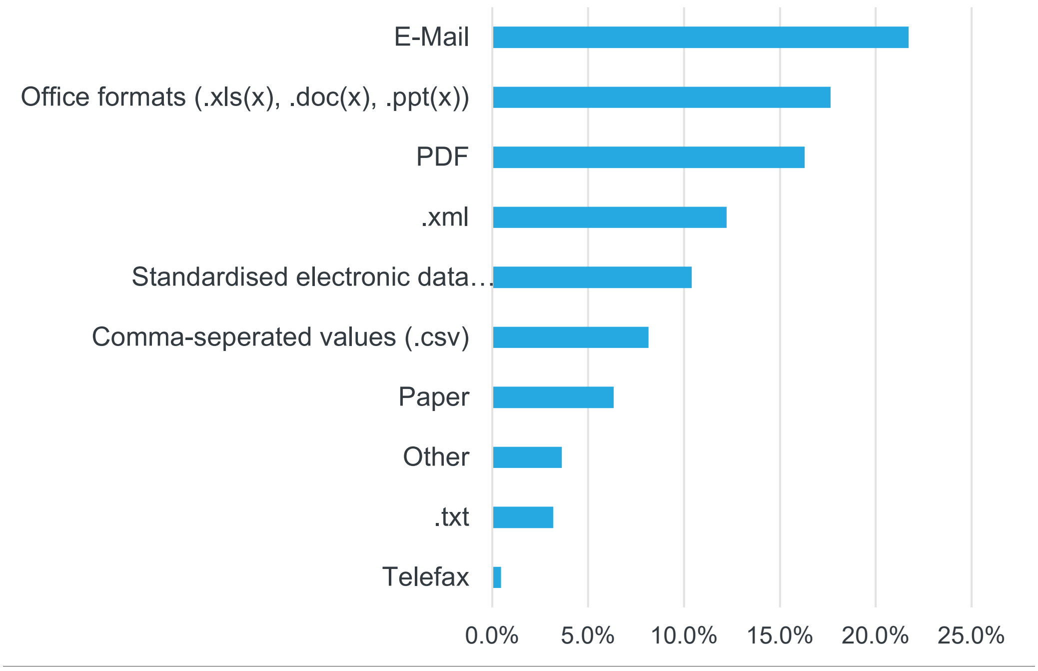

Figure 18: Survey results on data exchange formats

Most information in the freight transport ecosystem is transmitted digitally, primarily through email, office formats, or Portable Document Format (PDF). Standardised formats like EDIFACT only account for about 10% of usage.

The following sections discuss document flows and the underlying systems, consolidating frequently used documents in multimodal transport processes. This approach seeks to establish consistency across the ecosystem while maintaining the flexibility needed to meet participants' unique requirements. Based on this foundation, pain points in the current system and requirements for the ReMuNet solution can be identified.

4.3.2.1 Transport Documents

In the transport logistics ecosystem, documents are critical for facilitating seamless information exchange among stakeholders, including consignors, carriers, freight forwarders, LSPs, and consignees. They support smooth operations by providing clear, standardised, and reliable data essential for each party to fulfil their roles effectively. However, as previously noted, there is no widely accepted standard, including consistent naming conventions for various documents:

"[...]one person refers to the container number, while another refers to the container item, and so on. This is where the problem begins, as there are unfortunately significant issues in both English and German, particularly with translations." (WS 2)

The following section summarises the most important documents exchanged during the process and seeks to establish a unified terminology for use within the project. A more detailed summary of the results in tabular form can be found in Annex II.

Consignment Note

The consignment note is a crucial document in international trade and transport logistics, serving multiple legal and operational roles as a document of title. It evidences the carriage contract between the shipper and the carrier, outlining details such as the origin, destination, type of goods, and transport conditions. Additionally, it functions as a receipt, confirming the carrier's possession of the goods in their declared condition for transport.

A key feature of the consignment note is its negotiability, enabling the transfer of ownership rights between parties. This is vital for trade finance and supply chain transactions, allowing the document to serve as collateral or be transferred to buyers, facilitating secure exchanges. As a document of title, it also has significant legal implications, granting the holder legal authority over the goods and ensuring only the rightful holder may claim the goods at their destination (Schmitz 2011; Khartoum 2023).

In addition to the key information, the consignment note may include the place and date of issue, the names and addresses of the consignor, carrier, and consignee, as well as any reporting address. It can specify the place and date of goods acceptance, the designated delivery location, a description of the goods and packaging, package numbers and markings, agreed freight costs, and payment terms. Other details may include cash-on-delivery amounts, customs instructions, official handling requirements, and agreements for open or deck carriage without tarpaulins (Bundesamt für Justiz 2024a).

In ReMuNet's multimodal transport ecosystem, the consignment note is created by the transport orchestrator, typically the LSP, on behalf of the consignor. It is then forwarded to carriers, terminal operators, and successive LSPs and MTOs. Common file formats include PDF, CSV, XML, JSON, and EDIFACT. In practice, the consignment note is often referred to as a loading list, waybill, or bill of lading.

Forwarding Contract

> *"The freight forwarding contract obliges the freight forwarder to arrange the shipment of the goods"* (Bundesamt für Justiz 2024c).

In ReMuNet's multimodal transport ecosystem, the consignment note is created by the transport orchestrator, typically the LSP, on behalf of the consignor. It is then forwarded to carriers, terminal operators, and successive LSPs and MTOs. Common file formats include PDF, CSV, XML, JSON, and EDIFACT. In practice, the consignment note is often referred to as a loading list, waybill, or bill of lading.

Handover Protocol

The handover protocol acts as an inspection checklist for multimodal transport units. Each time a transport unit is transferred or its transportation state changes, the protocol is prepared by the previous owner and accepted by the new one (Achahchah 2019).

The protocol includes ELO and International Organization for Standardization (ISO) codes on the container, the CSC plate, an assessment of the exterior condition, and verification of the completeness of attached freight documents. If necessary, it may also include reports on the interior condition and the transported cargo. Common file formats are PDF, CSV, XML, JSON, and EDIFACT. In practice, the handover protocol may also be called an inspection checklist, handover confirmation, delivery note, or handover document. The proof of delivery, which is signed at the end of the process from the consignee is in this discussion referred as a handover protocol.

Invoice

The invoice in transportation logistics details the financial aspects of a shipment. It includes customer master data, type and quantity of goods, article numbers, product variants, pricing, taxes, and additional fees. Shared between the consignor, LSP, carrier, and terminal upon transport completion, it can be transmitted in formats such as PDF, CSV, XML, JSON, and EDIFACT. Integrated into systems like Supply Chain Management (SCM) systems, Customer Relationship Management (CRM) systems, and Transport Management System (TMS), the invoice ensures accurate billing and seamless tracking of financial transactions for all parties involved.

Order

In transport logistics, an order - whether a purchase, supply, or procurement order - initiates the movement of goods. Orders are communicated through various channels like email, API, or EDI, and are formatted in formats such as PDF, XML, or EDIFACT to streamline processing. Key order details include customer data, product type, quantity, and product identifiers, which are crucial for accurate handling. The consignee (recipient) and consignor (sender) roles define the parties involved, while systems like ERP, SCM, TMS, and CRM work together to integrate, manage, and track the order throughout the supply chain, ensuring efficient delivery to the customer.

Pick-up Form

In transport logistics, the pick-up form arranges the collection of goods from the consignor or warehouse, authorising the next transport step. Also referred to as a pick-up request, order, receipt, confirmation, or slip, it can be sent via fax, email, API, or EDI in formats such as PDF, XML, or EDIFACT. The form includes essential details like consignor and destination information, pick-up specifics (date, time, location, weight, and instructions), and service options. It facilitates coordination between the LSP, carrier, and TMS, ensuring timely and accurate pick-up arrangements. (R+L Carriers)

Real Time Status Report

A real-time status report provides up-to-the-minute tracking and delivery updates, ensuring transparency throughout the transport process. Accessible via live tracking, delivery status, and track-and-trace updates, it is transmitted through API or EDI and formatted as XML, JSON, or EDIFACT. The report includes GPS coordinates, real-time ETA, ELO/ISO codes, and identification details like CSC and vehicle plates.

This tool enhances operational efficiency for carriers, LSPs, consignors, and consignees by maintaining real-time visibility and control through systems like Asset Tracking System

(ATS), ERP, SCM, and TMS. Technologies such as IoT, GPS, Radio Frequency Identification (RFID), and Wi-Fi generate vast real-time data, improving decision-making, process performance, and resource optimisation. Big data analytics further transforms logistics networks into self-organising systems, using real-time data for tasks like route optimisation (Borgi et al. 2017).

Sustainability Balance Sheet

The sustainability balance sheet provides an overview of the environmental impact associated with logistics activities. Known as an environmental report, sustainability documentation, or green report, it is transmitted via API or EDI in formats such as PDF, XML, or JSON. This report includes key indicators like CO_2 emissions and offers routing alternatives based on sustainability criteria. Utilised by carriers, terminals, and LSPs, as well as consignors and consignees, the sustainability balance sheet is integrated into CRM and SCM systems to promote and document sustainable practices within the supply chain.

Traffic Report

The traffic report offers real-time insights into traffic conditions, including traffic jams, construction sites, and infrastructure blockages. This information is accessible through various formats such as PDF, CSV, XML, JSON, and EDIFACT, enabling seamless integration with TMS for efficient route planning and decision-making. The report helps optimise logistics operations by addressing potential delays and adjusting routes accordingly to ensure timely deliveries.

Transport Order

A transport order details information for the shipment of goods. It includes the sender, consignee, forwarder, delivery locations, and the date and place of goods handover. The order also outlines the number of packages, packing method, and specifics on the nature, size, and weight of the goods, including any dangerous goods considerations. It specifies transport details such as the route, mode of transport, and applicable Incoterms. Additionally, the freight contract obligates the carrier to transport goods to the destination and deliver them to the recipient, while the sender is responsible for paying the agreed freight charges (Bundesamt für Justiz 2024b). The transport order facilitates efficient coordination between the LSP, carrier, and other stakeholders to ensure timely and safe delivery, and the relevant regulations apply when the goods are transported as part of a commercial enterprise (Bundesamt für Justiz 2024b). This information is exchanged via multiple formats like PDF, CSV, XML, JSON, and EDIFACT, ensuring seamless integration with systems like CRM, TMS, and ERP.

Weather Report

The weather report provides information on weather forecasts, water levels, and extreme weather conditions. This data helps logistics companies plan and adjust routes to avoid delays caused by adverse weather, ensuring timely deliveries. The report is available in various formats such as PDF, CSV, XML, JSON, and EDIFACT, and can be integrated through API or EDI into TMS for real-time decision-making. By utilising weather data, transportation operations can be optimised for safety and efficiency, reducing the impact of weather disruptions.

4.3.2.2 Information Systems

Information systems play a critical role in the collection, transmission, and processing of data, acting as the backbone of any organisation. Often referred to as the “nervous system” (Grabara und Kot 2014) of a company, these systems are particularly critical in the transportation sector, where efficiency and accuracy are highly important. Their effective implementation is essential for optimising operations and enhancing overall performance across the industry (Grabara und Kot 2014). The following sections provide a brief overview of the different systems used in the ecosystem with its main functionalities. Additionally, the survey provides insights into the types of systems employed by different actors, including whether they use common commercial solutions or custom in-house systems.

Asset Tracking System

An ATS in logistics is a technology-driven solution for real-time monitoring and management of assets like vehicles, containers, and inventory throughout the supply chain. Its primary purpose is to provide enhanced visibility into asset location, condition, and movement, allowing logistics providers to optimise efficiency, minimise losses, and improve service quality. ATSs leverage technologies such as IoT, GPS, barcodes, Near Field Communication (NFC), and RFID, integrating operational data with strategic decision-making processes and forming a core component of modern logistics networks (Krit 2019).

A core function of an ATS is location monitoring. Using GPS and wireless sensors, these systems provide real-time asset location data, ensuring accurate tracking and enabling route optimisation. Adjustments can be made based on traffic, weather, or demand changes, improving delivery efficiency and reliability. According to the survey, GPS is the most used tracking method, with 50% of participants employing an ATS with GPS functionality (see Figure 19). However, there is no evidence from the survey to suggest that companies integrate GPS data with systems like Warehouse Management Systems (WMS) or similar tools (Devlin und McDonnell 2009; Mehta et al. 2021).

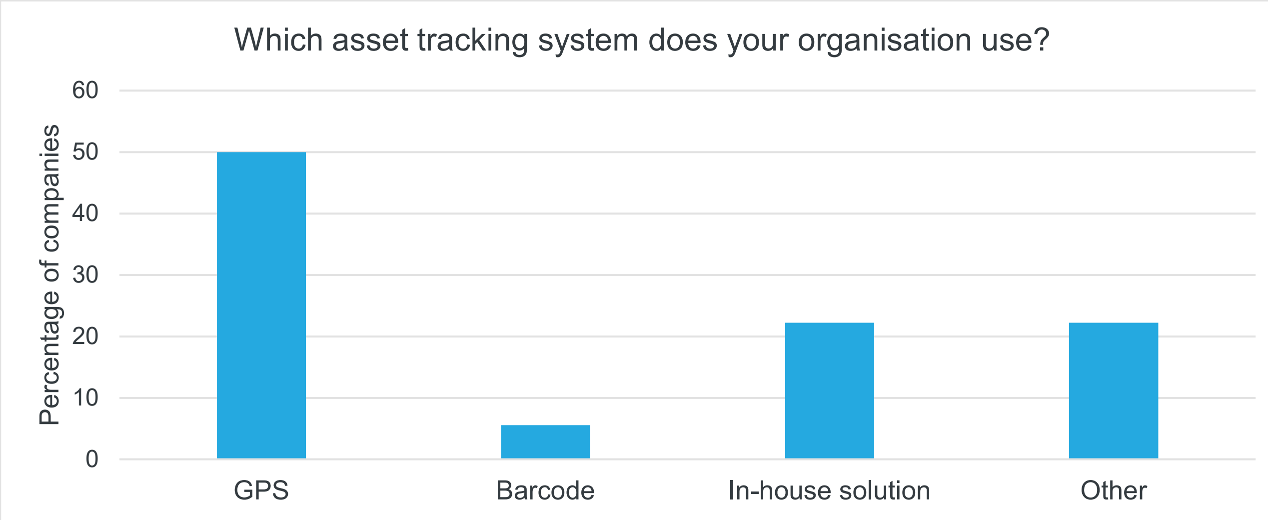

Figure 19: Overview of Survey Results: Usage of asset tracking systems

Another key function of an ATS is condition monitoring. Advanced ATS use sensors to track variables such as temperature, humidity, and vibration, ensuring assets remain in optimal condition during transit. This is particularly vital for industries with stringent quality standards, such as food and pharmaceuticals. Condition monitoring often integrates with WMS and TMS, combining storage and transit details with condition data to maintain quality control across storage and distribution points (Elpro 2024).

Inventory management is another essential activity supported by ATSs. RFID technology plays a significant role here, providing seamless integration between tracking systems and inventory databases to update asset counts automatically as items move in and out of warehouses. Nevertheless, this technology does not seem to be widely used in daily operations, visible in Figure 19 (Bhanage et al. 2007).

An increasingly prominent application within ATS is security and traceability through blockchain technology. By logging each asset's movement within a blockchain, companies can create a tamper-proof record of location and condition data, which ensures authenticity and reduces the risk of loss or fraud. This function is especially valuable for high-value or sensitive assets, as it enables full traceability across the entire supply chain and intersects with financial and compliance systems that require proof of asset integrity and security (Mehta et al. 2021).

Enterprise Resource Planning System

Enterprise Resource Planning (ERP) systems are integrated software platforms that manage and automate core business functions. By centralising data, they provide real-time access to improve decision-making and reduce manual tasks. ERP systems are widely adopted across industries for their ability to enhance data quality through efficient, real-time processing. However, their standardised designs, rooted in manufacturing, often struggle to meet the unique needs of the logistics sector.

In addition to ERP systems, EDIs are increasingly used to standardise and automate data exchanges between different systems. Despite their advantages, EDIs face challenges, including high implementation costs, which can be prohibitive for small and medium-sized enterprises (SMEs). Furthermore, diverse customer requirements often necessitate multiple standards, limiting EDI practicality in logistics.

To address these challenges, many companies have adopted Extensible Markup Language (XML) as an open standard for internet-based data exchange. Unlike EDI, which operates as a defined process, XML functions as a flexible language for handling data. EDI systems tend to be rigid and specific to systems, whereas XML's design-agnostic nature allows for data editing and modification across formats. XML is also more cost-effective, requiring lower investment for implementation and usage, making it a practical alternative in many scenarios. (Tapaninen et al. 2010)

According to the survey, SAP is the most used ERP system. Companies not using SAP rely on either in-house solutions or other niche systems (see Figure 20).

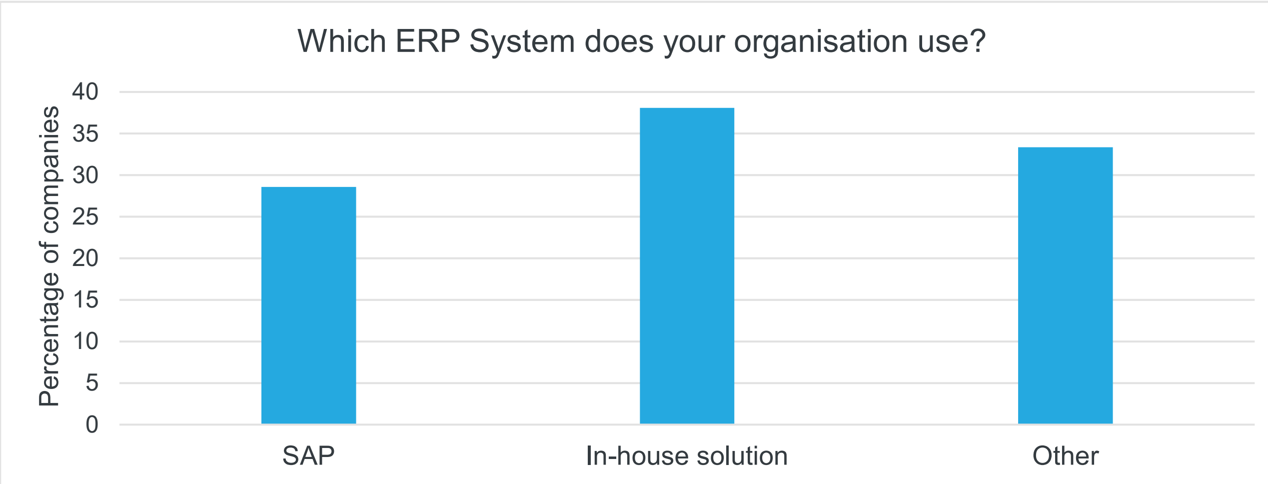

Figure 20: Overview of Survey Results: Usage of ERP systems

Supply Chain Management System

A Supply Chain Management System (SCMS) is essential within the logistics ecosystem for coordinating the efficient flow of materials, information, and finances throughout the supply chain. Its primary goal is to streamline the movement of goods from suppliers to consumers, reduce costs, ensure timely deliveries, and improve overall customer satisfaction (AltexSoft 2023).

One of the core logistics functions in SCMS is inventory management. By optimising inventory levels across various locations, an SCMS ensures that stock is available where and when needed while avoiding excess that could lead to increased holding costs. This capability often overlaps with WMS, which track inventory within storage facilities, helping logistics providers meet demand accurately and promptly (Deufol SE 2024).

Transportation and distribution management is another central aspect, as it coordinates the movement of goods from storage to final delivery points. SCMS integrates closely with TMS, which handle route planning, carrier selection, and tracking to optimise delivery times and minimise costs. This integration is essential in logistics, where unpredictable factors like weather and traffic can impact delivery schedules. Advanced SCMS platforms also use real-time data from IoT devices for live tracking and adaptive routing, making logistics more resilient to disruptions (Deufol SE 2024).

Warehouse operations are further streamlined through SCMS, allowing for efficient handling, storage, and retrieval of goods. A close integration with WMS facilitates order fulfilment by managing picking, packing, and shipping processes. Advanced SCMS platforms utilise automated solutions, such as robotics and AI-driven picking systems, to boost speed and accuracy within warehouses, thus directly benefiting logistics timelines and customer service levels (AltexSoft 2023).

Customer demand forecasting and order management in logistics are also enhanced by SCMS. By analysing historical data and real-time inputs, SCMS helps predict demand, ensuring adequate stock levels across the logistics network. This alignment with CRM systems further strengthens demand planning and order processing, minimising stockouts and improving delivery times. Figure 21 shows that CRM systems used in the industry vary a lot (Deufol SE 2024).

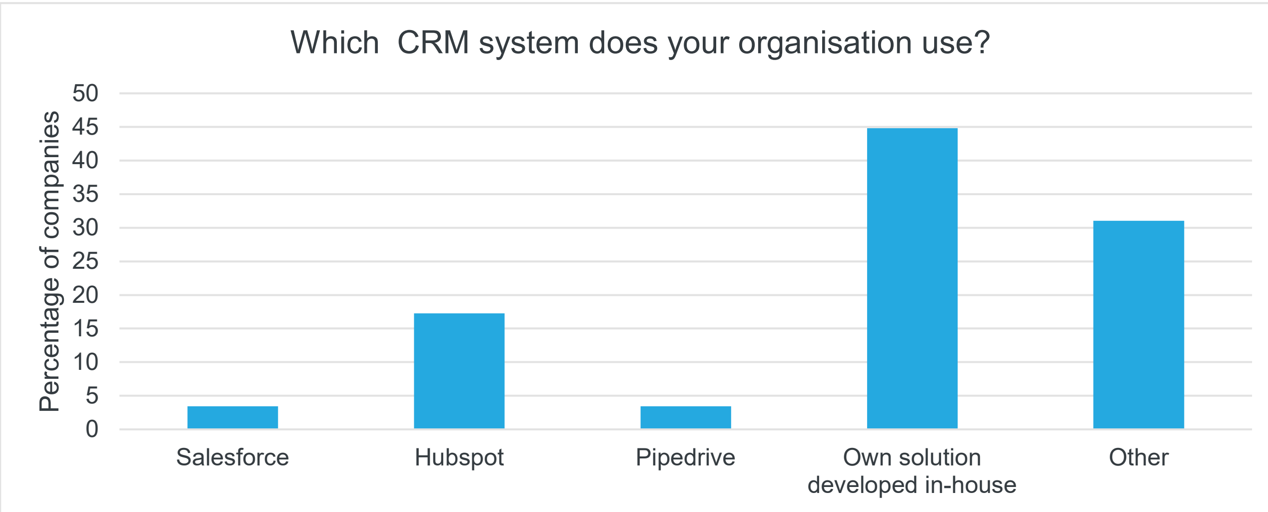

Figure 21: Overview of Survey Results: Usage of CRM systems

As part of a logistics ecosystem, SCMS not only supports internal processes, but also enables seamless integration with external systems such as ERP and TMS. This collaboration allows logistics providers to operate as part of a wider, interconnected network, ensuring that goods flow efficiently through every stage of the supply chain. SCMS is therefore central to creating a resilient and responsive logistics ecosystem that meets today's challenges of speed, efficiency and customer satisfaction (AltexSoft 2023). SAP provides the SCM solution to the most of companies, which does not use an in-house system (see Figure 22).

