

D3.3

ReMuNet Ecosystem Design and a Catalogue of sustainable Business Models for key Actors

FIR an der RWTH Aachen

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Pioneering resilient and adaptive multimodal transport networks

TABLE OF CONTENTS

1.	INTRODUCTION	12
1.1	Project Background	12
1.2	Key Objectives of the ReMuNet Project.....	13
1.3	Objective of Deliverable 3.3	15
1.4	From Deliverable 3.2 to 3.3.....	16
1.5	Structure of Deliverable 3.3	17
2.	THEORETICAL BACKGROUND	18
2.1	Disruption Management.....	18
2.2	Digital Platform Architecture	18
	2.2.1 Concept Origin and Definition.....	19
	2.2.2 Dimensions of Platform Architecture	19
2.3	Sustainable Business Models	20
2.4	Coopetitive Ecosystem Design	21
3.	RESEARCH DESIGN AND DATA COLLECTION	23
3.1	Designing the Disruption Management Process	24
	3.1.1 Desk Research & K3 Method	24
	3.1.2 Validation-Workshops for Disruption Management Process.....	24
3.2	Designing the Platform Architecture	25
	3.2.1 Desk Research.....	26
	3.2.2 Consortium Workshops for Platform Architecture.....	27
3.3	Designing sustainable and coopetitive Business Models.....	28
	3.3.1 Desk Research & internal Workshop.....	28
	3.3.2 Business Model Validation Questionnaire	29
3.4	Designing the coopetitive Ecosystem	31
4.	DISRUPTION MANAGEMENT PROCESS	33
4.1	Best Practices in Disruption Management	33
	4.1.1 Lessons learned from past Disruptions	33
	4.1.2 Cross-Industry Insights in Disruption Management	35
4.2	Disruption Management Process Design.....	37
	4.2.1 Process Assumptions.....	38
	4.2.2 Incoterms.....	38
	4.2.3 Responsibilities during disruptive Events	41

4.2.4	Phase I – Task Force Assembly	41
4.2.5	Phase II – Mitigation	43
4.2.6	Phase III – Evaluation	44
5.	REMuNET PLATFORM	46
5.1	Success Factors for digital Platforms in Transport Logistics	46
5.1.1	Insights from D3.2	46
5.1.2	Success Factors of digital Platforms in Transport Logistics	47
5.2	ReMuNet Platform Architecture Design	51
5.2.1	Core Value Proposition and Vision of ReMuNet	51
5.2.2	Core Service Components	52
5.2.3	System Interaction and Data Exchange	53
6.	MAPPING OF THE NEW REMuNET ECOSYSTEM	54
6.1	Core Value Proposition	54
6.2	Description of Roles	55
6.3	Determination of User Needs	55
6.4	Definition of Value Streams	57
6.4.1	Flow of Goods	57
6.4.2	Flow of Finances	58
6.4.3	Flow of Information	59
6.4.4	Combined Value Flow Model	60
6.5	Advantages and Disadvantages for Actors	61
6.6	Multidimensional View of Business Models	63
6.6.1	Infrastructure Operator and Manager	64
6.6.2	Carrier	65
6.6.3	Multimodal Transport Operator	67
6.6.4	Terminal Operator	68
6.6.5	Software Provider and Consulting Companies	70
6.6.6	Freight Forwarder	71
6.6.7	Digital Logistics Service Provider	72
6.6.8	Consignor	72
6.6.9	Consignee	73
6.6.10	Governmental Entities	74
6.7	Competition Index for ReMuNet Ecosystem	74



7. CONCLUSION AND OUTLOOK77

REFERENCES79

APPENDIX87

 A1: Interview Guide87

 A2: List of Interviewees89

 A3: Survey - List of Assumptions.....90

 A4: Disruption Management Process95

LIST OF FIGURES

Figure 1: Research Framework.....	23
Figure 2: K3-Methodology basic Shapes.....	24
Figure 3: Platform Design Methodology	25
Figure 4: Ecosystem Design Canvas	32
Figure 5: Overview of Incoterms	39
Figure 6: Phase I - Task Force Assembly	42
Figure 7: Phase II - Mitigation	43
Figure 8: Phase III - Evaluation	44
Figure 9: ReMuNet's Platform Architecture Design	51
Figure 10: ReMuNet Ecosystem Canvas and Coopetition Analysis.....	54
Figure 11: Stakeholder Requirements.....	56
Figure 12: New Ecosystem Landscape	57
Figure 13: Flow of Goods.....	58
Figure 14: Flow of Finances.....	59
Figure 15: Flow of Information.....	60
Figure 16: Combined Value Flow Model	61
Figure 17: Distribution of Roles participated in the Survey	63
Figure 18: Coopetition Index Matrix	