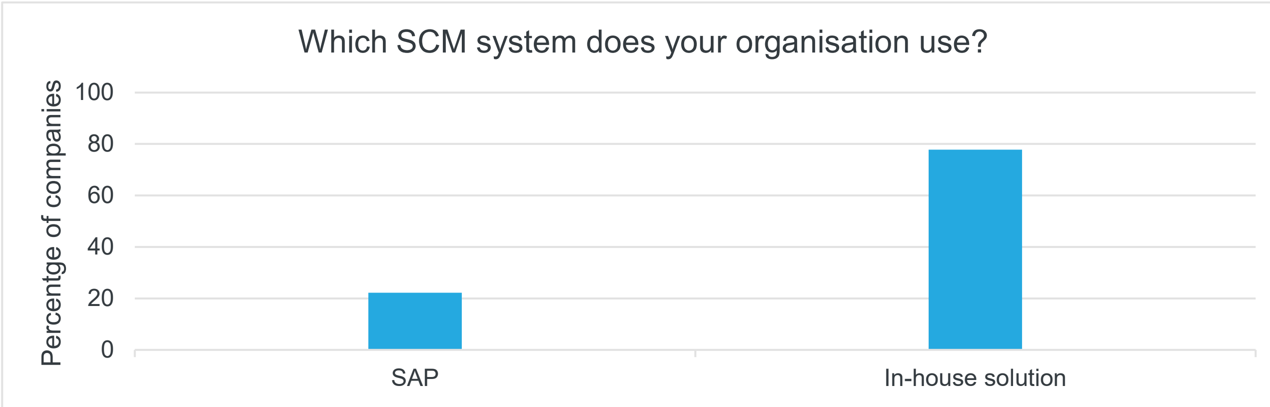

Figure 22: Overview of Survey Results: Usage of SCM systems

Transport Management System (TMS)

Since standard ERP systems have not fully met the unique demands of the logistics sector, and with supply chains growing in complexity, the late 1990s saw the creation of systems specifically designed to address these logistics challenges. Known as TMS, these systems now perform a variety of essential tasks, including managing orders, allocating resources, controlling costs, and tracking and tracing shipments, among other functions (Nettsträter et al. 2015).

Figure 23: Capabilities of Transport Management Systems (Nettsträter et al. 2015)

The TMS market today is diverse, offering solutions from various providers with notable differences in features and functionalities. Generally, as the range of features in a TMS expands, so does the system's complexity and cost. This means that functionality often correlates with company size, with SMEs usually working with fewer features than large corporations. Because the logistics industry is largely made up of SMEs that handle a broad spectrum of activities along the supply chain, their TMS requirements and capabilities vary widely. Additionally, recent advancements have introduced new demands for TMS solutions, further broadening the scope of available features.

There is also an increasing focus on cross-modal modelling, which is especially relevant to intermodal transport and represents a major area of future growth (Nettsträter et al. 2015). As a result, the functionality and scope of TMS are expected to expand, further supporting the role of TMS in intermodal transport going forward. Figure 23 showcases the wide variety of functions that can be covered by a TMS. Within the survey sample the most used TMS were in-house solutions or smaller alternatives (Figure 24).

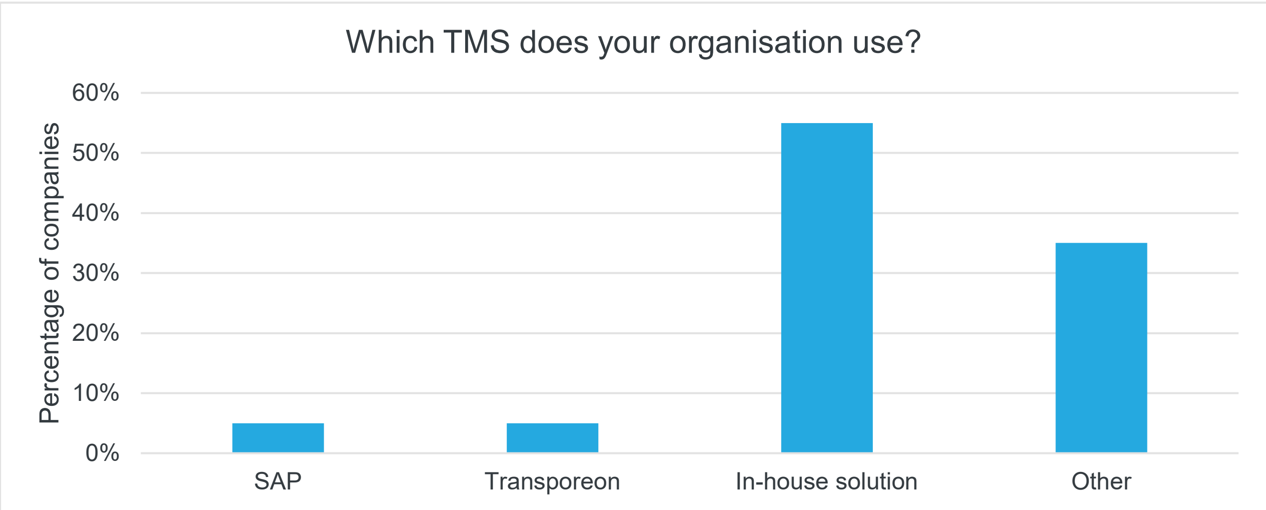

Figure 24: Overview of Survey Results: Usage of TMS systems

Terminal Operating System (TOS)

Information systems function as the "nervous system" (Grabara und Kot 2014) of an organisation, and in a similar way, Terminal Operating Systems (TOS) are the central command for terminal operations. The main advantage of TOS is its capacity to automate a vast number of processes that would otherwise need to be done manually, streamlining operations and boosting efficiency. TOS serves as the core software of a terminal, coordinating the planning, management, and monitoring of all activities within and around the terminal. It also allocates personnel to various tasks in real-time to optimise resource usage.

A comprehensive TOS can include up to 107 specific functions, which are categorised into six primary groups: *Warehouse*, *Maritime Operations*, *Goods Inbound and Outbound Logistics*, *Master Data*, *ERP Dashboard*, and *Communication* systems (Hervás-Peralta et al. 2019). Rather than providing an exhaustive enumeration of each function, the following sections offer a synthesis of the principal categories and their constituent elements. This summary aims to provide an accurate representation of the essential capabilities that a TOS provides. It should be noted that not all features are applicable in every setting. The capabilities of TOS are contingent upon operational requirements, and this subsection provides a theoretical overview, which is summarised in Figure 25.

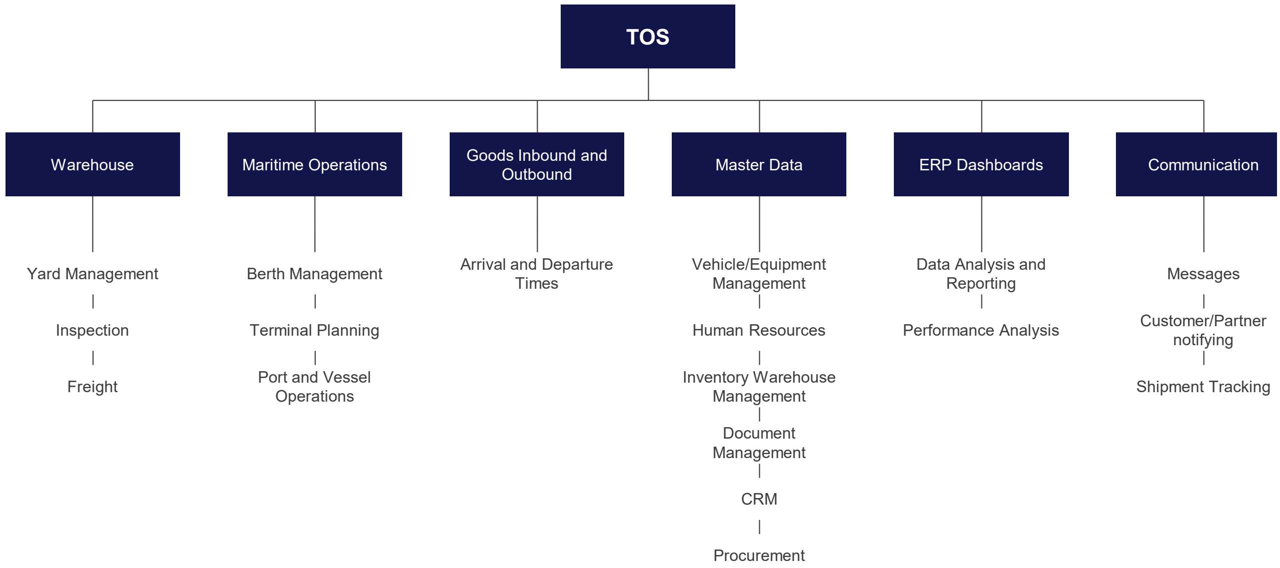

Figure 25: Capabilities of Terminal Operating Systems (Hervás-Peralta et al. 2019)

The *Warehouse* category in TOS includes yard management, inspection, and freight. Yard management details warehouse layout and space usage, while inspection records track scheduled checks and outcomes. Freight deals with cargo tracking, monitoring load unit locations and logging inspection details like cargo condition and weight (Hervás-Peralta et al. 2019).

Maritime Operations covers berth scheduling and vessel management, recording ship arrival times, crew details, and loading/unloading status, essential for inland and maritime terminals. These tasks are grouped into berth management, terminal planning and port and vessel operations (Hervás-Peralta et al. 2019).

The *Goods Inbound and Outbound* category records carrier arrival and departure times, which can be tracked through TOS (Hervás-Peralta et al. 2019).

Master Data includes the categories vehicle and equipment management, Human resources, inventory and warehouse management, document management, CRM and procurement. In addition to basic documentation, the focus is primarily on reviewing and evaluating the data. This can be done, for example, using KPIs. The needed time to complete an order or the ability to collect and analyse real-time data is also taken into account. (Hervás-Peralta et al. 2019).

In the *ERP Dashboard* category, data analysis automates reporting, with logs accessible to monitor activities and performance. The performance analysis outlines the cost structure of the terminal and gives an overview of KPI achievement rate (Hervás-Peralta et al. 2019).

The *Communication* category supports external communication, allowing data sharing with customers and intermodal partners, and offers vehicle traceability and data integration (Hervás-Peralta et al. 2019).

Warehouse Management System (WMS)

WMS may be interpreted as an integral component of the TOS (Hervás-Peralta et al. 2019). They facilitate the management and oversight of daily warehouse operations through the utilisation of software solutions which are vital for the seamless management of inventory, enhancing supply chain efficiency, and reducing long-term operational expenses (VCA Logistik).

"*In particular, WMS systems are designed to support the needs of a comprehensive global supply chain, including distribution, manufacturing, capital-intensive, and service companies*" (Oracle Deutschland).

At the same time, WMS support decision-making regarding the expansion and growth of your business. Given the numerous WMS solutions available on the market, selection of a suitable system depends on individual company needs. With 75% of the WMS used being in-house solutions, the variety of different systems is very high. The only other WMS used by the participants of the survey was from SAP (Figure 26).

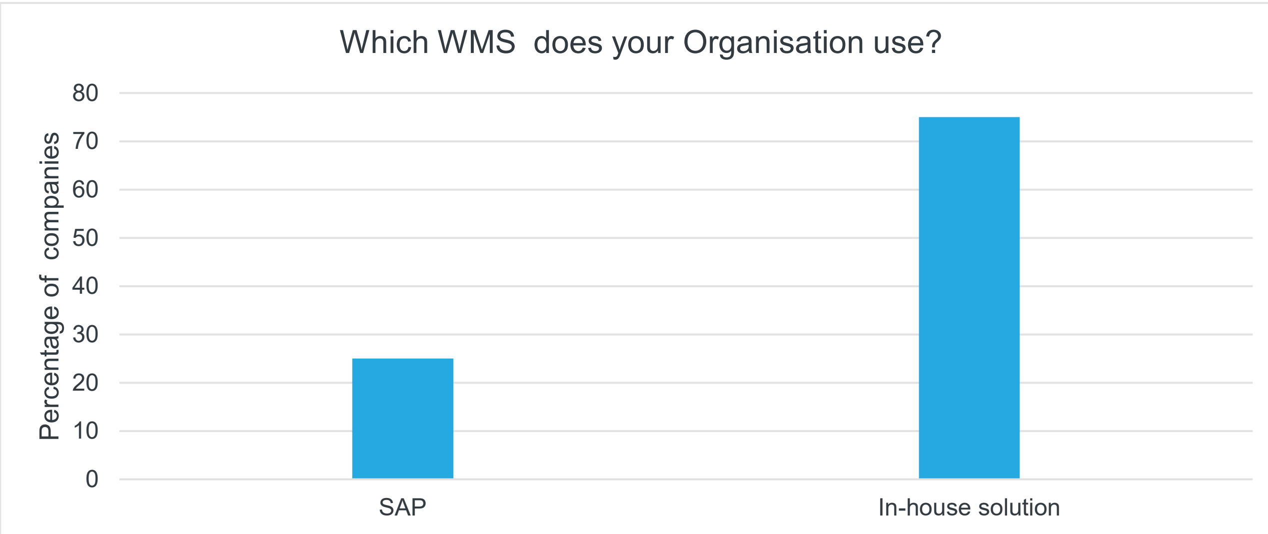

Figure 26: Overview of Survey Results: Usage of WMS systems

To optimise overall warehouse management, WMS provide a variety of different functions. Key features include, in addition to supporting goods receipt and storage, inventory management, management of storage locations, picking and packing of goods, shipping management, workflow management, yard and gate management, as well as reporting and analysis. A WMS is recommended for businesses of all sizes that need to manage inventory and related processes. Without a computerised system, errors are more likely to occur. WMS software helps minimise these inaccuracies by automating and streamlining warehouse operations.

4.3.2.3 Information Flow Model

Following the methodology of den Ouden (2012), Figure 27 highlights the diversity of documents and information exchanged in logistics, including orders, invoices, handover protocols, and status reports.

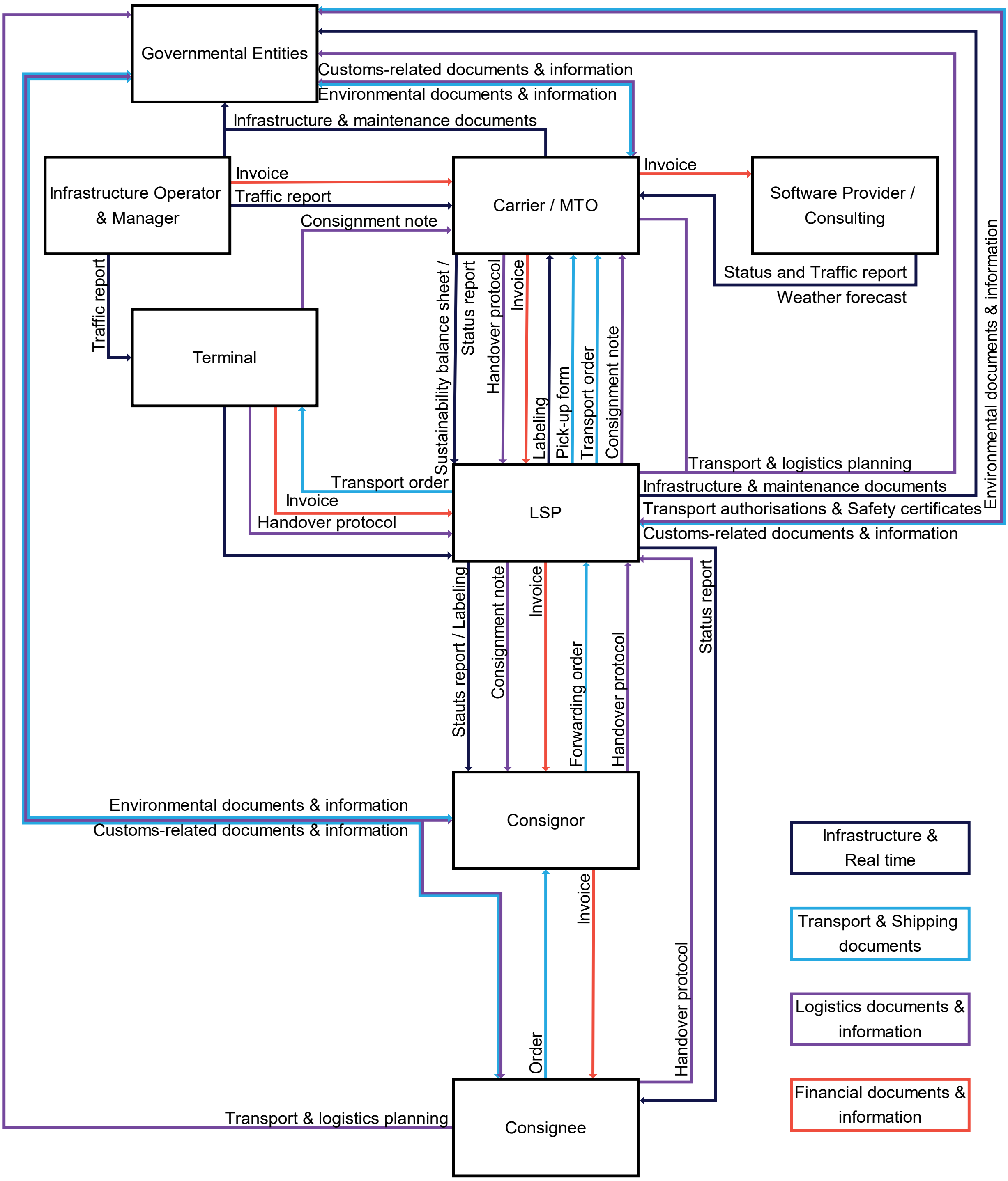

Figure 27: Information Flow Model of the multimodal freight transport ecosystem

While this work consolidates these documents into a coherent overview, their types and contents can vary greatly depending on factors such as country, transport mode, and contractual agreements. The information flow presented represents a standard case and focuses on elements most relevant to the ReMuNet project.

To simplify analysis and discussion, the figure summarises the most important aspects rather than every detail from interviews and workshops. Certain data types are grouped into broader categories for clarity. For example, capacity details from infrastructure operators and terminals, along with delay notifications from carriers, are classified as "traffic reports." Communications from governmental entities related to traffic controls are labelled as "invoices," and ETA or GPS-based tracking updates are categorised as "status reports." This grouping emphasises core information exchanges crucial to the project's objectives.

The LSP, operating as a 2PL to 4PL, facilitates the largest volume of information exchange as the intermediary between actors. It prepares and shares key documents, such as pickup forms detailing carrier instructions and consignment notes ensuring consistency and traceability throughout the logistics chain. This central role of the LSP as an information hub ensures all parties receive necessary documentation, maintaining a continuous and organised information flow.

4.3.3 Flow of Finances

Financial flows are an important aspect for ReMuNet as in future deliverables, the operator and business models of the ReMuNet solutions are going to be designed. Therefore, the following subchapter discusses the financial flow and incoterms which help to standardise these processes.

4.3.3.1 Financial Transactions

During the analysis of financial flows within logistics services, it was observed that payment structures typically follow a common sequence, though significant variability exists in practice. Generally, the consignee pays the consignor after the delivery of goods, at which point the consignor settles the payment with the LSP (see Figure 28).

The LSP, responsible for organising the transport, then proceeds to compensate all parties involved in the transport process, such as carriers and subcontractors (Chen et al. 2019). Despite a typical flow, consultations with experts reveal an absence of standardised payment rules. No governing mechanism dictates when each supply chain entity should be compensated, resulting in significant variability in payment contracts.

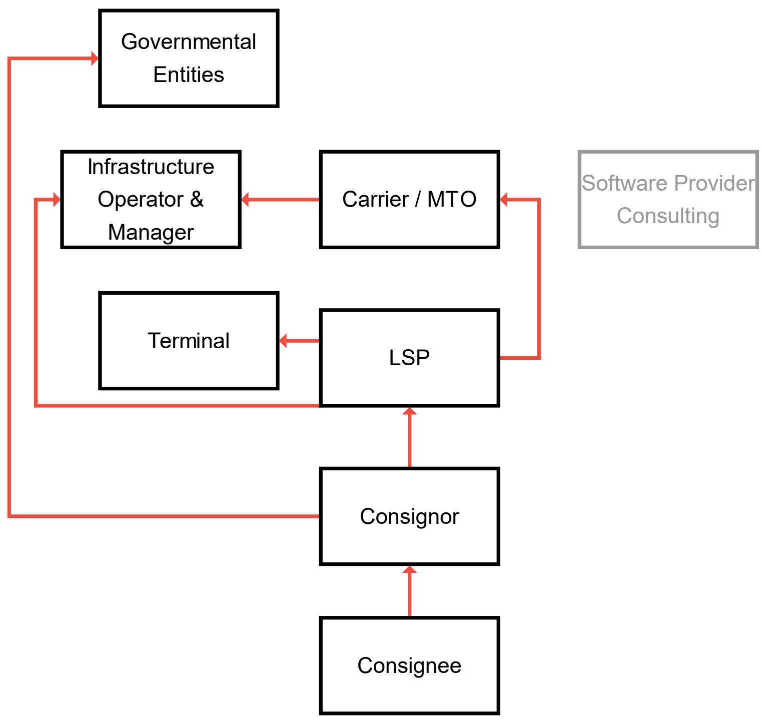

Figure 28: Visualisation of financial flows in the multimodal freight transport ecosystem

Payment terms in the logistics industry - whether prepayment, payment upon delivery, or post-delivery payment - are often individually negotiated. These terms vary significantly based on the relative bargaining power of the parties. For instance, an LSP may offer different payment schedules to clients depending on their negotiation position and the nature of their relationship. This customisation adds complexity to financial transactions across the logistics chain, as agreements are tailored case by case rather than following a universal standard.

Customs duties also play a key role in financial flows. Typically, the consignee is responsible for covering customs fees. However, LSPs may handle these payments on behalf of consignees, reflecting the sector's flexibility. Such arrangements depend on the specific contractual terms between the consignee and the LSP, further underscoring the lack of uniformity in financial responsibilities.

Overall, payment flows and contractual agreements in Business to Business (B2B) logistics lack standardisation. While this flexibility allows for tailored negotiations, it also presents an opportunity to improve efficiency. Streamlining payment processes and establishing clearer financial agreements could deliver cost and time-saving benefits for all stakeholders.

4.3.3.2 Incoterms

The complexity of financial responsibilities in logistics is further compounded by the influence of Incoterms (International Commercial Terms). They represent are a set of globally recognised trade terms published by the International Chamber of Commerce (ICC). They serve as a standardised framework used in international and domestic contracts for the sale of goods, clearly defining the responsibilities, costs, and risks between sellers and buyers during the transportation process. By specifying the exact point at which the risk of loss or damage to the goods transfers from the seller to the buyer, Incoterms help prevent misunderstandings and disputes related to shipping, insurance, and tariffs. The use of different Incoterms can significantly affect financial flows, as responsibilities for transport costs, customs, insurance, and other logistical expenses are distributed differently depending on the chosen term. The primary purpose of Incoterms is to provide a common language that outlines each party's obligations in a sales contract, particularly concerning the delivery of goods. They detail who is responsible for tasks such as:

a) Arranging transportation and bearing its costs.

b) Managing export and import customs clearance.

c) Obtaining insurance.

d) Handling documentation and providing necessary information.

Incorporating Incoterms into contracts involves specifying the chosen term, followed by the named place or port, and referencing the version of Incoterms being used (e.g., "FOB Hamburg Incoterms 2020"). This precision ensures both parties have a mutual understanding of their duties, reducing the potential for legal disputes and facilitating smoother international trade operations.

The latest version, Incoterms 2020, includes 11 terms divided into two categories based on the mode of transport:

Incoterms Applicable to Any Mode of Transport:

- EXW (Ex Works): The seller makes the goods available at their premises. The buyer bears all costs and risks involved in taking the goods from there to the desired destination, including loading.
- FCA (Free Carrier): The seller delivers the goods to a carrier, or another party nominated by the buyer at the seller's premises or another specified location. The seller is responsible for export clearance.
- CPT (Carriage Paid To): The seller pays for the carriage of goods to the named destination. Risk transfers to the buyer once the goods are handed over to the carrier.
- CIP (Carriage and Insurance Paid To): Like CPT, but the seller also procures insurance against the buyer's risk of loss or damage during transit.
- DAP (Delivered at Place): The seller delivers when the goods are placed at the disposal of the buyer at the named destination, ready for unloading. The seller bears all risks involved in bringing the goods to this point.
- DPU (Delivered at Place Unloaded): The seller delivers the goods unloaded at the named destination. This is the only Incoterm that requires the seller to unload the goods.

- DDP (Delivered Duty Paid): The seller delivers the goods to the buyer at the named destination and bears all costs and risks, including duties, taxes, and customs formalities.

Incoterms Applicable to Sea and Inland Waterway Transport:

- FAS (Free Alongside Ship): The seller delivers when the goods are placed alongside the vessel at the named port of shipment. The buyer assumes all costs and risks from that point forward.
- FOB (Free On Board): The seller delivers when the goods are loaded on board the vessel at the named port of shipment. Risk transfers to the buyer once the goods are on board.
- CFR (Cost and Freight): The seller pays the costs and freight to bring the goods to the port of destination. Risk transfers to the buyer when the goods are loaded on the ship.
- CIF (Cost, Insurance, and Freight): Similar to CFR, but the seller also provides insurance cover against the buyer's risk of loss or damage during transit.

By clearly outlining these responsibilities, Incoterms help streamline international trade, reduce the likelihood of disputes, and ensure that both parties are aware of their obligations, leading to more efficient and effective transport processes (Laudwein, 2024) (Zoll Germany, 2024).

4.4 Combined Value Flow Model of the multimodal Freight Transport Ecosystem

The development of the Value Flow Model (VFM) followed a holistic approach to synthesise and visualise the intricate interactions within the logistics ecosystem. Presented in Figure 29, the VFM offers a unified and simplified representation of previous building blocks.

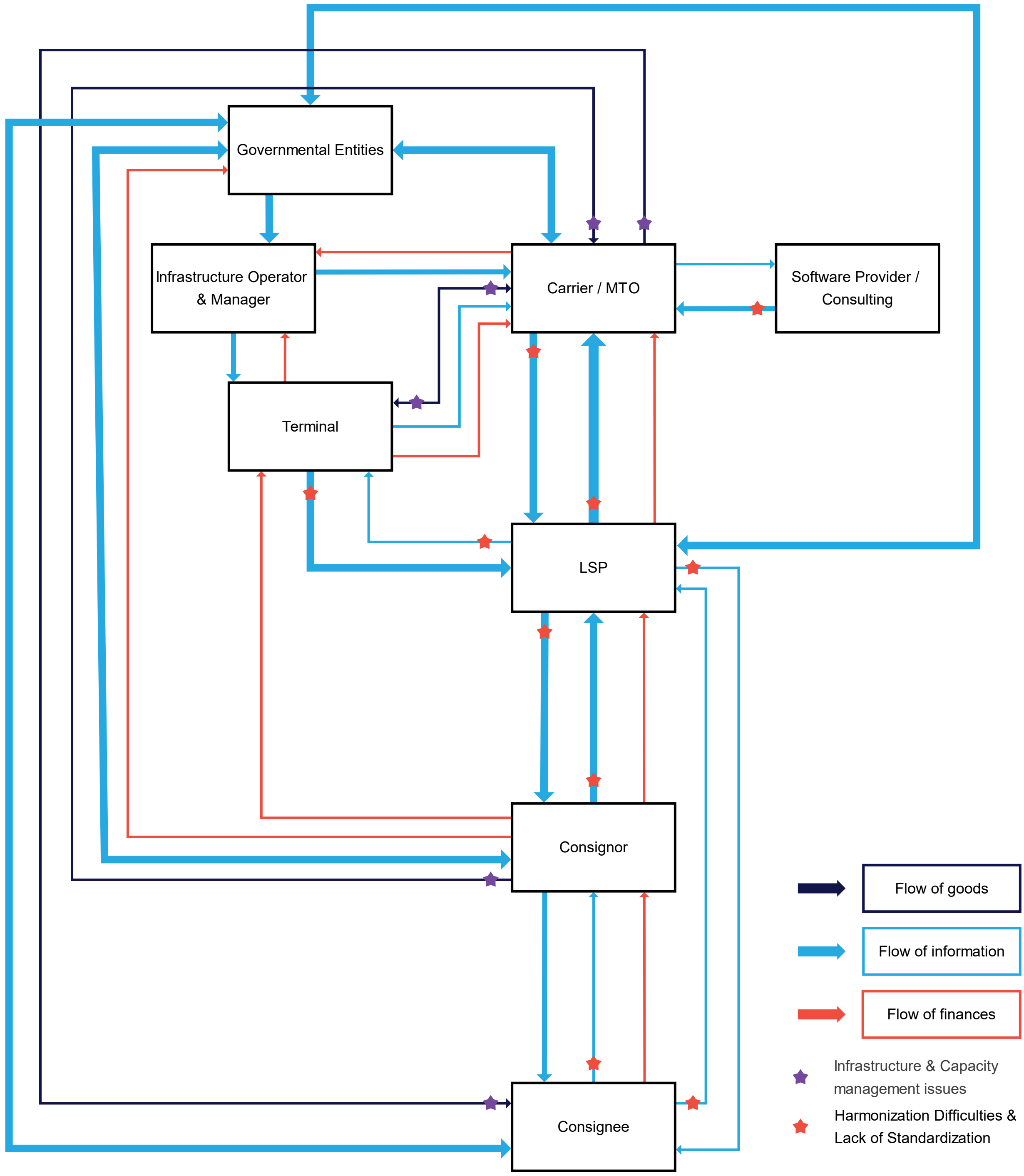

Figure 29: Simplified Value Flow Model of the multimodal freight transport ecosystem

It consolidates information from earlier chapters, providing a comprehensive overview of value flows among logistics network actors. The VFM captures key aspects of information exchange and value creation. Arrow thickness in the model signifies the volume of information exchanged, with thicker arrows representing higher frequency or intensity of interactions. This feature highlights the most critical relationships within the network.

A key observation from the VFM is the concentration of information exchange among three primary roles: Carrier, LSP, and Terminal. These entities form the core of the logistics network, with the most significant value and information flows occurring between them, underscoring their critical interactions.

Not all roles are involved in every flow depicted, reflecting the specialised nature of certain interactions and varying levels of stakeholder integration. The VFM provides insights into the structure of the network, illustrating the relative importance of different relationships.

The model also incorporates identified pain points within the multimodal transport process, spotlighting areas for potential improvement. A notable number of issues stem from information flows, including the lack of standardisation and document inconsistencies. Goods and services flows are hindered by infrastructure and capacity management problems, such as aging transportation networks, insufficient maintenance, and misalignment between order timelines and capacity planning, particularly in barge and train transport. These challenges contribute to inefficiencies and vulnerabilities in the logistics system and will be discussed extensively in chapter 5.

The VFM is designed to serve as a foundational tool for business model development. Its simplified yet comprehensive structure enables stakeholders to quickly grasp key relationships and value flows, guiding further progress and facilitating decision-making.

In conclusion, the VFM is a critical step in understanding and optimising the logistics network. By visually representing the complex interplay of information and value among roles, it serves as a powerful tool for analysis, strategic planning, and improving the broader logistics sector.

4.5 Ecosystems of Rhine-Danube and North Sea Baltic corridors

The previous chapters provide a generalised mapping of the multimodal freight transport business ecosystem. While much of the input is derived from partners active in the Rhine-Danube and North-Sea Baltic corridors, the findings are broadly applicable to most multimodal transport ecosystems. As the project aims to deliver a proof of concept for these two corridors, this chapter aligns the ecosystems of the Rhine-Danube and North-Sea Baltic corridors with the previously mapped framework. Actors from both corridors are analysed and categorised based on the roles they fulfil within the ecosystem.

Notably, several large-market actors fulfil multiple roles, performing various actions and tasks across the ecosystem. However, the role-based descriptions remain intact, as the same actors may occupy multiple nodes in the value flow model without altering its structure.

Describing the flows in greater detail for each corridor proves more complex due to outdated and limited data (~2017). Deliverable 1.1 already addressed the description of these corridors, but insufficient data makes identifying concrete differences in flows challenging. Consequently, this chapter focuses on differences between actors operating in the two regions.

Sorting actors entirely into distinct corridor categories is also difficult, necessitating three classifications: cross-corridor actors, North-Sea Baltic actors, and Rhine-Danube actors.

4.5.1 Cross-Corridor Actors

This subsection describes exemplary actors who assume ecosystem roles across corridors are presented here. As outlined in Chapter 4, actors are assigned to archetypal roles within the ecosystem using a simplified approach. However, larger players frequently fulfil multiple roles, which are not fully detailed in this section. To ensure clarity and consistency, the actors have been assigned to the primary roles deemed most appropriate based on the research findings.

4.5.1.1 Carriers

DHL Group offers a range of logistics services across all common transportation modes – air, road, rail, and IWW. In addition to standard transportation, DHL offers customised multimodal solutions to meet the diverse needs of various industries. With a comprehensive network across Europe, DHL plays a key role in both corridors, providing tailored freight forwarding and logistics services across air, ocean, rail, and road transport.

DHL's advanced digital platform enhances efficiency and visibility by providing transparency and tracking for logistics operations along strategic European trade routes. With a presence in over 220 countries, DHL also offers customs, insurance, and e-commerce services, supporting businesses, particularly in the Baltic region. Accordingly, DHL fits the roles of both *carrier* and *freight forwarder*.

DB Schenker is a leading global logistics service provider, operates as a *carrier*, *freight forwarder*, and *multimodal transport operator*. The company delivers a broad range of services, including air, sea, and land transportation, as well as supply chain management solutions. Active along the Rhine-Danube corridors and the North Sea-Baltic region, DB Schenker supports local industries with comprehensive logistics services. With over 1,850 locations worldwide, DB Schenker delivers efficient logistics solutions, including warehousing, distribution, and specialised transport. The company leverages advanced ERP systems and the eSchenker tracking tool to ensure real-time transparency, data analysis, and streamlined supply chain management.

Active in both established and emerging markets, DB Schenker connects major economic regions with pan-European land transport services, offering time- and cost-effective solutions for less-than-truckload, full truckload, and door-to-door shipments. In air and sea freight, DB Schenker ranks among the top global providers, offering a wide range of international transport services.

4.5.1.2 Freight forwarders

Kühne + Nagel is a leader in global logistics that originated as a *freight forwarder*, now offers integrated and specialised supply chain solutions across a wide range of industries. As one of the global leaders in freight forwarding via ocean, the company is also one of the key carriers in both the Rhine-Danube and North Sea-Baltic corridors. In addition to its strong presence in ocean and air freight, Kühne + Nagel focuses on contract logistics and land transport, operating one of the largest international less-than-truckload networks in the industry.

With over 1,300 locations in more than 100 countries, Kühne & Nagel serves key regions, including Europe, and is committed to sustainability through innovative solutions such as carbon-free transportation, biofuel shipments, and its collaborative platform, myKN, for real-time shipment management. These efforts reflect the company's dedication to providing efficient, sustainable, and transparent logistics services to meet the evolving needs of its global customer base.

Rhenus Group is an important logistics service provider in the Rhine-Danube corridor specialising in *freight forwarding* across road, rail, and sea. The company offers multimodal transport services, facilitating efficient trade and supply chain operations between Central and Eastern Europe. Furthermore, Rhenus Group is also a leading logistics provider in the North Sea-Baltic corridor, playing a crucial role in connecting key European markets and facilitating efficient trade flows between Northern Europe and the Baltics. Through its logistics solutions, Rhenus ensures smooth and reliable supply chain management along these transport routes.

4.5.1.3 Multimodal transport operators

Hupac Group is a provider of multimodal transport solutions in Europe, handling approximately 1 million road consignments annually. The company primarily focuses on rail transport but also offers road and sea freight services. As Europe's leading operator in intermodal transport, Hupac operates 24 companies across countries including Switzerland, Italy, Germany, the Netherlands, Poland, and Belgium, with a network that extends to the Far East. With a strong commitment to environmental sustainability, Hupac’s rail transport solutions help shift traffic from road to rail, contributing to reduced emissions and promoting environmental protection. The company provides high flexibility, excellent service, and reliable solutions to its customers.

Hupac operates 12 key terminals across Europe, particularly in the Rhine-Danube corridor, at strategic hubs such as Duisburg, Cologne, Ludwigshafen, and Vienna. These terminals are equipped with its own personnel, resources, and advanced software solutions, ensuring efficient and seamless intermodal transport across Europe. Concluding, Hupac can be sorted as a *multimodal transport operator*.

Contargo is with an annual transport volume of over 2 million Twenty-foot Equivalent Unit (TEU) one of the leading providers in container logistics services in Europe as a *multimodal transport operator*. Contargo has a stronger presence in the North Sea-Baltic Corridor. Operating an extensive trimodal network, the company plays a key role in connecting the Western seaports, the German North Sea ports, and the European hinterland. Through multimodal transport using waterways, rail, and road, Contargo offers not only cost-effective but also environmentally friendly transportation solutions. As a terminal operator, Contargo is primarily active in the Rhine-Danube Corridor, where it connects key logistics hubs such as Duisburg, Mannheim, and Basel, facilitating the efficient movement of goods across Central and Eastern Europe. It operates a growing network of 24 container terminals, mostly trimodal, providing a combination of rail, road, and water transport. With a presence in six countries, the company ensures the secure transport of goods by selecting optimal combined transport solutions.

The **CFL multimodal Group** is a leading provider in the field of multimodal logistics, with 11 locations in 5 European countries. The company offers comprehensive services, including rail transport, wagon maintenance, customs clearance, as well as freight forwarding and logistics solution. The intermodal terminal in Bettemburg-Dudelange (Luxembourg), strategically located on Rail Freight Corridor 2 (North Sea-Mediterranean), serves as an important hub for multimodal transport flows, bringing together freight from across Europe and beyond. As a multimodal transport operator, CFL multimodal is primarily active in the North Sea-Baltic Corridor. With this the CFL Group is an important *multimodal transport operator*.

CFL Terminals, a subsidiary of CFL multimodal, is a multimodal *terminal operator* in Bettembourg-Dudelange on the Eurohub Sud site. This terminal, covering an area of 33 hectares, specialises in handling all types of intermodal transport units. Strategically located along the North Sea-Mediterranean Freight Corridor, the terminal sits at the crossroads of key European transport routes, making it ideally positioned to consolidate multimodal traffic flows both within Europe and internationally. Due to the terminal’s location, CFL multimodal is also active as a terminal operator in the Rhine-Danube Corridor, supporting multimodal connections and facilitating trade flows between Western Europe and Central/Eastern Europe.

4.5.1.4 Digital logistic service providers

4PL Intermodal is a digital logistics service provider that supports companies in organising and executing goods transports from industry and commerce. The company specialises in digitalising the successful order networking of partial services. It utilises innovative IT-based solutions for logistics networks, enabling clients to manage their transport processes efficiently. 4PL Intermodal's high-quality intermodal supply chain solution ensures that intermodal customers can find and successfully complete the right connections. As a DLSP, the company supports customers in organising and completing goods transport for industry and trade. 4PL Intermodal focuses on digitalising intermodal order networking by integrating partial services to help clients efficiently execute desired connections. Tailored and standardised software products are provided to intermodal operators.

To address communication gaps in TMS software, the company automates and connects system landscapes, ensuring compatibility across platforms. This maximises resource visibility and supports efficient utilisation.

Transporeon is a leading cloud-based transportation management platform that enables shippers, freight forwarders, and carriers to efficiently manage, monitor, and execute their logistics processes. Since its founding, the company has grown from a startup to a multinational provider, now with over 1,000 employees and operations in more than 17 locations worldwide, including in Asia, Europe, and America. By combining industry knowledge with

IT expertise, Transporeon offers an end-to-end software solution that connects all parties in the transport logistics supply chain. The platform enables seamless integration and optimisation of logistics processes, from planning through to execution. Transporeon is a prime example of a *digital logistic service provider.*

4.5.1.5 Software providers

SAP is a global leader in enterprise software, helping companies optimise their critical business processes in areas such as finance, procurement, human resources, supply chain, and customer experience for over 50 years. With offices in 130 countries, SAP helps businesses achieve better results by integrating these processes. SAP also offers solutions to enhance transportation management, fleet management, and logistics, driving sustainable goals and maximising the return on global transportation and domestic shipping costs. These include interactive freight tendering, transportation demand planning, and efficient freight settlement. It is one of the most dominant examples of a *software provider.*

PTV Group is a global leader in traffic planning, simulation, and real-time traffic management. With more than 40 years of experience, the Germany-based company develops advanced software solutions that span from traffic modelling and simulation to real-time traffic control. Over 2,500 cities and municipalities, as well as businesses in more than 120 countries, trust PTV's innovative solutions to optimise traffic flow, improve infrastructure planning, and enhance transportation efficiency worldwide. With this kit, PTV is an important *software provider* for route planners, network planner and dispatchers in the freight transport industry.

Dassault Systèmes is a company with over 193 locations worldwide that develops science-based solutions to improve various aspects of life and work. It primarily operates as a *software provider*. The company encompasses 13 brands offering services such as 3D design, Digital Mockup (DMU), and Product Lifecycle Management (PLM). These technologies help companies make progress in areas like green logistics, product lifespan, and waste reduction. In the transportation sector, Dassault Systèmes supports the redevelopment and revitalisation of infrastructures with their software. Their tools also give the possibility to connect the essential systems during transport operations to optimise end-to-end supply chain management.

4.5.1.6 Terminal Operators

DP World operates over 60 ports and terminals worldwide, providing smart, seamless gateways for global trade – from the factory floor to the customer’s door. With an end-to-end strategy covering ports, terminals, onward transportation, and warehousing, DP World ensures a smooth flow of goods across the entire supply chain. In Europe, DP World’s portfolio includes fourteen inland terminals strategically located in key economic centres in Belgium, France, Germany, Serbia, Switzerland, and Romania. Some of these terminals are fully owned by DP World, while others are operated in partnership, such as Swissterminal and DP World Liège Container Terminals SA. It is one of the most important *Terminal operators.*

4.5.1.7 Consulting and support service providers

Tplan Consulting specialises in providing *support and consulting services* for transport infrastructure projects. The company offers market and economic analysis throughout the entire lifecycle of transport infrastructure, helping clients make informed decisions at every stage. Additionally, Tplan provides expert consulting services to public authorities, investors, and infrastructure managers, supporting the successful planning, development, and management of transport infrastructure projects.

CSE COE (Central and Southern Europe Centre of Excellence) is a *consulting* firm specialising in providing support and advisory services to the public sector, with a particular focus on government, public policies, and IT advisory. The company operates across several regions, including the Baltic States and the EU, offering solutions aimed at improving public service delivery and optimising the use of IT tools to enhance governance. CSE COE works closely with public authorities to streamline operations, boost efficiency, and promote innovation in government processes, ensuring better outcomes for citizens and more effective use of technology in public administration.

4flow provides services in logistics consulting, logistics software, and 4PL management. As a *consulting* company, 4flow supports businesses across the entire supply chain, from procurement and production to distribution and delivery to end customers. In addition to consulting, 4flow operates as a *software provider* and *digital logistic service provider,* including tools for supply chain network design, TMS, and integrated transport planning. The company also offers SAP-based solutions and applications built on Kinaxis. With more than 20 locations in Europe, Asia, North America, and South America, 4flow handles over 300 projects annually.

4.5.2 Rhine-Danube Corridor

The Rhine-Danube Corridor is a key east-west link across Continental Europe. Following the Danube River, it connects Strasbourg and Southern Germany to Central European cities such as Vienna, Bratislava, and Budapest, then continues through Bucharest to the Black Sea port of Constanta. A second branch extends from Frankfurt to the Slovakian Ukrainian border, linking Munich, Prague, Žilina, and Košice. The corridor spans France, Germany, Austria, the Czech Republic, Slovakia, Croatia, Bulgaria, and Romania, while also touching Switzerland, Ukraine, Serbia, and Bosnia (von Stamm et al. 2024).

The corridor includes 4,488 kilometres of roads connecting Member State capitals, with all roads set to be upgraded to motorways by 2030. Its rail network covers 5,715 kilometres, 91% of which are electrified. The inland waterway network spans 3,650 kilometres, primarily along the Danube (2,400 kilometres), with additional sections on rivers such as the Rhine, Main, and Sava. This network connects to 19 inland ports (von Stamm et al. 2024).

The following subsection will provide an exemplary overview of relevant actors operating in the Rhine-Danube corridor and explore their roles in the ecosystem.

4.5.2.1 Carriers

The **Rail Cargo Group** is one of the key *carriers* in the Rhine-Danube Corridor. As a subsidiary of Austrian Federal Railways (ÖBB), it is the largest rail logistics provider in Europe, offering comprehensive rail transport services across the continent. The group plays a crucial role in facilitating the movement of goods between Central and Eastern Europe.

The **Gysev Cargo Zrt.** Is a Hungarian company specialising as a carrier in rail freight transport, while also providing logistic services. It operates in several European countries such as Hungary, Romania and Austria, with its primary focus on the Rhine-Danube Corridor. Gysev Cargo Zrt. is not only active as a carrier, but also acts as a multimodal transport operator, offering the service of combining different modes of transport – water, air and land. The company works in close cooperation with its Austrian subsidiary, Raaperbahn Cargo GmbH.

4.5.2.2 Freight Fowarders

Gebrüder Weiss offers transport solutions worldwide. In Europe, it is mainly active in the Rhine-Danube Corridor. As a freight forwarder, the company provides transport and logistics solutions covering all modes of transport – air, sea, rail and road – while managing the entire process of transport execution.

Spedition Dettendorfer is a family-owned company from Bavaria that operates as a freight forwarder in several European countries, with a particular focus on Germany and Austria, thus covering the Rhine-Danube Corridor. The company primarily offers transportation services by truck but also relies on intermodal solutions that combine road and rail transport. Additionally, Spedition Dettendorfer complements its service range with logistics and warehousing solutions.

Schachinger Logistik is an Austrian road *freight forwarder* and *logistics service provider* specialising in sustainable and efficient supply chain solutions. The company offers a range of services, including transport, warehousing, and value-added logistics, with a focus on innovative and environmentally friendly practices. It operates across various industries, providing tailored solutions to meet customer needs.

4.5.2.3 Multimodal transport operators

Ekol is a logistics company founded in 1990, offering top-tier services in freight, warehousing, domestic and international trade, customs, and supply chain management across 11 countries. The company is known for its high-quality service, providing efficient, punctual, cost-effective, and environmentally friendly transport of goods between destinations. As a *multimodal transport operator* Ekol utilises a range of intermodal transport methods, including road vehicles, Ro-Ro ships, and trains.

XPO Logistics is an important *multimodal transport operator* offering new and sustainable end-to-end logistics solutions in Europe. With a global reach across seven continental corridors and numerous short-sea connections in Europe and Morocco, it offers customised, multimodal transport solutions tailored to the specific needs of its customers.

4.5.2.4 Software providers

Alpega provides *software* solutions that enable shippers, freight forwarders, and carriers to achieve smarter and more sustainable logistics. The company promotes collaboration and efficient decision-making through an open freight network. With a wide range of solutions for transport execution, planning, freight sourcing, and payment, Alpega gives freight forwarders and carriers access to three leading freight exchanges in Europe, with a particular focus on Iberia, Romania, and Central and Southeastern Europe, which is why it plays a significant role in the Rhine-Danube corridor.

4.5.2.5 Terminal operators

With 20 intermodal terminals across Central and Eastern Europe, the **Metrans** network is optimally positioned to efficiently meet logistical needs. The terminals, covering a total area of 2 million square meters, serve as central hubs for cargo handling and enable smooth transitions between rail and truck and are hence an important *terminal operator*. Key locations in the Rhine-Danube Corridor include Krems an der Donau and Dunajska Streda.

Hafen Wien is a key logistics hub in Austria, serving as a multimodal transport and logistics centre. Located on the Danube River, it integrates road, rail, and inland waterway transport, facilitating efficient freight handling and distribution. Hafen Wien provides *infrastructure* for cargo handling, storage, and value-added logistics services. Its strategic location supports regional and international trade, particularly within the Danube corridor. **WienCont** is a subsidiary of Hafen Wien, specialising in container logistics and terminal services. Operating Austria's largest container *terminal*, WienCont offers services such as container handling, storage, repair, and maintenance. It also provides intermodal connections, supporting seamless transfers between road, rail, and waterway transport modes.

4.5.2.6 Infrastructure operators and managers

The **ÖBB Infrastruktur AG** is a fully owned subsidiary of ÖBB-Holding AG, which in turn is entirely owned by the Republic of Austria. The company invests over 3 billion euros annually in the Austrian rail network and is committed to utilising the latest railway technology. It handles the planning, construction, and operation of the entire ÖBB infrastructure, including stations, tracks, buildings, terminals, telecommunications systems, and hydroelectric power plants for the environmentally friendly generation of railway power. For railway transport it is one of the most important *infrastructure operators and managers* in Austria.

MÁV Zrt. operates the majority of Hungary's public railway network, MÁV Zrt. oversees the operation of approximately 7,000 kilometres of railway tracks and the associated infrastructure. It undertakes all tasks related to operations, traffic control, and maintenance, as well as some of the renovation work. We therefore classify it as *an infrastructure operator and manager*.

The Rumanian national railway *infrastructure manager* company called **Caile Ferate Romane (CFR)** provides all railway operators with a high-performance, reliable, and environmentally friendly infrastructure that ensures the safe transport of passengers and goods.

DB InfraGO was formed through the merger of DB Netz AG and DB Station & Service AG and is primarily responsible for managing and developing railway infrastructure in Germany, which boasts the largest rail network in Europe. The company's mission is to enhance the efficiency of the rail network and improve the appeal of railway stations, aiming to create a seamless and attractive travel experience for passengers while supporting the growth and modernisation of Germany's rail infrastructure.

Due to the strategic importance of Germany's rail network, DB Infrastructure Go is primarily associated with the Rhine-Danube Corridor. However, the company also plays a significant role in the North Sea-Baltic Corridor. It is one of the most important *infrastructure operator and manager* of Germany.

4.5.2.7 Governmental entities

Below in Table 20 relevant governmental entities of the different countries within the Rhine-Danube corridor are listed.

Table 20: Governmental entities of the different countries in the Rhine-Danube corridor

Country	Transport authorities
Germany	Federal Ministry for Digital and Transport (BMDV): Oversees national transport policies across all modes.
	Federal Railway Authority (EBA): Regulates rail transport.
	Federal Waterways and Shipping Administration (WSV): Manages inland waterways.
Austria	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK): Responsible for transport policy and infrastructure.
	Austrian Federal Railways (ÖBB): Manages rail operations.
	Via Donau – Österreichische Wasserstraßen-Gesellschaft mbH: Oversees the Danube waterway.
Czech Republic	Ministry of Transport (MDČR): Oversees transport policy and infrastructure.
	Správa železnic: Manages railway infrastructure.
	Ředitelství vodních cest ČR (ŘVC): Oversees inland waterways.
Slovakia	Ministry of Transport and Construction (MDV SR): Responsible for transport policy and infrastructure.
	Železnice Slovenskej republiky (ŽSR): Manages railway infrastructure.
	Slovak Water Management Enterprise (SVP): Oversees inland waterways.
Hungary	Ministry of Construction and Transport (ÉKM): Oversees transport policy and infrastructure.

	Hungarian State Railways (MÁV): Manages rail operations.
	National Water Authority (OVF): Oversees inland waterways.
Croatia	Ministry of the Sea, Transport and Infrastructure (MMPI): Responsible for transport policy and infrastructure.
	HŽ Infrastruktura: Manages railway infrastructure.
	Agency for Inland Waterways (AVP): Oversees inland waterways.
Romania	Ministry of Transport and Infrastructure (MTI): Oversees transport policy and infrastructure.
	Căile Ferate Române (CFR): Manages railway infrastructure.
	Administration of the Navigable Canals (ACN): Oversees inland waterways.
Bulgaria	Ministry of Transport and Communications (MTC): Responsible for transport policy and infrastructure.
	National Railway Infrastructure Company (NRIC): Manages railway infrastructure.
	Executive Agency for Exploration and Maintenance of the Danube River (EAEMDR): Oversees inland waterways.
Ukraine	Ministry of Infrastructure of Ukraine (MinInfra): Oversees transport policy and infrastructure.
	Ukrzaliznytsia (Ukrainian Railways): Manages railway operations and infrastructure.
	Ukrainian Sea Ports Authority (USPA): Oversees inland and maritime waterways, including operations along the Danube River.
Country	**Customs Authorities**
Germany	Federal Customs Service (Zoll): Handles customs operations, including inspections and compliance.
Austria	Austrian Customs (Zollamt Österreich): Manages customs procedures and enforcement.
Czech Republic	Customs Administration of the Czech Republic (Celní správa ČR): Handles customs operations and compliance.
Slovakia	Financial Administration of the Slovak Republic (Finančná správa SR): Manages customs procedures and enforcement.
Hungary	National Tax and Customs Administration (NAV): Handles customs operations and compliance.

Croatia	Customs Administration of the Republic of Croatia (Carinska uprava): Manages customs procedures and enforcement.
Romania	National Agency for Fiscal Administration (ANAF): Handles customs operations and compliance.
Bulgaria	National Customs Agency (NCA): Manages customs procedures and enforcement.
Ukraine	State Customs Service of Ukraine (SCS): Manages customs procedures, inspections, and enforcement for imports, exports, and transit.

4.5.3 North Sea Baltic Corridor

The North Sea-Baltic TEN-T Corridor serves as the primary link between northern European countries, connecting the northwest and northeast of Europe.

The corridor includes 6,934 kilometres of roads as of 2021, spanning from Finland and northern Sweden through Poland to the Ukrainian border. Initially covering 4,092 kilometres, these roads connect the capitals of all Member States along the route. Its railway network extends 8,828 kilometres, though some Baltic sections face challenges with non-electrified tracks and differing track gauges. The inland waterway network spans 2,839 kilometres, linking North Sea ports in northern France, the Netherlands, and Germany to Berlin (von Stamm et al. 2024).

The following subsection presents an exemplary overview of key actors operating within the North Sea-Baltic Corridor and examines their roles within the logistics ecosystem.

4.5.3.1 Carriers

DFDS Freight is a leading company in European freight transportation with one of the largest networks in Europe. It Mainly operates in the North Sea – Baltic Corridor covering connections to the North Sea, Baltic Sea, Mediterranean and the English Channel. DFDS primarily operates as a *carrier*, offering a wide range of container ship options. The company is also a major *freight forwarder* and acts as a *terminal operator*, owning eight terminals across Europe.

Ahola Transport is one of the leading companies in the North Sea-Baltic corridor and is also expanding its presence and influence in Central and Eastern Europe. As a family-owned business, Ahola is primarily active as a *carrier* in road freight transport. At the same timer, the company also takes on tasks that are typically associated with freight forwarders, such as route planning and coordinating transport assignments.

PKP Cargo, Poland's largest rail freight operator and a leading EU *carrier*, offers services including *rail transport,* logistics, *terminal operations*, and rolling stock maintenance. With subsidiaries like PKP CARGO CONNECT and PKP CARGO INTERNATIONAL, it provides integrated logistics solutions across Europe. Headquartered in Warsaw and employing around 21,000 people (2022), PKP Cargo became the first EU rail freight operator listed on the Warsaw Stock Exchange in 2013.

4.5.3.2 Freight forwarders

DSV is one of the world's leading freight forwarders, founded in 1976 and headquartered in Denmark. Operating in over 80 countries, DSV specialises in air, sea, road, and rail freight forwarding, as well as warehousing and supply chain management.

As a *freight forwarder*, DSV coordinates efficient and reliable transport solutions across its global network. Its key divisions include DSV Air & Sea, managing international air and ocean freight; DSV Road, providing road transport services across major markets; and DSV Solutions, focusing on contract logistics and supply chain optimisation. With advanced IT systems and a commitment to innovation, DSV supports diverse industries while prioritising sustainability in global logistics.

Freja Transport and Logistics, part of the Danish, family-owned United Shipping & Trading Company (USTC), provides transport, logistics, and warehousing solutions across Europe and globally. The company is one of the leading logistics service providers in the Nordic countries and operates in 40 countries. Freja acts as a *freight forwarder*, organising transport by combining various modes of transport such as sea freight, air freight, and road transport.

4.5.3.3 Multimodal transport operators

C.H. Robinson is a global leader in logistics, known for its solutions in supply chain and freight logistics. The company provides over 90,000 customers with customised solutions for designing and optimising supply chains, advancing freight technologies, and solving logistics-related challenges – from the simplest to the most complex. C.H. Robinson operates a network of 450,000 contracted carriers and handles an annual freight volume of $22 billion. With unmatched expertise, an unrivalled market size, and tailored concepts, the company ensures the smooth and efficient delivery of goods across industries and continents – whether by truck, less-than-truckload, ocean and air freight, or through intermodal solutions as a *multimodal transport operator*.

Kombiverkehr operates as a *multimodal transport operator* in 25 European countries, connecting 220 terminals with over 170 train departures daily. The focus is on the North Sea-Baltic Corridor. The company specialises in the development, organisation, and marketing of transport services in combined transport, utilising trucks, trains, and ships.

4.5.3.4 Terminal operators

PSA International is a global leader as *a terminal operator*. The company operates over 60 deepwater, rail, and inland terminals across more than 170 locations in 45 countries, including two major flagship ports in Singapore and Belgium. PSA works closely with port authorities, business organisations, and multinational companies to develop, manage, and operate world-class port infrastructures.

Samskip sea and *land terminals operation* plays an important role in the European transport network. In addition to door-to-door services, Samskip also offers quay-to-quay services, where these terminals act as hubs for delivery or collection by shippers, with the United Kingdom and Ireland being the most frequently used areas. Therefore, Samskip is primarily assigned to the North Sea-Baltic Corridor as a terminal operator. The new terminal and future hub in Rotterdam, operated in collaboration with Matrans Rotterdam Terminal, was recently opened and will become another important hub in Samskip's network.

4.5.3.5 Infrastructure operators and managers

The **Finnish Transport Infrastructure Agency** is responsible for the development, maintenance, and optimisation of the state-owned road network, railways, and waterways. Due to its geographical location, it is assigned to the North Sea-Baltic Corridor. Its tasks include the planning and development of transport routes, ensuring service standards on these infrastructures, as well as coordinating transport and land use. Additionally, the FTIA is also responsible for traffic management and winter navigation. It is the biggest finish *Infrastructure operator and manager.*

Polskie Linie Kolejowe S.A. (**PLK)** is *infrastructure operator and manager* responsible for the railway infrastructure in Poland, which spans over 3,700 kilometres and is part of the Core Network Corridors of the trans-European transport network. Due to its geographical location, it is assigned to the North Sea-Baltic Corridor. PLK's tasks include the maintenance of rail tracks, the scheduling of timetables, and the management of railway infrastructure.

AB LTG Infra is responsible for the rail infrastructure in Lithuania, operating 1,767 kilometres of railway lines with a focus on modernisation and network development. Key priorities include the renovation and expansion of international corridors to ensure technical interoperability with European systems and to meet safety and environmental requirements. By utilising EU funding for *infrastructure operators and managers*, the agency works to increase capacity, train speeds, and axle load, while also implementing advanced communication and alarm systems.

Rijkswaterstaat, the executive agency of the Ministry of Infrastructure and Water Management, is responsible for the planning, construction, management, and maintenance of the key infrastructure facilities in the Netherlands, including the main road network, major waterways, and the national water system. With the big harbours and logistics sector present in the Netherlands it is an important *infrastructure operator and manager* who plays a key role in the North Sea-Baltic Corridor.

4.5.3.6 Governmental entities

Table 21: Governmental entities of the different countries in the North Sea-Baltic corridor

Country	Transport Authorities
Netherlands	Ministry of Infrastructure and Water Management (IenW): Oversees transport policy and infrastructure.
	ProRail: Manages railway infrastructure.
	Rijkswaterstaat: Responsible for inland waterway management and maintenance.

Belgium	Federal Public Service for Mobility and Transport: Oversees transport policy across all modes.
	Infrabel: Manages rail infrastructure.
	Flemish Waterway Authority (De Vlaamse Waterweg NV): Oversees inland waterways in Flanders.
Poland	Ministry of Infrastructure (MI): Oversees national transport policy and infrastructure.
	PKP Polskie Linie Kolejowe (PKP PLK): Manages railway infrastructure.
	Polish Inland Navigation Authority (PZMiNW): Oversees inland waterways.
Lithuania	Ministry of Transport and Communications (Susisiekimo ministerija): Responsible for transport policy and infrastructure.
	Lithuanian Railways (LTG Infra): Manages railway infrastructure.
	Inland Waterways Authority (Kelių direkcija): Oversees waterways where applicable.
Latvia	Ministry of Transport (Satiksmes ministrija): Responsible for national transport policy and infrastructure.
	Latvijas Dzelzceļš (Latvian Railways): Manages railway infrastructure.
	State Navigation Authority (Valsts Navigācijas pārvalde): Oversees waterways.
Estonia	Ministry of Economic Affairs and Communications (MKM): Oversees transport policy and infrastructure.
	Estonian Railways (AS Eesti Raudtee): Manages railway infrastructure.
	Estonian Maritime Administration (Veeteede Amet): Oversees inland and maritime waterways.
Finland	Ministry of Transport and Communications (Liikenne- ja viestintäministeriö): Oversees transport policy and infrastructure.
	Finnish Transport Infrastructure Agency (Väylävirasto): Manages road, rail, and waterway infrastructure.
	Finnish Transport and Communications Agency (Traficom): Responsible for transport safety and licensing.
Country	**Customs Authorities**
Netherlands	Dutch Customs (Douane): Manages customs procedures and enforcement.
Belgium	Federal Public Service Finance - Customs and Excise Administration: Handles customs procedures and compliance.
Poland	National Revenue Administration (KAS): Manages customs operations and enforcement.

Lithuania	Lithuanian Customs Department (Muitinės departamentas): Handles customs operations and compliance.
Latvia	State Revenue Service (Valsts ieņēmumu dienests - VID): Manages customs operations and compliance.
Estonia	Estonian Tax and Customs Board (Maksu- ja Tolliamet): Handles customs operations and enforcement.
Finland	Finnish Customs (Tulli): Oversees customs procedures, inspections, and enforcement.

5 Existing Shortcomings and Pain Points

For the further progression of the project, particularly to derive specific requirements, it is crucial to have a detailed understanding of the pain points that influence the transport process. As part of D1.1, extensive exploratory research was already conducted through expert interviews. This research resulted in the following categorisation of identified pain points.

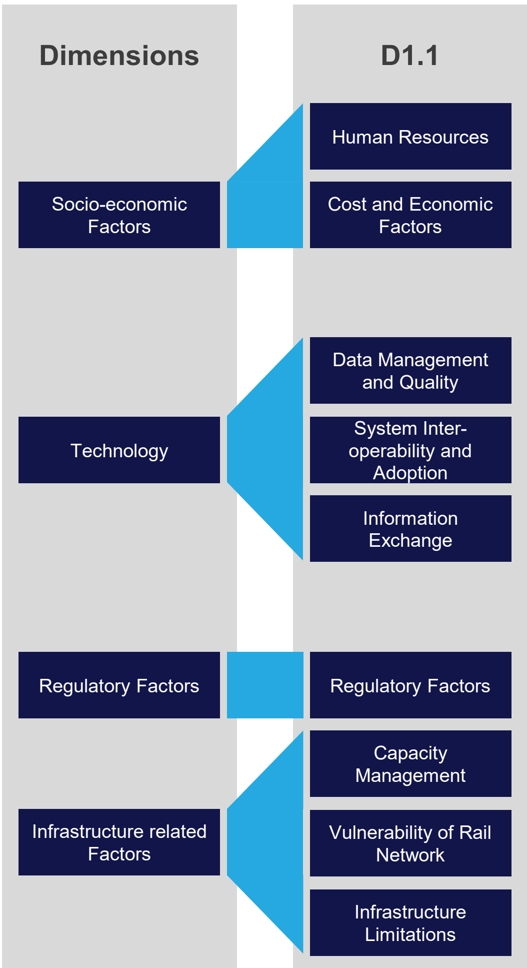

Figure **30**: Reflection of pain point categorisations

The findings from D1.1, visible in Figure 30 were thoroughly challenged, validated, and refined during the interviews and workshops conducted within the framework of D3.2.

During this process, the categorisation which will be described in the following subchapters proved to be the most accurate.

5.1 Socio-economic factors

The multimodal freight transport sector faces significant challenges, primarily driven by low margins and intense competition. Coupled with limited digitalisation and a general reluctance to share data, these factors place considerable cost pressure on companies and hinder collaboration. Additionally, the industry's environmental impact, particularly in transport, handling, and storage, makes sustainability a key driver for transformation. Another pressing issue is the shortage of skilled labour, exacerbated by generational changes, with many low-paid jobs in the sector facing a lack of successors. These interconnected challenges create a cycle of increased price pressure and competition, further complicating efforts for cross-company cooperation.

The following section expands on the insights from Deliverable 1.1, with a particular focus on the key socio-economic challenges facing the sector: human resources, sustainable transformation, and the lack of cooperation. These issues are central to the industry's current and future performance, influencing both operational efficiency and resilience.

Human Resources

Driver shortages in the logistics sector have become a critical issue, significantly impacting supply chain efficiency and reliability. As highlighted in the interview, the lack of skilled personnel represents a persistent challenge, with such people-related disruptions being classified under the broader category of social factors:

"So, non-availability of skilled personnel is, once again, a disruption that we are actively facing today. These people-related disruptions could be grouped into the category of social." (WS 4)

This challenge stems from a combination of factors, including an ageing workforce, low job attractiveness due to demanding working conditions, and regulatory restrictions on driving hours. Taking the jobs as truck drivers or barge captains as example, younger generations often view the profession as unappealing, given its long hours, time away from home, and limited career progression opportunities. The shortage is particularly pronounced in road transport, where the demand for skilled drivers far exceeds supply, leading to delays, increased costs, and inefficiencies across the logistics network as the following interview quote illustrates:

“We also had a period of when we were having a lot of difficulties related to […] Brexit and other things, and we had too little staff ourselves to handle things. And then what that

leads to, if we're not able to respond in time, they just accumulate more and more problems, because then things go south even further, things worsen, and we just need to do more and more work. So that's the thing that it's a snowball effect, really." (WS1)

Addressing this issue requires industry-wide efforts, such as improving working conditions, offering competitive wages, and investing in automation technologies like autonomous trucks to mitigate the workforce gap.

Sustainability Transformation

The logistics industry is facing increasing pressure from industry, politics and society to adopt more sustainable and environmentally friendly practices. Researchers and policymakers emphasise the urgent need to reduce greenhouse gas emissions, improve energy efficiency, and minimise the environmental impact of logistics operations, particularly considering global climate change. Logistics activities, including transportation, warehousing, and packaging, contribute significantly to carbon emissions, and the call for change is growing louder.

Society's demand for greener logistics is also intensifying, driven by heightened consumer awareness and expectations. Customers are increasingly prioritising companies that demonstrate a commitment to sustainability, and public opinion is shifting toward holding industries accountable for their environmental footprints. Businesses within the logistics sector are being pushed to adopt cleaner technologies, such as electric or alternative-fuel vehicles, and to optimise supply chain processes to reduce waste and emissions.

Lack of Cooperation

In the logistics industry, a lack of cooperation stands as a central challenge, strongly shaped by deep-seated distrust among stakeholders. This mistrust prevents potential synergies and efficiency gains from being fully realised, as companies are reluctant to share information and resources. The industry is highly competitive, and many companies fear that closer collaboration or data-sharing could endanger their competitive edge and economic interests. The lack of cooperation is also due to concerns over data security and confidentiality

In an industry where even minor details about pricing, route planning, or customer relationships are treated as valuable trade secrets, the risk of revealing operational strategies or financial information to competitors is simply too high for many stakeholders. As a result, the fear that sensitive data could end up in the wrong hands or be misused leads companies to adopt a cautious or even resistant stance toward collaborative initiatives. This concern was stated in several expert interviews and workshops:

"On the other hand, carriers are very overjealous of protecting and sharing how much capacity they have available in their shipment" (IP 3)

"The other issue is, of course, that because so many people in logistics are skimming off margins, the inherent inclination to share data is not necessarily very strong." (WS 3)

Protective attitudes in the industry often hinder transparency and collaborative problem-solving. While technical solutions, such as encryption and secure data exchange platforms, exist to ensure data security and confidentiality, they frequently fail to address the deeper concerns surrounding trust and openness. Establishing a culture of trust is critical, where companies are motivated not only by technical and contractual safeguards but also by the desire to work towards common goals.

Concerns regarding the security of data management systems and the risk of sensitive data being shared also persist in the context of digital platforms within the industry. These issues were highlighted during interviews, underscoring the ongoing challenges to secure, transparent collaboration:

> *"On the other hand, carriers are very overjealous of protecting and sharing how much the capacity they have available in their shipment."* (IP 2)

This observation is further supported by the results of the survey (see Figure 31).

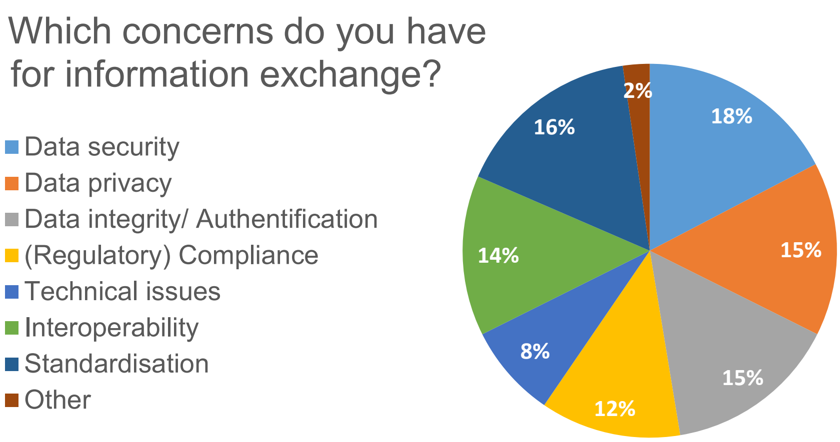

Figure 31: Interview results about concerns in information exchange

The lack of trust and reluctance to share data hinder the development of integrated digital infrastructures and standardised processes. This fragmentation leads to companies operating their own systems and workflows, making collaboration across the supply chain more difficult. As a result, inefficiencies slow down the entire transport process and raise costs. Many opportunities, particularly in capacity management, remain untapped. During disruptions, inadequate communication further delays or obstructs response efforts.

5.2 Technology-related Pain Points

Here the two Points “Data Management and Quality” and “System interoperability and adoptions” were summarised into one category “Inadequate system operability and data management”. According to the statements of the participants and this summarisation “Information Exchange” will be treated as a standardisation issue and assigned into the Regulations dimension. Furthermore, the category “Disruption Management” was added leading to following result:

Bad Disruption Management

One major pain point in disruption management is the lack of real-time visibility and communication across the logistics network. Many companies still rely on outdated systems that do not provide up-to-the-minute tracking or accurate location data, limiting their ability to respond quickly to unexpected events. This lack of visibility prevents timely decision-making and often leaves companies reacting to disruptions instead of proactively managing them. As one industry expert highlighted:

“The idea is to have a European train ID, unique ID number. I think that should be implemented. They are starting with that, but not easy because the problem we have a system that is based on national, they have really created national rules, national way to do the tracking. And then suddenly for cross border you have then to match and to map, I think the rules of, for example, DB from SBB and RFI, for example in Italy. And that's really a big gap, that's something that is not yet solved and that makes the life to get operational data quite strongly difficult.” (WS 1)

Another significant issue is the rigidity of many logistic networks and schedules, which limits flexibility in the face of disruptions. For example, tight delivery schedules, complex routing, and interdependent supply chain nodes leave little room to adapt when disruptions occur. Many logistics providers do not have backup plans or alternative routes readily available, making it challenging to reroute shipments or reschedule deliveries. One expert mentioned in an interview:

*“And I would say the lack of options for rerouting regarding real traffic, there are limited options sometimes, or even no options which then of course makes it very difficult to plan rerouting.“ (*IP 7)

This inflexibility can lead to bottlenecks, missed delivery windows, and increased costs as companies scramble to find alternative solutions. As another expert explained in an interview (translated from German):

"That’s the issue with both transport systems, railways and inland shipping. These are more or less closed systems where there’s no flexibility. You can’t just pull an inland ship aside somewhere on the Rhine. That’s simply not possible; you have to call at a port. It’s the same with railway stations for trains, you can compare it in that way. If there’s some kind of disruption in transit, it has a massive impact on the entire transport process. And in these systems, problems escalate into much bigger problems in a very short time, because then other trains or other inland ships can’t get through, the river gets blocked,

there's an investigation, and so on. Trains get rerouted, and suddenly everyone is re-routed, which creates problems in the next corridor. Issues spread through the network so rapidly and significantly that it takes a long time to bring these systems back to normal operations." (IP 2)

Capacity management during disruptions is another notable pain point. When disruptions occur, there is often a sudden need for additional capacity - whether that means finding additional trucks, storage, or personnel to handle rerouted or delayed shipments. However, in a tightly managed logistics ecosystem with limited resources, finding extra capacity on short notice is challenging and expensive. The shortage of available assets during disruptions can escalate costs and further delay the recovery process, as companies must often compete for limited resources in high demand.

Disruption management is further complicated by regulatory constraints that can slow down response times. Different regions may have specific rules and restrictions on rerouting goods or using alternative transportation modes, which can make quick adaptations difficult. For instance, customs regulations, labour laws, and environmental standards often prevent rapid responses or alternative solutions. In an interview, the challenges in the regulatory domain were described as follows:

"As I say, the challenges that we face is the complexity of the framework around the regulations and sometimes the frequent challenges that we need to adapt. So, I would say that this is the challenge that we face in the regulatory part." (IP 1)

These regulatory hurdles increase the time and resources needed to address disruptions, making it difficult for logistics providers to restore normal operations swiftly. This pinpoints how the different pain points are connected to each other.

Finally, the lack of predictive and analytical tools for risk assessment and proactive disruption management is a growing pain point in the industry. Many companies struggle to accurately anticipate disruptions and assess potential impacts, relying instead on reactive measures. The absence of advanced analytics, artificial intelligence, or predictive modelling tools limits the industry's ability to identify vulnerabilities and prepare for potential disruptions. Without these tools, logistics providers find it difficult to establish risk mitigation strategies or create contingency plans, leaving them vulnerable to even minor disruptions. This challenge was highlighted by an industry expert during an interview, who mentioned:

"On the other side, to try to handle these non-repetitive, sudden disruptions by making it more predictable. Here, once again, data would be very useful for us. And I think, with the help of data availability and probably through AI solutions, we can bring in an aspect of predictability also to non-predictable disruptions." (WS 4)

Inadequate system operability and data management

The systems used to manage documents and data within the multimodal transport ecosystem differ significantly across the various stakeholders involved. Each stakeholder often utilises unique solutions, whether for data management, document handling, or communication protocols, leading to a high degree of variability, as it was discussed during the information flows. Figure 31 highlights the high number of in-house system solutions in operation along both transport corridors.

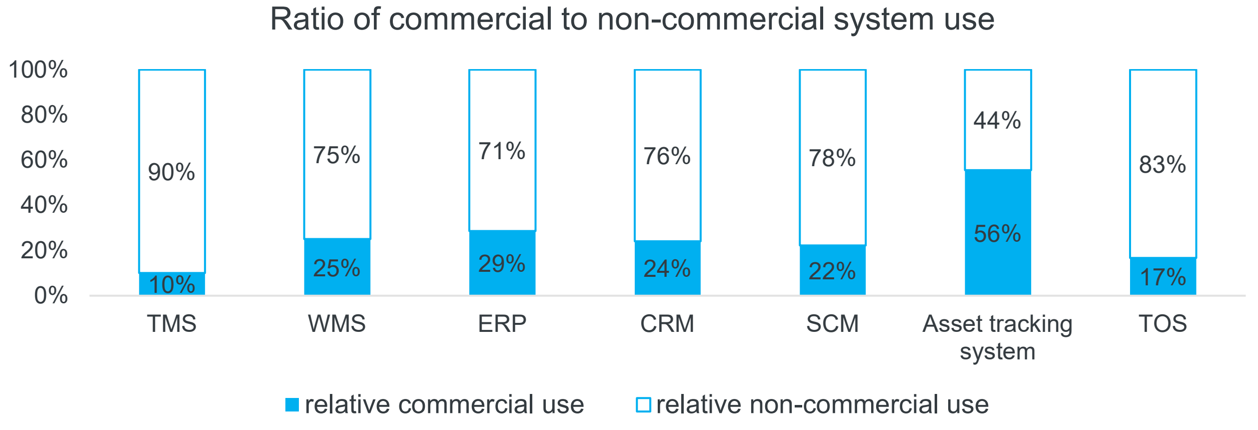

Figure 32: Overview of Survey Results: Ratio of commercial to non-commercial system use

This fragmentation creates a significant barrier to the exchange of standardised data, as the bespoke systems used by companies often lack compatibility with one another. As a result, the absence of interoperability hampers the smooth transfer of data and communication between stakeholders. This lack of cohesion complicates efforts to align processes and information flows, leading to inefficiencies, delays, and an increased risk of errors in document exchange. These challenges were also highlighted in several interviews and discussions:

“About the challenges, I would say that, for example, if we decided to adopt a system, it would be very difficult to have an integration between our system and the different systems that our clients use. So, the first challenge I can think is that. And what else about system interoperability? Yes, the systems may be not fully compatible, also may not offer this smooth data exchange because of the compatibility. So, this is what I can think about the system interoperability in general.” (IP 1)

Furthermore, this technological fragmentation has been a prominent topic of concern in several interviews and discussions with industry experts and stakeholders. They emphasised the urgent need for more harmonised solutions that facilitate interoperability, highlighting the critical impact that this disjointed system landscape has on the efficiency and reliability of multimodal transport operations. Developing unified standards and promoting broader adoption of compatible systems have emerged as key priorities for overcoming these challenges and fostering a more streamlined and interconnected ecosystem.

Different levels of Digitalisation

The challenge of interoperability is particularly acute for SMEs, which play an important role in logistics systems in several regions. The level of digitalisation among SMEs is comparatively low. In some areas, most of the transport is conducted by very small road carriers who possess limited digital capabilities and lack the resources to upgrade their technologies in the short to medium term. This situation creates additional barriers to standardisation and efficient exchange of information. The difficulties faced by these smaller carriers were also highlighted during a workshop:

“On the land side you have this one man and truck types of companies.” …They don't have an IT department, they cannot in a way do it themselves. So, either they need to be a subcontractor for somebody bigger, or then they're just going to drop out unless it's some super easy application that they can just download and start using.” (WS 3)

This observation highlights the pain points caused by the varying levels of digitalisation among stakeholders, particularly small enterprises. The lack of standardised documents, combined with the overwhelming variety of systems used for information handling, creates significant barriers for small carriers. These companies often lack the resources to adapt to complex digital solutions, which further complicates efforts to achieve interoperability and efficiency within the multimodal transport ecosystem. This underscores the importance of ensuring that smaller companies can be easily integrated, as outlined in the ReMuNet project requirements.

As discussed earlier in the chapter on the flow of information, the degree of digitalisation varies significantly across stakeholders, contributing to persistent challenges in data and document exchange. While larger companies typically have access to advanced digital platforms that facilitate communication and integration, many small and medium-sized enterprises (SMEs) lag behind in adopting such technologies. This digital divide creates bottlenecks, as stakeholders with limited digital infrastructure struggle to participate in real-time data exchange. SMEs often face financial and technical barriers, preventing them from implementing modern solutions, leaving them reliant on manual processes or outdated systems. These disparities exacerbate fragmentation within the supply chain, hindering interoperability and slowing the flow of critical documents and information. Addressing this imbalance is crucial for achieving greater harmonisation and efficiency in the logistics industry.

5.3 Regulatory Pain Points

Information exchange as a standardisation problem leads to the following subdivision:

Lack standardised Documents (former Information Exchange)

Highlighted in chapter 4.3.2.1 and 4.2, one core issue, which complicates the description and management of the information flow and process, lies in the lack of harmonisation across the various documents exchanged during the multimodal transport process. While standards do exist for different types of documents, they are often limited in scope. Many of these standards are specific to transport sectors - such as maritime shipping - making it challenging to apply or adapt these standards effectively across different modes of transport, such as rail or air freight. Furthermore, even when standards are in place, not all stakeholders adhere to them consistently. This lack of comprehensive, universally adopted standards creates friction in the information flow, resulting in inefficiencies and communication challenges across the entire multimodal logistics chain.

Regulatory Factors (Governmental Regulations/Customs)

The logistics sector faces numerous pain points and complications due to complex regulatory issues, which vary significantly across regions and transportation modes. Regulatory frameworks often differ from country to country, creating a fragmented landscape that requires logistics providers to navigate a maze of local, national, and international laws. These regulatory discrepancies can complicate cross-border operations, as companies must adapt to various legal requirements, customs procedures, and compliance standards. This lack of uniformity slows down transit times, creates additional administrative burdens, and leads to increased costs associated with legal compliance and paperwork.

One major regulatory challenge in the sector is customs regulations, which differ widely and can impact import and export processes. Customs procedures often require extensive documentation and can be subject to sudden policy changes, resulting in delays and unpredictable costs. For instance, requirements for cargo inspection, declarations, and tariff classifications can vary significantly by country, creating bottlenecks at borders and increasing the risk of non-compliance penalties. An industry expert highlighted this point, noting that:

“When goods must cross the border, this is where you could actually have disruptions that you cannot really control because it’s behind your control. You do not know how the border police or the customs (how) they (might) react to the documents you have. And that means that you have to stay there for hours, or you have to go back, and you don’t really know how to engage with them to get these things in place.” (IP 6)

Environmental regulations also pose significant challenges. The push for greener logistics has led to stricter emission standards, fuel regulations, and waste management policies. While these policies support sustainability, compliance often requires investment in new technologies, fuel alternatives, and sustainable practices, which can be costly and difficult to implement for smaller companies. This regulatory pressure is particularly burdensome in multimodal logistics, where different modes-such as road, rail and barge - are subject to different environmental standards, further complicating the coordination required for sustainable operations.

Labor regulations add yet another layer of complexity, affecting hiring practices, working hours, safety standards, and wages. Many countries impose strict labour laws, especially in road transport, where regulations on driver hours and rest periods are in place to ensure safety. While necessary, these regulations can disrupt schedules and increase operational costs, particularly in regions facing driver shortages. Adhering to varying labour laws in different regions requires careful planning and can hinder flexibility, especially in an industry that often requires real-time adaptation to changing conditions. As noted in an expert interview:

“*I don't know if that also could be an issue that you have different pallet standards for different types of vehicles, you have different regulations, for example, for driving for drivers, depending on where the driver contract or driver is located is how much you can drive*.” (IP 3)

The cumulative effect of these regulatory challenges results in operational inefficiencies, increased costs, and logistical complications. Addressing these regulatory pain points will require greater harmonisation of policies, especially in international and multimodal logistics, to help streamline operations and reduce the burden on logistics providers, enabling them to focus on efficient, reliable service across borders and regions.

5.4 Infrastructure-related Pain Points

Challenges related to infrastructure shortcomings can be divided into two key subcategories, which will be explained in the following section.

Suboptimal Capacity Management

Capacity management in logistics faces significant challenges, particularly during the capacity check phase in the preparation stage and in the final step of asset management. A core issue lies in aligning incoming orders with the available network capacity, as the lead times for order planning often do not match the timelines required for capacity planning, as also mentioned in one of the interviews:

"*So basically, the capacity planning is certainly, I think one of the biggest challenges, I think that we are facing in the railway. So how can we better use the current capacity and of course how can we extend it? And that's the part of the new regulation on rail capacity and that's major*." (WS 1)

This challenge is particularly pronounced in barge and train transport, where securing capacity requires booking well in advance to avoid high costs. However, customer orders frequently come in on much shorter notice, creating a persistent mismatch between capacity supply and demand. Additionally, double booking of train capacities is a typical operation:

"*Freight forwarding companies and transport operators often book multiple operators for their volume and then make a last-minute decision based on price. They think, "I've made a reservation, but now I'll cancel with the others." These so-called "last-minute" cancellations frequently occur the day before the scheduled rail shipment*." (WS 5)

This misalignment often results in two main outcomes: either excess capacity is reserved, leading to wasted resources and higher operational costs, or critical shortages occur, causing disruptions in the supply chain. Shortages can delay shipments, create bottlenecks, and force logistics providers to rely on costly, last-minute solutions. The situation is further worsened by the rigidity of booking systems in certain transport modes, which limits the ability to adjust capacity in real time as demand fluctuates. To resolve these issues, more dynamic capacity management solutions, improved forecasting, and greater flexibility in planning processes are needed to better align capacity with actual demand.

Increasing frequency of Disruptions

Rail network infrastructure is a crucial yet vulnerable element in the logistics sector, presenting significant challenges to reliability and efficiency. Many rail systems suffer from aging infrastructure, inadequate maintenance, and capacity limitations, which make them prone to disruptions. Issues like track degradation, outdated signalling systems, and a lack of investment in modernization contribute to frequent delays and bottlenecks. Issues such as track degradation, outdated signalling systems, and underinvestment in modernisation contribute to frequent delays and bottlenecks. Rail networks are also highly susceptible to external factors like extreme weather, accidents, and equipment failures, which can severely disrupt supply chains. For logistics providers relying on rail as a cost-effective and sustainable mode of transport, these vulnerabilities result in increased unpredictability, delays, and higher operational costs. (Attinasi et al. 2022)

Figure 33 summarises the pain points outlined above, which were derived from insights in Deliverable 1.1 and further analysed in-depth within the multimodal freight transport ecosystem in Deliverable 3.2.

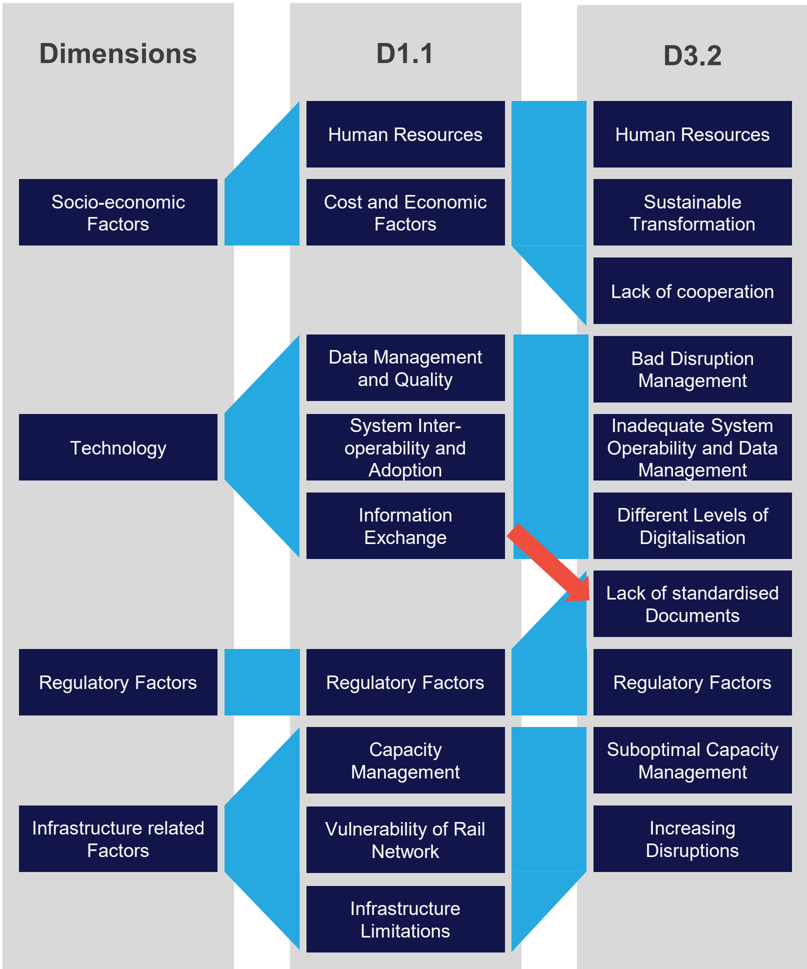

Figure **33**: Pain Points resulting from D1.1 and ecosystem mapping

5.5 Identification of main Transformation Drivers

Pain points were initially categorized in Deliverable 1.1 and are organized into four dimensions, which have been further validated and expanded in this deliverable. These pain points will be analysed in greater detail to identify correlations and assess their impact on the system, ultimately deriving requirements for how ReMuNet can address existing challenges.

Pain points are typically assigned to a single category but often span multiple dimensions, revealing interactions both within and between categories. For instance, the evolving requirements driven by climate change begin as a socio-economic issue, necessitating political action to adapt laws and regulations to shifting social demands. However, these changes also impact the regulatory framework. This interdependence highlights how dimensions influence each other—socio-economic factors shape regulations, technical solutions follow regulatory changes, and infrastructure adapts accordingly. While this causal chain generally holds, deviations may occur, and the sequence may not always be linear.

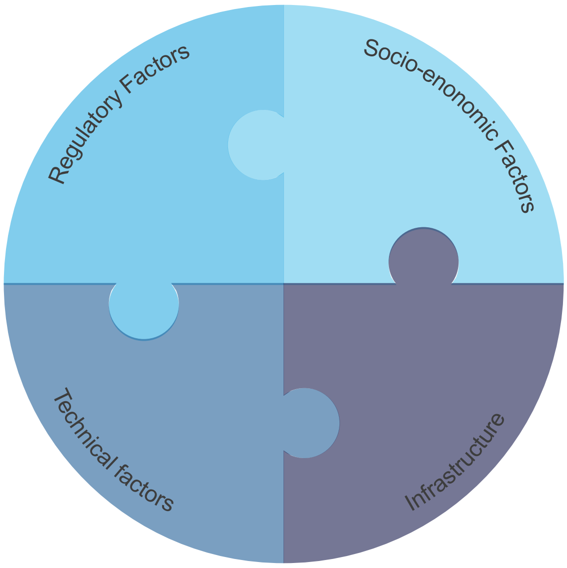

Figure **34**: Pain Point Dimensions

To elaborate how to address each pain point, it is important to understand the driving forces behind each point, which lead into the following categorisation for the factors impacting the transformation of the transport and logistic sector. The following section discusses the transformation drivers—climate change, digitalisation, demographic change, and increased market complexity—and their influence on the ecosystem and its pain points.

Climate Change

The logistics industry is undergoing significant changes as a result of the growing impacts of climate change. Extreme weather events - such as flooding, storms, and heatwaves - are increasingly disrupting transportation infrastructure, affecting all modes of transport, including road, rail, and inland shipping. A report by KPMG (2008) highlights that these climate-related risks, such as infrastructure damage, threaten the safety, economic efficiency, and punctuality of the transport sector (Nils Marscheider 2013). The study "Climate Risks and

Consequential Damage from Climate Change 2024" reveals that 67% of companies in Germany and 58% in the international supply chain are already experiencing challenges related to resource shortages, supply chain disruptions, and rising raw material and energy prices - issues that are exacerbated by climate change (KPMG 2024).

Climate risks, both direct and indirect, are driving up costs and uncertainty within the logistics industry. Despite growing awareness of these risks, many logistics companies have yet to fully integrate climate-related factors into their risk management strategies. A recent study revealed that only 37% of surveyed companies effectively address climate risks, particularly in relation to regulatory requirements and Environmental, Social, and Governance (ESG) criteria. As a result, businesses remain vulnerable to unforeseen disruptions, such as transport delays or infrastructure failures, leading to higher operational costs and reduced reliability. (Korn et al. 2023).

The increasing regulatory pressure also reflects a societal shift. Governments worldwide are implementing stricter environmental regulations, pushing logistics companies to reduce their carbon footprint and adapt to climate impacts:

“Climate change's disruptive impact on global supply chains and the urgent call for resilience.” (Economist Impact 2024)

This growing pressure from both society and policymakers is intensifying the need for logistics companies to adopt more sustainable and resilient business models (Economist Impact 2024).

To navigate these challenges, the logistics industry must urgently rethink its approach to climate-related risks. Proactive strategies, including better risk management frameworks and investments in resilient infrastructure, are essential to maintaining operational efficiency and minimising the economic consequences of climate change. The ongoing adaptation of the logistics sector will not only ensure its long-term survival but also help mitigate the broader environmental impacts of the global supply chain.

Digitalisation

In addition to climate change, digitalisation is another key driver that needs to be focused on. Several problems can be identified due to the lack of digitalisation in transport and logistics industries.

50 % of transport and logistic companies state that a lack of digital tools and training is preventing them from achieving their digitalisation goals (pwc 2016b). This is largely due to the lack of IT specialists and digital expertise in this sector. 62 % of logistics companies report a shortage of IT specialists, while 87 % complain of a lack of digital expertise in their workforce, which is slowing down the implementation of digital solutions and the digitalisation of the entire industry. (Bitkom e.V. 19.10.2022)

The lack of digital solutions in the logistics industry has resulted in highly inefficient processes. Traditional, paper-based methods are increasingly inadequate, particularly as global supply chains become more complex and customer expectations continue to rise

(HDS International Group AG). Digitalisation offers significant potential for process optimisation, allowing companies to better meet customer demands, respond efficiently to market changes, and streamline supply chains. However, the logistics sector faces considerable challenges due to its slow adoption of digital solutions, which must be addressed to stay competitive. This need for digital transformation is underscored by the sector's strong emphasis on data and analytics, with 90% of logistics companies prioritising it over the next five years - outpacing the 83% average across other industries (pwc 2016a).

Demographic Change

Demographic change presents significant challenges for the transport and logistics sector. The ageing population is contributing to a shrinking labour force, resulting in a decline in the availability of workers, both in operational roles and management positions. (Bretzke et al. 2016). Demographic changes are further exacerbating the labour shortage, with the ratio of working to retired people shifting. According to calculations, by 2030, there will likely be only 2.1 working people for every retired person in Germany alone (ver.di 2024). This trend is impacting the logistics sector significantly, as many experienced logistics workers are retiring, and there are not enough new recruits to fill the gaps (Allcox GmbH 2024).

A 2014 empirical study highlights the impact of demographic change on the transport and logistics sector, providing specific figures. It predicts that by 2030, up to 300,000 of the 800,000 truck drivers in Germany are expected to retire, with no sufficient replacements in sight. In contrast, the number of tertiary-educated 25-34-year-olds is steadily increasing, with an 8% rise between 2012 and 2022. It is also projected that the EU will surpass its target of 45% of 25-34-year-olds in higher education by 2030, potentially reaching this target as early as 2025 (see Figure 34) (BERTOLETTI 2023).

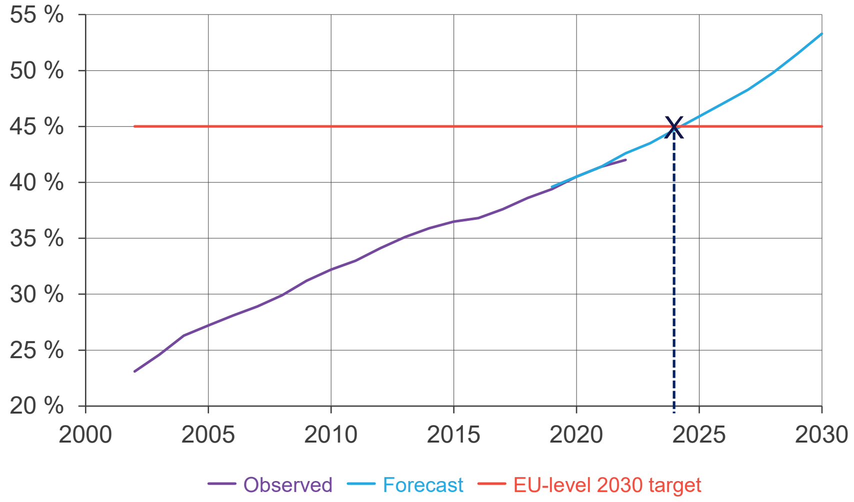

Figure 35: 25 to 34-year-olds with a university education (BERTOLETTI 2023)

As a conclusion, demographic change is a long-term trend that will have a lasting impact on the transport and logistic industry. Society's lack of appreciation for lorry drivers, the unattractiveness of the job profile of the transport and logistic sector compared to the job profiles in industry, trade, and the rest of the service sector (Bretzke et al. 2016), as well as the increasing number of academics will result in fewer young people considering a career in Transport (Allcox GmbH 2024; Kersten et al. 2014).

High market complexity

The topic of “high market complexity” deals with the issues and problems resulting from the following areas: delivery times, globalisation, sustainability, and pricing. The average transport time for containers increased significantly in 2024. The latest E2open Shipping Index shows that container ship transport will take 8 days longer in 2024 than in 2023 due to port congestion, geopolitical conflicts, extreme weather events, and the after-effects of the COVID-19 pandemic. In addition, European container shipping is currently experiencing a shift towards slower but more efficient transport methods. Shipping lines are increasingly focusing on “slow steaming”, where ships travel at reduced speeds. While this gradually increases the overall response time of the supply chain system and creates an imbalance between the supply and demand of services and products, it also could result in reduced fuel consumption, lower CO_2 emissions and overall cost savings for shipping companies (Carpenter et al. 2021).

However, the delays and challenges in container transport have a meaningful impact on costs and logistics planning. A significant increase in freight rates has been observed. In the worst-case scenario, freight rates per container have been increasing by more than 300 % (Jüngst 2024). In addition, companies have to factor longer lead times and greater uncertainties into their logistics planning.

Finally, the container logistics market is characterised by intense competition and complex market dynamics and increasing length of supply chains. Intense competition, high cost pressure and strong interdependencies between customers and logistics service providers characterise the market conditions (Dispan 2024).

Pressure exerted by transformation drivers

These developments represent the external framework for the transformation of the logistics sector. They are effectively the environment or climate to which the transport and logistic sector must adapt, visualised in Figure 35.

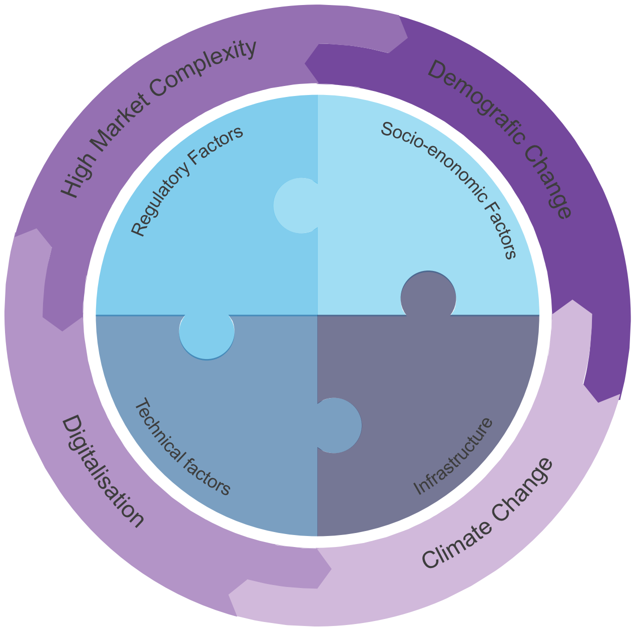

Figure 36: Dimensions of pain points influenced by transformation drivers

All pain points identified in the interviews and workshops can be traced to one of the driving forces, which impact the transport and logistics sector across four categories (Figure 36). While these driving forces are distinct, they are interrelated. For example, increased market complexity can be influenced by demographic changes, which affect demand. Moreover, transformation drivers exert pressure not only on individual pain point dimensions but on the entire system, with varying effects across different dimensions. Thus, the outer circle of Figure 36 could be seen as a dynamic representation, with the order of drivers potentially shifting over time.

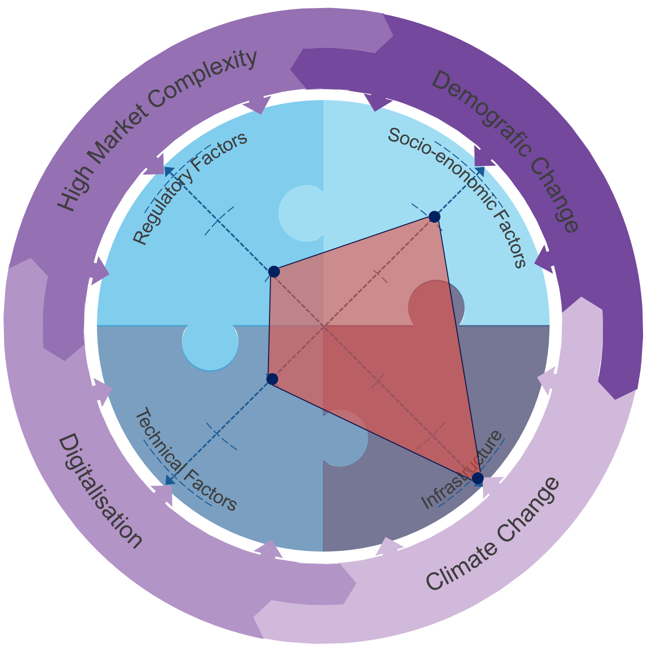

Figure 37: Framework to describe impact of concrete pain points

This framework enables the analysis of pain points by examining the overlap of relevant dimensions and their causes. It employs a three-level spider web analysis (low, medium, high) to create specific profiles for each pain point, showing which dimensions are involved and to what extent. This allows for a methodical assessment of the pain points and clarifies which dimensions need attention for solutions. The main driver behind each pain point is identified through the rotatable outer wheel in Figure 37.

The resulting graphical profiles serve two purposes: First, they help analyse potential interactions between pain points. For example, similar profiles may suggest interdependence. Second, they guide the design of platform architecture and solutions by ensuring that all relevant dimensions are addressed.

In this deliverable, potential requirements for a ReMuNet solution are derived from the pain points, and the platform, operator, and business model will be designed in subsequent deliverables to define concrete measures. The profiles will be revisited to ensure that the design focuses on the right areas for a sustainable, applicable solution, addressing the needs of all stakeholders comprehensively.

6 Requirements for ReMuNet

The following chapter describes the requirements the ReMuNet platform could fulfil. These requirements emerge from the pain points of the previous chapter and discussions during the workshops and the interviews. First categorisation of these requirements with concepts and ideas to address these in future deliverables is shown.

6.1 From Pain Points to Requirements

The pain points discussed in the previous chapter were categorised to highlight key challenges within the transport ecosystem, particularly regarding disruptions. ReMuNet aims to enhance resilience during such events by addressing these pain points through a digital solution. While certain issues, such as workforce shortages or inadequate infrastructure maintenance, cannot be directly resolved by ReMuNet, the platform focuses on increasing overall efficiency, which indirectly mitigates these challenges. The identified pain points provide a foundation for developing requirements tailored to the ReMuNet platform.

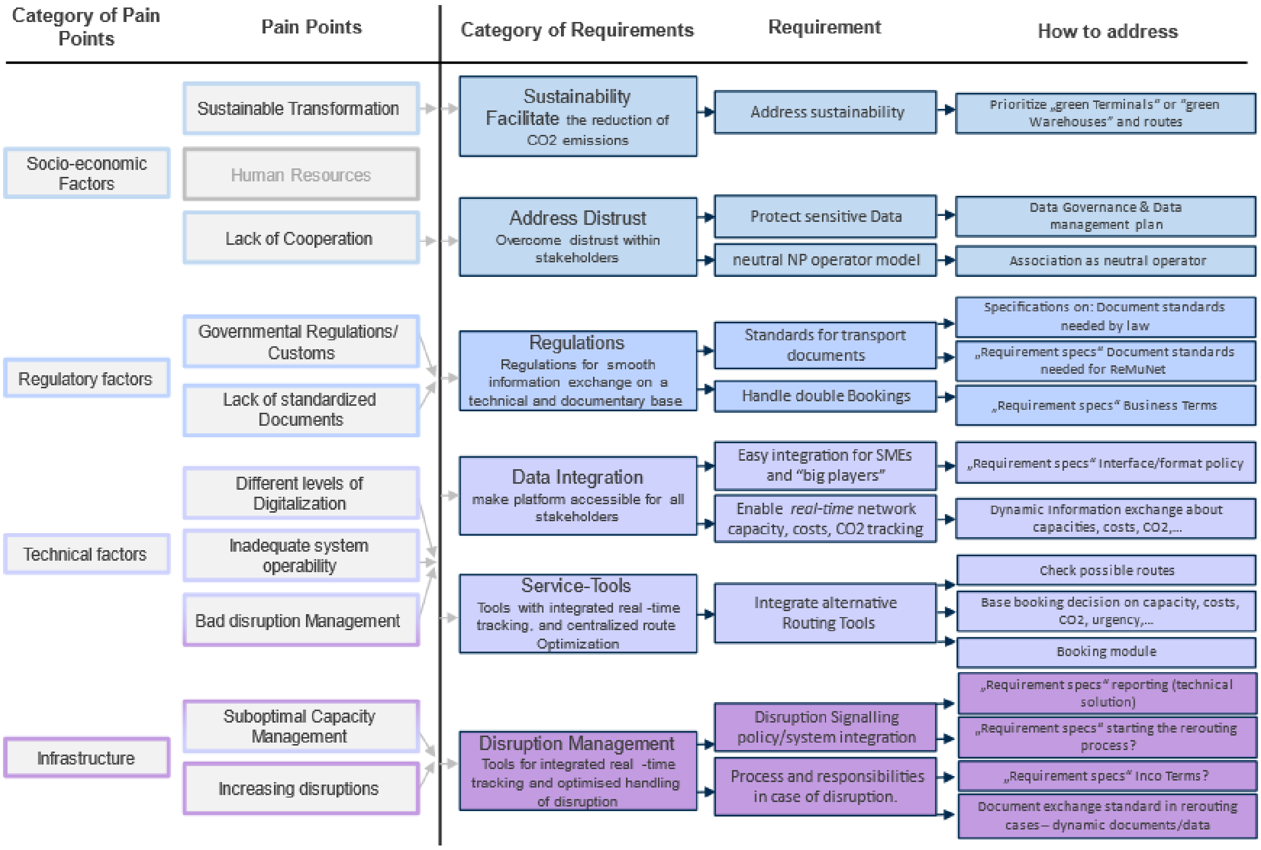

Figure 38: Requirements resulting from pain points

To develop a robust and efficient ReMuNet platform that addresses the complexities of multimodal transport networks during disruptions, several categories of requirements have been defined based on the pain points discussed earlier (see Figure 38). Many pain points are addressed by multiple requirements, so a clear distinction between a single requirement and a pain point is not always practical as it is a highly correlated system. The key categories of requirements are as follows:

- **Sustainability:** Sustainable transformation is a key objective of this project, aiming to reduce the logistics sector's impact on climate change while ensuring long-term compliance with EU regulations. The platform facilitates CO_2 emissions reduction by prioritising environmentally friendly routes and operations. By supporting sustainability initiatives, it helps companies meet regulatory requirements and avoid potential emissions-related taxation, contributing to both environmental and economic goals.
- **Addressing Distrust:** For the successful adoption of the ReMuNet platform, overcoming distrust and low levels of cooperation is essential. Participation should not be hindered by the involvement of competitors, as the platform's success relies on widespread collaboration. This requires robust privacy and data governance measures to safeguard sensitive information and ensure the platform's integrity and security, fostering trust among all participants.

- **Regulations:** Valid regulations are essential to enable the smooth exchange of information on both technical and documentary levels. Both pain points of a low level of standards and the regulation from the governance needs to be considered. This includes adherence to legal standards for transport documents and compliance with international and local regulations governing multimodal transport operations. Important is to discuss the border crossing regulations, as in case of disruption new routes can lead to new regulations and new borders which need to be crossed.
- **Data Integration:** To make the platform accessible to all stakeholders—including SMEs and large organisations, adequate concepts and interfaces for data integration are necessary. This ensures seamless connectivity and interoperability among the diverse systems used by different participants. This requirement emerges from pain points of bad system operability and different levels of digitalisation, but real-time network tracking would also improve the disruption and capacity management.
- **Service Tools:** The platform should offer service tools that include integrated real-time tracking, multimodal capabilities, and centralised route optimisation. These tools enhance operational efficiency and provide users with valuable functionalities to manage their transport processes effectively with special focus on rerouting in case of disruption.
- **Disruption Management:** Tools for integrated real-time tracking of disruptions and enhanced handling of such events are one of the key promises of the platform. Disruption management capabilities enable stakeholders to respond promptly to unforeseen events, minimising delays and maintaining the continuity of supply chains. Hereby the capacity and disruption management can be enhanced, while also the increasing number of disruptions have less impact.

These categories provide a framework, ensuring that all aspects of the platform are considered from a high-level perspective. While some requirements may overlap and may not fit neatly into a single category, this structured approach minimises the risk of overlooking critical needs and facilitates a thorough analysis of the platform's development.

It is important to acknowledge that not every requirement can be fulfilled in its entirety due to practical constraints. Therefore, the goal is to develop a solution that is both effective and efficient, achieving the desired outcomes with the lowest possible level of complexity. This approach ensures that the platform remains user-friendly and accessible, particularly for stakeholders with varying levels of technological capability.

6.2 Addressing Requirements

6.2.1 Regulations

Standards for Transport Documents

A key requirement for ReMuNet is to address the standards for transport documents. While ReMuNet does not need to define a universal standard for all actors, it must establish guidelines for the essential information and key documents required. This can be achieved through two approaches:

1. Legal Document Standards: Identify and adhere to legally required document standards commonly used in multimodal transport. These standards vary by region, mode, and contract. The information flow chapter provides an overview of relevant documents, which can inform platform development by incorporating defined regulations. Existing AI-driven projects may offer solutions to support this approach.
2. ReMuNet-Specific Document Standards: Define document standards tailored to ReMuNet, particularly for re-routing and disruption scenarios. This could involve creating standardized templates or data fields critical for the platform's operations.

Handle regulations on border crossing

The lack of standardisation for border crossing operations and shifting responsibilities creates new requirements for managing such situations, especially in disruption scenarios where operations can change locally. Additionally, regulations for technologies like autonomous ships vary by country, which needs to be considered long-term. ReMuNet could help optimize these processes within both corridors by:

1. Finding a Common Description: Building on existing projects that address this issue, ReMuNet could develop a unified way to describe border regulations, streamlining many related processes.

Handling Double Bookings and Terms & Conditions

Double bookings and last-minute cancellations present the loss of capacities in transport operations, which can be reduced. To mitigate these issues, the platform can have two mechanisms to handle such cases effectively:

1. Utilisation of Secondary Bookings: Implementing strategies to utilise the second booked system when cancellations occur, ensuring resources are optimally used.
2. Clear Terms and Conditions: Developing comprehensive terms and conditions that outline procedures and penalties related to double bookings and cancellations. This promotes accountability and reduces the likelihood of such occurrences and enhance the systems overall efficiency.

6.2.2 Addressing Distrust

Protecting Sensitive Data

Protecting sensitive data is the key for building trust among stakeholders. As the information and data can be very confidential there is the need of clear rules of what type of data and information is exchanged between the different stakeholders, which can be competitors. To address this, these two steps need to be discussed:

1. Data Governance Framework: Implementing a robust data governance structure based on recognised standards (e.g., ISO/IEC) to ensure data privacy and security.
2. Data Management Plan: Developing a detailed plan outlining how data is collected, stored, processed, and shared, with strict access controls and compliance with data protection regulations like the General Data Protection Regulation

Neutral Non-Profit Platform Operator Model

Establishing a neutral platform operator is essential to maintain trust in the platform and ensure that the benefits of all users equally. Two points need to address this:

1. Non-Profit Association: Creating an association or consortium to operate the platform as a neutral entity, preventing conflicts of interest and promoting collaborative growth. The collaborative grow is of very high importance as it was also discussed in one of the interviews performed for deliverable 1.1:

"And it may lead to people, some players or parties to say, wait, why am I getting as a reroute this option and not that option? Why is that guy getting that option? And that definitely can happen. So there needs to be a lot of trust" (IP 3).

2. Transparent Governance: Implementing governance structures where stakeholders have input in decision-making processes, enhancing transparency and mutual trust.

6.2.3 Data Integration

Easy Integration for all Players

Facilitating easy integration for all stakeholders, regardless of size or technological capability, is crucial and coming from the pain point of the different levels of digitalisation. SMEs who are low digitalised are key actors for the ReMuNet solution next to the "big players" who have very big data systems which cannot be easy integrated to ReMuNet:

1. User-Friendly Frontend: Developing a simple and intuitive frontend interface that allows users with limited digital infrastructure to access the platform without significant barriers.
2. Real time Connectivity: Providing tools for seamless integration with existing systems used by larger organisations, enabling efficient data exchange.
3. Flexible Integration Options: Offering multiple methods of connectivity to accommodate varying levels of digital maturity among participants.

Clean data for ReMuNet

One important requirement on ReMuNet is the need for clean data which needs to be used for route planning and AI training. Therefore, it is not only important to connect with as many actors as possible, but also to find ways to clean the data and make it usable. Without clean data most of the process won't be realisable.

1. Data cleansing plan: with several experts in fields of digital solutions a plan can be designed to use clean data for the ReMuNet platform

Real-Time Tracking of Network Capacity, Costs, and CO_2 Values

Enabling real-time tracking is essential for network optimisation and providing possible alternative routes. The idea to address this is by having a:

1. Dynamic Data Exchange, allowing stakeholders to share up-to-date information on locations of freight, capacities, costs, and CO_2 emissions, facilitating informed decision-making.

6.2.4 Service Tools

Alternative Route Optimisation

Integrating tools for alternative route optimization improves resilience and efficiency during disruptions. Key areas to address include:

1. Route Identification: Enabling the platform to identify alternative routes upon request from carriers, logistics providers, or consignors.
2. Decision Parameters: Selecting routes based on factors such as transit time, capacity, cost, urgency, and CO_2 emissions.
3. Booking Module Development: Developing modules to facilitate booking new routes and managing document exchanges with involved stakeholders.

6.2.5 Disruption Management

Disruption Signalling and Integration

Effective disruption management requires timely detection and response, which is challenging due to the large volume of often unshared data. However, this data is critical for ReMuNet to prevent disruptions during rerouting and, in the long term, for refining routing algorithms under Work Package 4 to improve incident prediction and response. Immediate disruption notifications can be handled in two ways:

1. Partnerships with Data Providers: Leveraging existing data from actors already collecting relevant information, by connecting their systems to ReMuNet. This can be challenging due to data privacy regulations that may prevent data sharing.
2. Reporting Feature: Integrating a disruption reporting feature within the platform, allowing ReMuNet to independently collect disruption data. This aligns with a non-profit operation model, where data sharing is more likely.

Terms and Regulations for Disruption Handling

Defining clear processes and responsibilities during disruptions is essential for the platform's effectiveness, with the consignor and consignee playing key roles in the current state, reducing the speed of reaction. Improving communication with these actors is crucial. By specifying how disruptions and rerouting should be handled, the platform's real-world applicability is determined:

1. Rerouting Process Specifications: Defining procedures for initiating rerouting, assigning responsibilities, and establishing protocols for implementing new routes.
2. Contractual Agreements and Incoterms Evaluation: Incorporating relevant contractual terms and Incoterms to clarify financial flows and responsibilities.
3. Document Exchange Facilitation: Ensuring timely updating and transfer of all necessary documents and data to new operators.

6.2.6 Sustainability

Prioritising Green Routes

Addressing sustainability in ReMuNet involves integrating environmental considerations into operations. While not directly tied to current pain points in the multimodal transport ecosystem, it is crucial for future plans and alignment with upcoming EU regulations:

1. Environmentally Friendly Routing: Optimizing algorithms to prioritize routes that reduce CO_2 emissions, factoring in distance, transport mode, and energy efficiency.
2. Green Infrastructure Utilization: Incorporating eco-friendly terminals and warehouses into planning, promoting sustainability across the supply chain.
3. Emission Tracking and Reporting: Providing tools to calculate and display CO_2 emissions for different routing options, enabling stakeholders to make environmentally informed decisions.

7 Conclusion and Outlook

Deliverable 3.2 advances the analysis of the European multimodal transport ecosystem, focusing on the North Sea-Baltic and Rhine-Danube corridors. Using Gassmann's business model approach, the roles of key actors in these corridors were identified. Value flow mapping and business ecosystem mapping helped describe the interconnections, including the flows of goods, information, and finances across the network. However, capturing the full complexity of the ecosystem, with its variations and exceptions, proved challenging, leading to some assumptions.

A key element of this analysis was developing a shared framework and common language to describe the ecosystem, which was essential given its complexity and inconsistent structures. While assumptions were made, the framework provides a foundation for the ReMuNet project, enabling a structured understanding of how the platform can integrate, influence key flows, and address specific challenges.

In addition to mapping the current ecosystem, the deliverable identifies key systemic pain points, grouped into four dimensions: socio-economic challenges, low standardization and regulatory issues, technical challenges, and infrastructure problems. These pain points create barriers to efficient operations and highlight the need for targeted solutions.

Based on this analysis, the deliverable defines clear requirements for ReMuNet, ensuring the platform is designed to address these pain points. The requirements are categorized into six areas: regulation, trust and transparency, data integration, service tools (e.g., route optimization), disruption management, and sustainability. This structured approach ensures that ReMuNet’s design aligns with the needs of the ecosystem, guiding future development.

With this, Deliverable 3.2 achieves two key outcomes:

1. It provides a detailed overview of the requirements needed to resolve systemic pain points, offering a roadmap for how ReMuNet can act as a transformative solution.
2. It establishes a robust basis for designing the ReMuNet platform, making it possible to visualise how the solution integrates into the existing ecosystem and supports critical flows of goods, information, and finances.

The next steps will focus on refining the requirements into actionable, implementable solutions, prioritising the most critical pain points within the project's scope. The goal is to ensure that these solutions are both feasible and impactful. This deliverable also lays the foundation for deeper stakeholder engagement to validate findings and co-create solutions that align with the ecosystem's operational and strategic needs.

Future deliverables will build on this foundation, further developing the ReMuNet platform's design to address pain points effectively, to drive change in the European multimodal transport sector.

8 References

Aarikka-Stenroos, Leena; Ritala, Paavo; D. W. Thomas, Llewellyn (2021): Circular economy ecosystems: a typology, definitions, and implications. In: Satu Teerikangas, Tiina Onkila, Katariina Koistinen und Marileena Mäkelä (Hg.): Research Handbook of Sustainability Agency: Edward Elgar Publishing.

Achahchah (2019): Lean Transportation Management. Using Logistics as a Stratecic Differentiator: Routledge. Online verfügbar unter https://www.google.de/books/edition/Lean_Transportation_Management/2jP-EAAAQBAJ?hl=de&gbpv=1&dq=documentation+of+handover+in+transport+logistics&pg=PA95&printsec=frontcover, zuletzt geprüft am 11.11.2024.

Adner, Ron (2017): Ecosystem as Structure. In: *Journal of Management* 43 (1), S. 39–58. DOI: 10.1177/0149206316678451.

Allcox GmbH (2024): Die Herausforderung des Fachkräftemangels in der Logistik meistern. Hg. v. Allcox GmbH. Online verfügbar unter https://allcox.de/die-herausforderung-des-fachkraeftemangels-in-der-logistik-meistern/, zuletzt geprüft am 28.11.2024.

Allee, Verna (2000): Reconfiguring the Value Network. In: *Journal of Business Strategy* 21 (4), S. 36–39. DOI: 10.1108/eb040103.

AltexSoft (2023): Supply Chain Management (SCM) Software, Process, and Roles. Online verfügbar unter https://www.altexsoft.com/blog/supply-chain-management-software/, zuletzt geprüft am 30.10.2024.

Attinasi, Maria Grazia; Balatti, Mirco; Mancini, Michele; Metelli, Luca (2022): Supply chain disruptions and the effects on the global economy. Online verfügbar unter https://www.ecb.europa.eu/press/economic-bulletin/focus/2022/html/ecb.ebbox202108_01~e8ceebe51f.en.html.

Autio, E. (2021): Orchestrating ecosystems: a multi-layered framework. In: *Innovation*, S. 1–14. DOI: 10.1080/14479338.2021.1919120.

Autio, Erkko; Thomas, Llewellyn D. W. (2014): Innovation Ecosystems: Implications for Innovation Management. In: Mark Dodgson, David Gann, Nelson Phillips, Ammon J. Salter, Jaideep C. Prabhu, Maureen D. McKelvey et al. (Hg.): The Oxford handbook of innovation management. Oxford: Oxford University Press, S. 204–228. Online verfügbar unter https://www.researchgate.net/publication/282122544_Innovation_Ecosystems_Implications_for_Innovation_Management.

Barratt, Mark (2004): Understanding the meaning of collaboration in the supply chain. In: *Supply Chain Management An International Journal* 9 (1), S. 30–42. DOI: 10.1108/13598540410517566.

Berentzen; Betz; Dosch (2021): Die Commerzbank auf dem Weg ins Ökosystem – Open Banking als Wegbereiter für kollaborative Geschäftsmodelle. In: *Banking and Information Technology*, S. 48–55. Online verfügbar unter https://developer.commerzbank.com/shared/documents/commerzbank-BIT-Maerz-2021.pdf, zuletzt geprüft am 03.08.2024.

BERTOLETTI, Alice (2023): Forecasting progress towards the EU-level targets of the European Education Area. In: *1831-9424*. DOI: 10.2760/146529.

Betz, Christian; Jung, Reinhard (2021): Value Creation in Business Ecosystems – A Design Theory for a Reference Model. In:. AMCIS 2021 Proceedings. Online verfügbar unter https://www.researchgate.net/publication/353622781_Value_Creation_in_Business_Ecosystems_-_A_Design_Theory_for_a_Reference_Model.

Bhanage, Gautam D.; Zhang, Yu; Zhang, Yanyong; Trappe, Wade; Howard, Richard. E. (2007): RollCall : The Design For A Low-Cost And Power Efficient Active RFID Asset Tracking System.

Bitkom e.V. (19.10.2022): In der Logistik werden die Sicherheitsmaßnahmen verschärft. Berlin. Wiez, Merle; Hannappel, Paul. Online verfügbar unter https://www.bitkom.org/Presse/Presseinformation/Digitalisierung-Logistik, zuletzt geprüft am 28.11.2024.

Borgi; Zoghlami; Abed (2017): Big Data for Transport of Logistics: A Review (2017 International Conference on Advanced Systems and Electric Technologies). Online verfügbar unter https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7983742, zuletzt geprüft am 11.11.2024.

Brandenburger, Adam M.; Nalebuff, Barry J. (1997): Co-opetition. 1. A Revolutionary Mindset that Combines Competition and Cooperation. 2. The Game Theory Strategy that's Changing the Game of Business. [Summary version]. New York: Doubleday Broadway.

Bretzke, Wolf-Rüdiger; Froschmayer, Andreas; Grotemeier, Christian; Hager, Hans-Jörg; Kille, Christian; Klug, Matthias et al. (2016): Logistik trifft Digitalisierung. Auswirkungen auf die Entwicklung in 2016. Hg. v. Christian Kille und Markus Meißner. Online verfügbar unter https://logistikweisen.de/wAssets/docs/Logistik_trifft_Digitalisierung_2016_LR.pdf, zuletzt geprüft am 28.11.2024.

Bundesamt für Justiz (2024a): § 408 Frachtbrief. Verordnungsermächtigung. In: Handelsgesetzbuch. Online verfügbar unter https://dejure.org/gesetze/HGB/408.html, zuletzt geprüft am 04.11.2024.

Bundesamt für Justiz (2024b): § 453 Frachtvertrag. In: Handelsgesetzbuch. Online verfügbar unter https://dejure.org/gesetze/HGB/407.html, zuletzt geprüft am 11.11.2024.

Bundesamt für Justiz (2024c): § 453 Speditionsvertrag. In: Handelsgesetzbuch. Online verfügbar unter https://dejure.org/gesetze/HGB/453.html, zuletzt geprüft am 04.11.2024.

Burkhalter, Marc; Betz, Christian; Auge-Dickhut, Stefanie; Jung, Reinhard (2021): Orchestrating Value Co-Creation in Business Ecosystems. In: Karen Wendt (Hg.): Theories of change. Change leadership tools, models and applications for investing in sustainable development. Cham: Springer International Publishing AG (Sustainable Finance), S. 4–26. Online verfügbar unter https://www.researchgate.net/publication/354935758_Orchestrating_Value_Co-Creation_in_Business_Ecosystems.

Carpenter, Angela; Johansson, Tafsir M.; Skinner, Jon A. (Hg.) (2021): Sustainability in the Maritime Domain. Cham: Springer International Publishing (Strategies for Sustainability).

Chen, Xiangfeng; Cai, Gangshu; Song, Jing-Sheng (2019): The Cash Flow Advantages of 3PLs as Supply Chain Orchestrators. In: *M&SOM* 21 (2), S. 435–451. DOI: 10.1287/msom.2017.0667.

Conrad, Ruben; Hoeborn, Gerrit; Neudert, Pia; Betz, Christian (2022): Seizing the Potentials of Ecosystems. Online verfügbar unter https://www.researchgate.net/publication/360796068_Seizing_the_Potentials_of_Ecosystems.

Cruijssen, Frans; Cools, Martine; Dullaert, Wout (2007): Horizontal cooperation in logistics: Opportunities and impediments. In: *Transportation Research Part E: Logistics and Transportation Review* 43 (2), S. 129–142. DOI: 10.1016/j.tre.2005.09.007.

David J. Teece (2017): Business Ecosystem. In: Mie Augier und David J. Teece (Hg.): The Palgrave encyclopedia of strategic management. Living Reference Work. United Kingdom: Palgrave Macmillan UK, S. 1–4. Online verfügbar unter https://www.researchgate.net/publication/312324064_Business_Ecosystem.

Dedehayir, Ozgur; Mäkinen, Saku J.; Roland Ortt, J. (2018): Roles during innovation ecosystem genesis: A literature review. In: *Technological Forecasting and Social Change* 136, S. 1–12. DOI: 10.1016/j.techfore.2016.11.028.

den Ouden (2012): Innovation Design. London: Springer London.

Deufol SE (2024): Supply Chain Management Software: Innovative und digitale All-In-One SCM Software für Ihre Logistik. Online verfügbar unter https://www.deufol.com/de/supply-chain-management-software/, zuletzt geprüft am 30.10.2024.

Devlin; McDonnell (2009): Assessing Real Time GPS Asset Tracking for Timber Haulage. 3. Aufl. The Open Transportation Journal.

Dispan, Jürgen (2024): Branchenanalyse Kontraktlogistik. Strukturen, Transformationen, Beschäftigungstrends - Schwerpunkte: Automotive Kontraktlogistik. Hans Böckler Stiftung (324). Online verfügbar unter https://www.boeckler.de/fpdf/HBS-008819/p_fofoe_WP_324_2024.pdf.

Economist Impact (2024): Climate change's disruptive impact on global supply chains and the urgent call for resilience. Online verfügbar unter https://impact.economist.com/projects/trade-in-transition/climate_change, zuletzt aktualisiert am 19.06.2024, zuletzt geprüft am 29.11.2024.

Elpro (2024): Real-time cold chain monitoring. Online verfügbar unter https://www.elpro.com/en/learn/real-time-cold-chain-monitoring, zuletzt geprüft am 30.11.2024.

Feyen; Penet (2024): Standard framework to describe European intermodal transport. UIRR.

Gassmann; Frankenberger; Csik (2014): The Business Model Navigator.

Glasow (2005): Fundamentals of Survey Research Methodology. MITRE. Online verfügbar unter https://www.mitre.org/sites/default/files/pdf/05_0638.pdf, zuletzt geprüft am 06.08.2024.

Grabara; Kot (2014): The role of information systems in transport logistics. 2. Aufl. International Journal of Education and Research. Online verfügbar unter http://www.ijern.com/.

Han, Jin; Zhou, Haibo; Lowik, Sandor; Weerd-Nederhof, Petra de (2022): Enhancing the understanding of ecosystems under innovation management context: Aggregating conceptual boundaries of ecosystems. In: *Industrial Marketing Management* 106, S. 112–138. DOI: 10.1016/j.indmarman.2022.08.008.

HDS International Group AG: Digitalisierung in der Logistik: Potenziale und Risiken. Hg. v. HDS International Group AG. Online verfügbar unter https://www.hds-international.group/digitalisierung-in-der-logistik-potenziale-und-risiken/, zuletzt geprüft am 28.11.2024.

Hervás-Peralta, Miguel; Poveda-Reyes, Sara; Molero, Gemma Dolores; Santarremigia, Francisco Enrique; Pastor-Ferrando, Juan-Pascual (2019): Improving the Performance of Dry and Maritime Ports by Increasing Knowledge about the Most Relevant Functionalities of the Terminal Operating System (TOS). In: *Sustainability* 11 (6), S. 1648. DOI: 10.3390/su11061648.

Hoeborn, Gerrit; Conrad, Ruben; Götzen, Rafael; Betz, Christian; Neudert, Pia Kerstin (2022): Understanding Business Ecosystems Using a Morphology of Value Systems. In: *Research-Technology Management* 65 (5), S. 44–53. DOI: 10.1080/08956308.2022.2095841.

Hoeborn, Gerrit; Gonzalez, Agustin (2023): Analysis of Strategic Business Ecosystem Role Models for Service-Oriented Value Creation Systems. Unter Mitarbeit von Technische Informationsbibliothek (TIB), David Herberger, Marco Hübner und Volker Stich: Hannover : publish-Ing. Online verfügbar unter https://www.repo.uni-hannover.de/handle/123456789/13621.

Hofmann Trevisan, Adriana; Gonçalves Castro, Camila; Gomes, L.A.V.; Mascarenhas, J. (2022): Unlocking the circular ecosystem concept: Evolution, current research, and future directions. In: *Sustainable Production and Consumption* 29 (1), S. 286–298. DOI: 10.1016/j.spc.2021.10.020.

Hou, Hong; Shi, Yongjiang (2021): Ecosystem-as-structure and ecosystem-as-coevolution: A constructive examination. In: *Technovation* 100, S. 102193. DOI: 10.1016/j.technovation.2020.102193.

Iansiti, M.; Levien, R. (2004): Strategy as ecology. In: *Harvard business review* 82 (3), 68-+. Online verfügbar unter https://pubmed.ncbi.nlm.nih.gov/15029791/.

Jacobides, Michael G.; Cennamo, Carmelo; Gawer, Annabelle (2015): Industries, Ecosystems, Platforms, and Architectures: Rethinking our Strategy Constructs at the Aggregate Level. Online verfügbar unter https://www2.uwe.ac.uk/faculties/BBS/BUS/Research/CENTIENT/ESRC%20seminar%204%20-%20UWE,%20Bristol/Michael%20G%20Jacobides.pdf, zuletzt geprüft am 03.05.2024.

Jacobides, Michael G.; Cennamo, Carmelo; Gawer, Annabelle (2018): Towards a theory of ecosystems. In: *Strat Mgmt J* 39 (8), S. 2255–2276. DOI: 10.1002/smj.2904.

Jüngst, Ilona (2024): Schiffe meiden das Rote Meer weitläufig. Die Kosten für Seecontainer explodieren. Online verfügbar unter https://www.eurotransport.de/logistik/spedition-und-logistik/schiffe-meiden-rotes-meer-laengerfristiges-problem/, zuletzt geprüft am 28.11.2024.

Kastalli, Ivanka Visnjic; Neely, Andy (2013): Collaborate to Innovate: How Business Ecosystems Unleash Business Value. Online verfügbar unter https://www.researchgate.net/publication/321361598_Collaborate_to_Innovate_How_Business_Ecosystems_Unleash_Business_Value.

Kersten, Wolfgang; Blecker, Thorsten; Ringle, Christian M. (2014): Next Generation Supply Chains: Trends and Opportunities. Proceedings of the Hamburg International Conference of Logistics (HICL). Berlin: epubli GmbH.

Khartoum (2023): EXAMINING TRANSPORT DOCUMENTS (BILL OF LADING) IN CARRIAGE OF GOODS BY SEA: DOMESTIC AND INTERNATIONAL LAW PRACTICES IN MAINLAND

TANZANIA. In: *Journal of International Trade, Logistics and Law* 9 (2), S. 70–78. Online verfügbar unter https://www.jital.org/index.php/jital/article/view/394/pdf_219, zuletzt geprüft am 11.11.2024.

Korn, Thorsten; Lempp, Jakob; van der Beek, Gregor (Hg.) (2023): Wirtschaftsförderung in der Krise. Konzepte zur Krisenbewältigung und Chancennutzung. Springer Fachmedien Wiesbaden. Wiesbaden, Heidelberg: Springer. Online verfügbar unter https://link.springer.com/content/pdf/10.1007/978-3-658-41390-3.pdf, zuletzt geprüft am 29.11.2024.

KPMG: Klimarisiken Transport 2024. Online verfügbar unter https://hub.kpmg.de/hubfs/LandingPages-PDF/kpmg-klimarisiken-und-folgeschaeden-des-klimawandels.pdf?utm_campaign=TRA%20-%20Klimastudie%202024&utm_medium=email&_hsenc=p2ANqtz-_-rYt48WCbGx7_Es3-aXg86J69RzrNE7gNgOFirz9o6P5szsxZpRUqLlgK3oPWOF3k9eCZENFyElz6N-2oUjoIse1wGA&_hsmi=330642478&utm_content=330642478&utm_source=hs_automation, zuletzt geprüft am 29.11.2024.

Krit, Salah-ddine (2019): Intelligent Asset Tracking System for Logistics Industry using IoT and Big Data (1).

Lusch, Robert F.; Vargo, Stephen L. (2014): Service-dominant logic. Premises, perspectives, possibilities. First published. Cambridge: Cambridge University Press. Online verfügbar unter http://ebooks.cambridge.org/ebook.jsf?bid=CBO9781139043120.

Mehta, Jay; Mehta, Darsh; Jain, Jainam; Dholay, Surekha (2021): Asset Tracking System Using Blockchain. In: 2021 Asian Conference on Innovation in Technology (ASIANCON). 2021 Asian Conference on Innovation in Technology (ASIANCON). PUNE, India, 27.08.2021 - 29.08.2021: IEEE, S. 1–7.

Moore, J. F. (1993): Predators and prey: a new ecology of competition. In: *Harvard business review* 71 (3), S. 75–86.

Moore, James F. (1996): The death of competition. Leadership and strategy in the age of business ecosystems. repr. Chichester: Wiley. Online verfügbar unter https://www.researchgate.net/publication/31744644_The_Death_of_Competition_Leadership_and_Strategy_in_the_Age_of_Business_Ecosystems_JF_Moore.

Mummendey; Grau (2014): Die Fragebogen-Methode. Grundlagen und Anwendung in Persönlichkeits-, Einstellungs- und Selbstkonzeptforschung.

Nettsträter, Andreas; Geißen, Tim; Witthaut, Markus; Ebel, Dietmar; Schoneboom, Jens (Hg.) (2015): Logistics Software Systems and Functions: An Overview of ERP, WMS, TMS and SCM Systems: Springer International Publishing.

Nielsen, Christian; Lund, Morten; Montemari, Marco; Paolone, Francesco; Massaro, Maurizio; Dumay, John (2018): Business Models: Routledge.

Nils Marscheider (2013): Arbeitspaper_stakeholderdialog_logistik_und_supply_chain. Online verfügbar unter https://www.umweltbundesamt.de/sites/default/files/medien/382/dokumente/02_arbeitspapier_stakeholderdialog_logistik_und_supply_chain.pdf#:~:text=F%C3%BCr%20Logistik%20und%20Supply%20Chain%20entstehen%20die%20wesentlichen,zu%20Verz%C3%B6ger-ungen%20und%20Ausf%C3%A4llen%20in%20Logisti-kprozessen%20f%C3%BChren%20kann., zuletzt geprüft am 29.11.2024.

Oh, Deog-Seong; Phillips, Fred; Park, Sehee; Lee, Eunghyun (2016): Innovation ecosystems: A critical examination. In: *Technovation* 54, S. 1–6. DOI: 10.1016/j.technovation.2016.02.004.

Oracle Deutschland: Insbesondere sind WMS-Systeme so ausgelegt, dass sie die Anforderungen einer gesamten globalen Lieferkette unterstützen, einschließlich Distributions-, Fertigungs-, anlagenintensiven und Serviceunternehmen. Was ist WMS (Warehouse Management System)? | Oracle Deutschland. Online verfügbar unter https://www.oracle.com/de/scm/logistics/warehouse-management/what-is-warehouse-management/.

Osterwalder; Pigneur (2010): Business Model Generation.

Parolini, Cinzia (1999): The value net. A tool for competitive strategy. Chichester, Weinheim: Wiley. Online verfügbar unter http://worldcatlibraries.org/wcpa/oclc/491697868.

Peltoniemi, Mirva (2004): Cluster, Value Network and Business Ecosystem: Knowledge and Innovation Approach. Online verfügbar unter https://www.researchgate.net/publication/251809312_Cluster_Value_Network_and_Business_Ecosystem_Knowledge_and_Innovation_Approach.

Porter, Michael E. (1990): The competitive advantage of nations. New York, N.Y.: Free Pr. Online verfügbar unter http://worldcatlibraries.org/wcpa/oclc/20671587.

Porter, Michael Eugene (2000): Location, Competition, and Economic Development: Local Clusters in a Global Economy. In: *Economic Development Quarterly* 14 (1), S. 15–34. DOI: 10.1177/089124240001400105.

pwc (2016a): Industry 4.0: Building the digital enterprise. Hg. v. pwc. Online verfügbar unter https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf.

pwc (2016b): Shifting patterns. The future of the logistics industry. Online verfügbar unter https://www.pwc.com/sg/en/publications/assets/future-of-the-logistics-industry.pdf.

R+L Carriers: Pickup Request. Online verfügbar unter https://m.rlcarriers.com/PickupRequest/, zuletzt geprüft am 29.11.2024.

Ritala, Paavo; Almpanopoulou, Argyro (2017): In defense of 'eco' in innovation ecosystem. In: *Technovation* 60-61, S. 39–42. DOI: 10.1016/j.technovation.2017.01.004.

Rong, Ke; Shi, Yongjiang (2014): Business Ecosystems. London: Palgrave Macmillan.

Schmitz, Torsten (2011): The bill of lading as a document of title. In: *Journal of International Trade Law and Policy* 10 (3), S. 255–280. DOI: 10.1108/14770021111165526.

Tapaninen, Ulla; Pulli, Hennariina; Posti, Antti (Hg.) (2010): Information Needs of Logistics Service Providers. Innovative perspectives. Hershey, Pa.: Business Science Reference (Premier reference source).

Thomas, Llewellyn D. W.; Autio, Erkko (2020): Innovation ecosystems in management: An organizing typology. In: Aldag (Hg.): Oxford research encyclopedias. Online verfügbar unter https://www.researchgate.net/publication/336603231_Innovation_ecosystems_in_management_An_organizing_typology.

VCA Logistik: Logistik-Lexikon. Warehouse Management System (WMS). Online verfügbar unter https://www.vca-logistik.de/logistik-lexikon/warehouse-management-system/.

ver.di (2024): Fachkräftemangel in Deutschland: Herausforderung und Wege in die Zukunft. Hg. v. ver.di. Online verfügbar unter https://www.verdi.de/themen/arbeit/++co++74debf86-472f-11ee-894c-001a4a160129, zuletzt geprüft am 28.11.2024.

von Stamm et al. (2024): Needs analysis of relevant stakeholders for the European multimodal transport network. FIR at RWTH Aachen University.

Williamson, Peter James; Meyer, Arnoud de (2012): Ecosystem Advantage: How to Successfully Harness the Power of Partners. In: *California Management Review* 55 (1), S. 24–46. DOI: 10.1525/cmr.2012.55.1.24.

Annexes

Annex I: Quantitative Online Survey

Key	Section	#	Topic	Question type	Questions	Options (if applicable)	Op-tional	Dependencies
LOG_01	01_Logis-tics	1	**Role in multi-modal transporta-tion**	Multiple Choice	What roles does your or-ganisation play in the trans-portation process?	1. Shipper 2. Carrier 3. Freight Forwarder 4. Multimodal Transport Operator (MTO) 5. Logistics Service Provider 6. Digital Logistics Service Provider 7. Support service provider or con-sultant 8. Software provider 9. Terminal operator 10. Infrastructure operator and/or manager 11. Governmental entity 12. Other...		
LOG_02	01_Logis-tics	2	**Relevant transport modes**	Multiple Choice	Please select all modes of transport (co-)operated with/by or relevant to your organisation?	1. Road 2. Rail 3. Inland waterways 4. Maritime (both deep sea and short sea) 5. Air 6. None		
LOG_03	01_Logis-tics	3	**# of transport modes per order**	Single Choice	On average, how many dif-ferent modes of transport does your organisation use per shipment?	1. None 2. 1 3. 2 4. 3 or more 5. I don't know/not relevant for our organisation		
LOG_04	01_Logis-tics	4	**Impact of multi-modality on effi-ciency**	Likert	Do you think using more than one mode per ship-ment helps to improve effi-ciency?	1. Not at all 2. Slightly 3. Moderately 4. Very 5. Extremely 6. I don't know		
LOG_05	01_Logis-tics	5	**Stages of the transport process**	Multiple Choice	What stages of the transport process do your organisation's activities cover, serve or address?	1. Pre-haulage 2. Main-run 3. Post-haulage 4. None		
LOG_06	01_Logis-tics	6	**Transport range**	Multiple Choice	What transport distances are relevant to your organi-sation?	1. < 15 km, commonly referred to as "last mile" 2. 15 km - 300 km 3. 300 km - 600 km 4. 600 km - 900 km 5. > 900 km 6. None		
LOG_07	01_Logis-tics	7	**Preference for re-lay traffic**	Single Choice	In the case of multimodal transportation, would you prefer many short distance segments or few long-dis-tance segments?	1. Many short distance segments (less than 300 km) 2. Few long-distance segments (more than 300 km) 3. I don't know		
TEN_01	02_TEN-T	1	**Relevance of TEN-T corridors**	Single Choice	Is the concept of the Trans-European Transport Net-work, also known as TEN-T corridors, relevant to your organisation?	1. Yes 2. No 3. I am not familiar with the concept of TEN-T corridors		
TEN_02	02_TEN-T	2	**Introduction to TEN-T**					TEN_01_03 re-quired
COR_01	03_Corri-dor	1	**Activities in North-Sea Baltic**	Single Choice	Is your organisation active in the North Sea-Baltic TEN-T corridor?	1. Yes 2. No 3. No, but there are plans to expand into the corridor 4. I don't know		
COR_02	03_Corri-dor	2	**Actors in North-Sea Baltic**	Text	What are the relevant carri-ers operating in the North Sea-Baltic TEN-T corridor?			
COR_03	03_Corri-dor	3	**Actors in North-Sea Baltic**	Text	What are the relevant Lo-gistics Service Providers (LSP) operating in the North Sea-Baltic TEN-T corridor?			
COR_04	03_Corri-dor	4	**Actors in North-Sea Baltic**	Text	What are the relevant termi-nals and/or companies op-erating the terminals in the North Sea-Baltic TEN-T cor-ridor?			
COR_05	03_Corri-dor	5	**Actors in North-Sea Baltic**	Text	What are the relevant infra-structure managing or oper-ating entities operating in the North Sea-Baltic TEN-T corridor?			
COR_06	03_Corri-dor	6	**Actors in North-Sea Baltic**	Text	What are the relevant gov-ernmental agencies operat-ing in the North Sea-Baltic TEN-T corridor?			

COR_07	03_Corri-dor	7	**Activities in Rhine-Danube**	Single Choice	Is your organisation active in the Rhine-Danube TEN-T corridor?	1. Yes 2. No 3. No, but there are plans to expand into the corridor 4. I don't know		
COR_08	03_Corri-dor	8		Text	What are the relevant carri-ers operating in the Rhine-Danube TEN-T corridor?			
COR_09	03_Corri-dor	9		Text	What are the relevant Lo-gistics Service Providers (LSP) operating in the Rhine-Danube TEN-T corridor?			
COR_10	03_Corri-dor	10		Text	What are the relevant termi-nals and/or companies op-erating the terminals in the Rhine-Danube TEN-T corridor?			
COR_11	03_Corri-dor	11		Text	What are the relevant infra-structure managing or oper-ating entities operating in the Rhine-Danube TEN-T corridor?			
COR_12	03_Corri-dor	12		Text	What are the relevant gov-ernmental agencies operat-ing in the Rhine-Dan-ube TEN-T corridor?			
TEN_03	02_TEN-T	3	**Activities in TEN-T corridors**	Multiple Choice	In which TEN-T corridors does your organisation op-erate?	a. Yes b. No c. No, but expansion plans d. Don't know 1. Baltic-Adriatic Corridor 2. North Sea-Baltic Corridor 3. Mediterranean Corridor 4. Orient/East-Med Corridor 5. Scandinavian-Mediterranean Cor-ridor 6. Rhine-Alpine Corridor 7. Atlantic Corridor 8. North Sea-Mediterranean Corri-dor 9. Rhine-Danube Corridor 10. None		
BM_01	04_Busi-ness Model	1	**Key activities**	Multiple Choice	What are your organisa-tion's key activities?	1. Transportation management: managing and executing the physi-cal transportation of goods across various transport modes 2. Logistics coordination: organising and managing all aspects of the shipping process, including route selection and carrier contracting 3. Scheduling and coordination: managing schedules for shipments to maximise throughput and mini-mise downtime 4. Loading and transshipment: exe-cuting the loading, unloading, and transfer of cargo 5. Shunting: moving and organising railway cars to assemble or disas-semble trains 6. Commissioning: preparing and verifying systems, equipment, or fa-cilities for operational use, ensuring they meet specified requirements and are ready for service 7. Customs and compliance: han-dling documentation and ensuring compliance with international trade regulations 8. Safety and security management: implementing and monitoring secu-rity protocols and safety practices within facilities 9. Maintenance and upkeep: con-ducting regular maintenance of in-frastructure and equipment 10. Container handling: provision or repair and maintenance of contain-ers 11. Storage and warehousing: stor-ing of goods in designated facilities to ensure their safekeeping, inven-tory management, and timely distri-bution 12. Traffic management: planning and controlling the flow of vehicles 13. Consulting and support: offering expert advice on digital transfor-mation and operational optimisation 14. Technology development: creat-ing digital solutions for logistics pro-cesses 15. Platform development: building and maintaining digital platforms for logistics processes		

						16. Data analytics services: analysing logistics data 17. Cybersecurity services: ensuring digital platforms and data exchanges are secure from cyber threats 18. Customer relationship management: developing and maintaining strong relationships with customers to ensure satisfaction and repeat business 19. Training and development: offering training services to upskill employees in transport and logistics firms 20. Stakeholder engagement: communicating and collaborating with all parties involved 21. Other...		
BM_02	04_Business Model	2	**Customer segments**	Multiple Choice	For whom does your organisation create value?	1. Shipper 2. Carrier 3. Freight Forwarder 4. Multimodal Transport Operator (MTO) 5. Logistics Service Provider 6. Digital Logistics Service Provider 7. Support service provider or consultant 8. Software provider 9. Terminal operator 10. Infrastructure operator and/or manager 11. Governmental entity 12. Other... 11. Other		
BM_03	04_Business Model	3	**Information exchange**	Multiple Choice	With which roles do you exchange information as you create value? What is the direction of information flow?	a. Yes, receive from b. Yes, send to c. Yes, receive from and send to d. No e. Don't know 1. Shipper 2. Carrier 3. Freight Forwarder 4. Multimodal Transport Operator (MTO) 5. Logistics Service Provider 6. Digital Logistics Service Provider 7. Support service provider or consultant 8. Software provider 9. Terminal operator 10. Infrastructure operator and/or manager 11. Governmental entity 12. Other...		
BM_04	04_Business Model	4	**Information exchange**	Likert	Which information streams does your organisation receive, pass on or both receive and pass on?	a. Receive b. Receive and pass on c. Pass on d. Neither e. Don't know 1. Regulatory and compliance requirements and documentation (customs, insurance) 2. Cargo requirements and documentation (cargo information, transport unit requirements, handling equipment, contact details, safety requirements) 3. Transport requirements and documentation (Transport order, booking confirmation, Shipment specifications [mode of transport, transshipments], schedules [origin and destination, ETD, ETA], Transshipment equipment) 4. Payment and billing information (billing instructions, Invoicing, handling and transshipment rates, freight rates, storage rates) 5. Track-and-Trace information (Position, Change notification, Condition report, transshipment tracking, shipment status) 6. Routing conditions (weather and traffic forecast, infrastructure status. Terminal status, Transshipment spot availability, Storage space availability, capacity constraints) 7. Sustainability indicators 8. Incident and exception reporting		
BM_05	04_Business Model	5	**Logistics-specific IT systems**	Single Choice	Does your organisation use a Transport Management System (TMS)?	1. Yes 2. No 3. I don't know		
BM_06	04_Business Model	6	**Logistics-specific IT systems**	Single Choice	Which TMS system does your organisation use?	1. SAP 2. Oracle 3. Alpega		BM_05_01 required

						4. Transporeon 5. Impargo 6. In-house 7. Other (free text)		
BM_07	04_Business Model	7	**Logistics-specific IT systems**	Single Choice	Does your organisation use a Warehouse Management System (WMS)?	1. Yes 2. No 3. I don't know		
BM_07	04_Business Model	7	**Logistics-specific IT systems**	Single Choice	Which WMS system does your organisation use?	1. SAP 2. Oracle 3. Körber 4. Manhattan Associates 5. Luminate 6. In-house 7. Other (free text)		BM_07_01 required
BM_08	04_Business Model	8	**Logistics-specific IT systems**	Single Choice	Does your organisation use a Enterprise Resource Planning System (ERP)?	1. Yes 2. No 3. I don't know		
BM_08	04_Business Model	8	**Logistics-specific IT systems**	Single Choice	Which ERP system does your organisation use?	1. SAP 2. Oracle 3. Sage 4. NetSuite 5. Epicor 6. In-house 7. Other (free text)		BM_08_01 required
BM_09	04_Business Model	9	**Logistics-specific IT systems**	Single Choice	Does your organisation use a Customer Relationship Management System (CRM)?	1. Yes 2. No 3. I don't know		
BM_09	04_Business Model	9	**Logistics-specific IT systems**	Single Choice	Which CRM system does your organisation use?	1. Salesforce 2. Monday sales 3. Nimble 4. HubSpot 5. Pipedrive 6. In-house 7. Other (free text)		BM_09_01 required
BM_10	04_Business Model	10	**Logistics-specific IT systems**	Single Choice	Does your organisation use a Supply Chain Management System (SCM)?	1. Yes 2. No 3. I don't know		
BM_10	04_Business Model	10	**Logistics-specific IT systems**	Single Choice	Which SCM system does your organisation use?	1. SAP 2. Oracle 3. MS Dynamics 4. Plex 5. IFS 6. In-house 7. Other (free text)		BM_10_01 required
BM_11	04_Business Model	11	**Logistics-specific IT systems**	Single Choice	Does your organisation use a Asset Tracking System?	1. Yes 2. No 3. I don't know		
BM_11	04_Business Model	11	**Logistics-specific IT systems**	Multiple Choice	Which asset tracking system does your organisation use?	1. RFID 2. GPS 3. Barcode 4. NFC 5. Other (free text)		BM_11_01 required
BM_12	04_Business Model	12	**Logistics-specific IT systems**	Single Choice	Does your organisation use a Terminal Operating System (TOS)?	1. Yes 2. No 3. I don't know		
BM_12	04_Business Model	12	**Logistics-specific IT systems**	Multiple Choice	Which TOS does your organisation use?	1. Navis 2. CyberLogitec 3. GullsEye 4. Autostore TOS 5. ContPark 6. Interman (B. Rekencentra) 7. Inform 8. Berghof BLU 9. In-house 10. Other (free text)		BM_12_01 required
BM_13	04_Business Model	13	**Data exchange formats**	Multiple Choice	What formats does your organisation use to exchange data?	1. Standardised electronic data exchange formats (EDI/EDIFACT) 2. Office formats (.xls(x), .doc(x), .ppt(x)) 3. Comma-separated values (.csv) 4. .xml 5. .txt 6. PDF 7. E-Mail 8. Telefax 9. Paper 10. Other (free text)		
BM_13	04_Business Model	13	**Revenue streams**	Multiple Choice	Who is the primary entity responsible for financing or paying for the value or service provided by your organisation?	1. The customer itself 2. The state or government 3. No one 4. Another role		
BM_14	04_Business Model	14	**Revenue Streams/Business Models**	Multiple Choice	What describes your organisation's business model best?	1. Direct Sales Model: Products or services are sold directly to consumers without intermediaries 2. Subscription Model: Customers pay a recurring fee (monthly, yearly, etc.) to access a product or service 3. Marketplace Model: The company takes a commission or fee on transactions made between buyers and sellers on the platform 4. Freemium Model: Basic services are offered for free, while premium features, advanced functionalities, or additional content are available		

						for a fee 5. Advertising Model: Revenue is generated through advertisements placed on the company's platform, paid for by advertisers who want to reach the platform's audience 6. Other...		
PLA_01	05_Platforms	1	**Potential of a digital platform on multimodality efficiency**	Likert	Do you think a digital platform could help orchestrate multimodal transportation more efficiently?	1. Not at all 2. Slightly 3. Moderately 4. Very 5. Extremely 6. I don't know		
PLA_02	05_Platforms	2	**Utilisation of digital platforms**	Single Choice	Does your organisation already use a digital platform for collaboration with its partners and customers?	1. Yes 2. No		
PLA_03	05_Platforms	3	**Platforms in use**	Multiple Choice	Which digital platform does your organisation use for collaboration with ist partners and customers?	1. Transporeon 2. Sennder 3. Cesar-Next 4. Insta-Freight 5. Forto 6. Shippeo 7. FreightHub 8. Quicargo 9. Other (Free text)		PLA_02_02 required
PLA_04	05_Platforms	4	**Integrated solution**	Single Choice	Would you prefer a digital platform that is integrated into your existing digital infrastructure or an independent stand-alone solution that works via interfaces with existing IT services?	1. Integrated system 2. Standalone solution 3. No preference		
PLA_05	05_Platforms	5	**Information streams via digital platforms**	Likert	How important is the processing of information streams via a digital platform?	a. Must b. Should c. May d. Should not e. Must not f. No preference 1. Regulatory and compliance requirements and documentation (customs, insurance) 2. Cargo requirements and documentation (cargo information, transport unit requirements, handling equipment, contact details, safety requirements) 3. Transport requirements and documentation (Transport order, booking confirmation, Shipment specifications [mode of transport, transshipments], schedules [origin and destination, ETD, ETA], Transshipment equipment) 4. Payment and billing information (billing instructions, Invoicing, handling and transshipment rates, freight rates, storage rates) 5. Track-and-Trace information (Position, Change notification, Condition report, transshipment tracking, shipment status) 6. Routing conditions (weather and traffic forecast, infrastructure status. Terminal status, Transshipment spot availability, Storage space availability, capacity constraints) 7. Sustainability indicators 8. Incident and exception reporting		
PLA_06	05_Platforms	6	**Concerns regarding information exchange**	Multiple choice	Which concerns do you have when exchanging information via a digital platform?	1. Data security 2. Data privacy 3. Data integrity/Authentication 4. (Regulatory) Compliance 5. Technical issues 6. Interoperability 7. Standardisation 8. Other (free text)		
NEE_01	06_Needs	1	**Needs**	Ranking	Please rank the following needs according to their importance to your organisation from highest to lowest:	1. Data standardisation and automation 2. Integrated digital solutions 3. Facilitated data exchange and collaboration 4. Streamlined transport regulations 5. Advanced analytics and forecasting tools		
NEE_02	06_Needs	2	**Needs**	Single Choice	Do you can think of additional needs that need to be addressed when designing a digital platform?	1. No 2. Other (free text)		
GEN_01	07_General	1	**Gender**	Single Choice	Which gender do you identify with?	1. male 2. female 3. non-binary	x	
GEN_02	07_General	2	**Job Level**	Text	What is your current job level in your organisation?	Free text	x	
GEN_03	07_General	3	**Number of employees**	Single Choice	How many employees does your organisation have?	1. up to 9 2. 10 to 49	x	

						3. 50 to 249 4. from 250		
GEN_04	07_Gen-eral	4	**Annual revenue**	Single Choice	How much is your esti-mated annual revenue in euros (€)?	1. up to € 2 million 2. up to € 10 million 3. up to € 50 million 4. more than € 50 million	x	
GEN_05	07_Gen-eral	5	**Participation**	Single Choice	Are you interested in con-tributing to our project by participating in an expert in-terview or stakeholder work-shop?	1. Yes 2. No		
GEN_06	07_Gen-eral	6	**Participation**	Text	Please enter your contact email address	Free text		GEN_05_01 re-quired

Annex II: Documents of the Freight Transport Ecosystem

Document name	Synonyms	Transmission	Format	Content	Created by	Send to	System
Consignment note	Loading list; Shipping list; Packing list; Packing slip; Bill of parcel; Waybill; Bill of lading; Unpacking note; Delivery list; Customer receipt	Fax; Mail; E-Mail; API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ Place and date of issue ▪ Name and address of the consignor ▪ name and address of the carrier ▪ place and date of acceptance of ▪ goods and the place designated for delivery ▪ name and address of the consignee and any reporting address ▪ usual description of the type of goods and the type of packaging; in the case of dangerous goods, the description provided for in the dangerous goods regulations, otherwise the generally recognised description ▪ number, marks and numbers of the packages; gross weight or otherwise indicated quantity of the goods ▪ agreed freight and the costs incurred until delivery as well as a note on the freight payment ▪ amount of any cash on delivery to be collected upon delivery of the goods ▪ instructions for customs and other official handling of the goods ▪ agreement on carriage in an open vehicle not covered by tarpaulins or on deck	LSP	Carrier; (Consignor)	TMS; SCM; TOS; WMS
Forwarding contract	Forwarding order	Fax; Mail; E-Mail; API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ Sender ▪ Consignee ▪ Forwarder ▪ Place of delivery of the goods ▪ Place and date of taking over the goods ▪ Documents attached ▪ Number of packages ▪ Method of packing ▪ Nature of the goods / dangerous goods ▪ Sender's instructions ▪ Fleet and transport operation data	Consignor	LSP	TMS; CRM; SCM
Handover protocol	Inspection checklist; Handover confirmation; Delivery note; Handover document; Proof of delivery	Fax; Mail; E-Mail; API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ ELO/ISO codes ▪ CSC plate ▪ Exterior check ▪ Shipping documents ▪ (Interior) ▪ (Cargo)	Terminal operator; Carrier; Consignee; Consignor	LSP	TMS
Invoice		Fax; Mail; E-Mail; API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ customer master data ▪ type of goods ▪ quantity ▪ article number ▪ product variant ▪ price ▪ taxes ▪ fees	Consignor; LSP; Carrier; Terminal	Consignee; Consignor; LSP	CRM; SCM; TMS
Order	Purchase order; Supply order; Procurement order	Fax; Mail; E-Mail; API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ customer master data ▪ type of goods ▪ quantity ▪ article number ▪ product variant	Consignee	Consignor	ERP; SCM; TMS; CRM
Pick-up form	Pick-up request; Pick-up order; Pick-up receipt; Pick-up conformation; Pick-up slip	Fax; Mail; E-Mail; API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ Consignor information ▪ Destination information ▪ Pick-up information (date, time, location, weight, pieces, additional instructions) ▪ Service options	LSP	Carrier	TMS
Real time status report	Live tracking; Real-time tracking; Tracking report; Delivery status; Track-and-trace report; Transport status	API; EDI	XML; JSON; EDIFACT; GPS	▪ Track and Trace data ▪ GPS data ▪ Real time ETA ▪ ELO/ISO codes ▪ CSC plate ▪ Vehicle plate	Carrier; (LSP)	LSP; (Consignor; Consignee)	ATS; ERP; SCM; TMS

Sustainability balance sheet	Environmental report; Sustainability documentation; Green report	API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ CO2 emissions ▪ Routing alternatives based on sustainability indicators	Carrier; (Terminal)	LSP; (Consignor; Consignee)	CRM; SCM
Traffic report	Mobility report; Traffic analysis	API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ Traffic data ▪ Traffic jams ▪ Construction sites ▪ Infrastructure blockages			TMS
Transport order	Shipping order; Freight order; Logistics order	Fax; Mail; E-Mail; API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ Sender ▪ Consignee ▪ Forwarder ▪ Place of delivery of the goods ▪ Place and date of taking over the goods ▪ Documents attached ▪ Number of packages ▪ Method of packing ▪ Nature of the goods / dangerous goods ▪ Size ▪ Weight ▪ Sender's instructions ▪ Fleet and transport operation data ▪ Route ▪ Mode of transport ▪ Incoterms	LSP	Carrier	CRM; TMS; ERP
Weather report	Weather forecast; Weather prognosis; Climate report; Weather information; Weather analysis	API; EDI	PDF; CSV; XML; JSON; EDIFACT	▪ Weather forecast ▪ Water levels ▪ Extreme weather			TMS

Annex III: Interviews conducted

IP	Role & Nationality	Business Activities	Why the Interview partner was selected
1	Freight Forwarder Greece	Intermodal freight transport, facilitating smooth movement of goods across various modes of transportation, acting as intermediaries between shippers and carriers, and operating primarily in Europe	This SME freight forwarder specialises in road and sea transport organisation and provides – besides specific industry knowledge - detailed insight into the challenges faced by smaller logistics companies when implementing digital solutions.
2	Carrier Terminals Infrastructure Manager/Operator Germany	Trimodal logistics company, specialising in container import/export via inland waterway, rail, and trucking, with a network of terminals across Europe	This company specialises in trimodal transportation connecting seaports with the European hinterland moving an annual freight volume of 2.1 million TEU within its network along the river Rhine. This partner therefore offers crucial industry information about all modes of transport.
3	Software Provider & Logistic Service Provider France	Product lifecycle software and collaborative platform provider for multiple industries, with a strong emphasis on mobility, manufacturing, aerospace, and defence.	As one of the largest software companies in Europe, this stakeholder has an extensive software and service portfolio for various industry segments. From the transport logistics perspective especially, the collaborative digital platform holds significant potential to address current business challenges in the transport sector.
4	Software Provider & Logistics Service Provider Finland	Software solutions for transparency, optimising parcel routing, acting as middleware between ecommerce stores and warehouses, and providing warehousing services for efficient picking and packing of goods	This logistics service provider helps e-commerce businesses to optimise their supply chain, speed up delivery times, and reduce costs with a modern 3PL service. With extensive experience in e-commerce shipment tracking and other logistics services this innovative SME contributes valuable information on digitalised supply chains.
5	Terminals Luxembourg	Multi-use terminal operator managing train operations, container trading, and employing sustainable practices, including renewable energy and battery electric vehicle	This operator of a public intermodal terminal in Luxembourg can handle all intermodal transport units on an area of 33 hectares and uses innovative technologies like AI-applications to increase the efficiency of transshipment processes. The company offers valuable insights from the perspective of terminal operators and provides suggestions for the use of digital technologies.
6	NGO (Humanitarian Logistics)	Providing auxiliary support, coordinating logistics operations, and establishing warehousing	One of the largest humanitarian networks worldwide provides aid support to people affected by conflicts or disasters. Their extensive expertise in the field of humanitarian logistics contributes fundamentally to

	Denmark	hubs for efficient disaster response and conflict management	understanding the challenges and requirements of aid organisations in freight transport logistics.
7	Terminals Carrier Netherlands	Creating a sustainable European network with assets like trucks, trailers, containers, vessels, and rail connections, and operating hub terminals for efficient customer service	The company is one of the largest European transport companies focusing on multimodal transport by operating own terminals, transport vehicles, and loading units. This stakeholder provides crucial information on multimodal transportation and disruption management.
8	4th Party Logistics Service Provider DLSP Germany	Optimisation service provider specialising in road transport, offering solutions to improve customers' transportation, warehousing, and handling processes, with a focus on transparency through their TMS platform	This company is a leading global provider of supply chain consulting, software, and fourth-party logistics (4PL) services. Insights on end-to-end logistics processes and technical requirements are especially relevant for the stakeholder analysis

Annex IV: Workshops conducted

WS	Role & Nationality	Business Activities	Why the workshop participant was selected
1	Industry Association Belgium	Raising stakeholder awareness, consulting policy makers, and standardising combined transport operations, while representing intermodal operators as key actors in the integrated freight transport chlain.	As one of the main industry associations in the European intermodal transport industry this stakeholder actively promotes Combined Transport, primarily towards European decision-makers and supports the daily functioning of this ecologically and economically sustainable mode of long-distance freight transport. The association has in-depth knowledge of existing standards, legal requirements and current challenges in intermodal transport and is familiar with the needs of its members due to its role as an interest representation body.
2	Freight Forwarder Germany	Managing standardised transport orders, unitising them based on client software systems, handling various container types, good types, commercial types, capacities, departure and provision times, duration of stay, customs clearance, and release processes from terminals	As a maritime, port-neutral operator and specialist in port-to-door logistics, this company organises global supply chains in combined transport and bringing together the system strength of rail with the flexibility of trucking. As an important link between maritime ports and hinterland transportation, this stakeholder contributes significant industry experience to the analysis
3	Infrastructure Manager/Operator, Finland	managing operations for ferry services, RoRo (Roll-on/Roll-off) cargo, and container traffic. It acts as a key hub for maritime transport, connecting international trade routes, particularly in the Baltic Sea region.	As a maritime hub, they provide valuable insights into the challenges and opportunities of port operations, sustainable practices in maritime logistics, and intermodal connectivity. Their involvement is crucial for understanding the role of seaports in multimodal freight networks and their integration with European transport corridors.
4	Industry Association Germany	Promotion and development of sustainable freight transportation using different loading units, conduct research, studies, and consulting activities, and advocate for the adoption of combined transport within the freight transport sector	This partner is one of the most important non-profit membership associations in intermodal logistics. For 80 years this association has connected relevant actors of the Combined Transport sector and created a neutral communication and knowledge platform for research and development.
5	Carrier, Terminals & Freight Forwarder	Offering a cost-effective and sustainable transport chain for continental transports, utilising sea, inland waterway, rail, and road modes, optimising efficiency for longer routes, and	This interview partner is one of the market leading combined transport operators in Europe. As a neutral combined transport operator, this company moves over 1 million road consignments annually and consolidates shipments from transport companies to complete trains utilising 9100 own wagon

	Switzer-land	providing cross-border transport services in Europe with seamless last-mile deliveries	modules. As a major combined transport operator, this company offers important industry insights and provides significant support in identifying challenges around combined transport.
6	DLSP Germany	Digital logistics service provider specialising in road freight optimisation and additional services, (with potential for multi-modal transportation)	This software-SME is one of Germany's most innovative logistics tech start-ups and has access to an extensive network of freight forwarders and transport companies. Their multi-tenant matching platform enables conducting event-based relay transports to circumvent disrupted infrastructure sections.
7	DLSP Germany	Neutral platform connecting intermodal actors and providing transport chain transparency and intermodal booking options	As a highly innovative SME and neutral platform for intermodal players, this stakeholder makes a decisive contribution to the analysis.
8	Software Provider Germany	Providing logistic planning products, including route and tour planning, load optimisation, geo-management/geo-marketing solutions, intermodal component solutions, and customised software-as-a-service options for automated tour planning and delivery time estimation	As a European market leader in traffic and transport route planning. In addition, the company is involved in many innovative projects to further develop its state-of-the-art software solutions and support the logistics industry.
9	Infrastructure Manager/Operator Austria	Operating an infrastructure provider, with a primary focus on container handling at a terminal, emphasising various modes of transportation and collaborating on urban logistics initiatives with an academic institution	This stakeholder operates one of the most important inland ports in the Rhine-Danube corridor and handles around 1200 cargo ships per year. The company offers a comprehensive service portfolio and has access to a large network of the most important hinterland logistics companies in Europe.

The project

ReMuNet identifies and signals disruptive events and assesses their impact on multimodal transport corridors. It reacts quickly and seamlessly upon disruptive events in real-time. It supports TMS providers to improve route planning resilience. ReMuNet communicates alternative, pre-defined, multimodal transport routes to logistics operators and subsequently to truck drivers, locomotive drivers and barge captains. Through this, it enables a faster and adaptive multimodal network response. ReMuNet orchestrates route utilisation, suggests transshipment points and optimises capacity allocation, minimising damage and shortening the recovery time. What is ReMuNet's core objective? As trailblazer for the Physical Internet, ReMuNet pursues the vision to enable and incentivise synchro-modal relay transport on European rail, road, and inland waterways to increase the holistic network resilience. It significantly reduces emissions and boosts freight transport corridor efficiency in case of disruptive events. stakeholders to ensure Europe-wide practicability and acceptance.

Coordinator: FORSCHUNGSINSTITUT FUER RATIONALISIERUNG (FIR)

PARTNER		SHORT NAME
	FORSCHUNGSINSTITUT FUER RATIONALISIERUNG	FIR
	SVENSKA HANDELSHOGSKOLAN	HANKEN
	PTV PLANUNG TRANSPORT VERKEHR GmbH	PTV
	4PL INTERMODAL GMBH	INT
	MANSIO GMBH	MAN
	FRAUNHOFER AUSTRIA RESEARCH GMBH	FHA
	HAFEN WIEN GMBH	HWI
	WHITE RESEARCH SRL	WRE
	UNION INTERNATIONALE DES SOCIETES DE TRANSPORT COMBINE RAIL-ROUTE SCRL	UIR
	CONTARGO GMBH & CO KG	CON
	VEDIAFI OY	VED

	DANSK RODE KORS (DANISH RED CROSS)	DRC
	ILMATIETEEN LAITOS	FMI
	ALLIANCE FOR LOGISTICS INNOVATION THROUGH COLLABORATION IN EUROPE	ETP-ALICE
	SCHACHINGER IMMOBILIEN UND DIENSTLEISTUNGS GMBH & CO OG	SCH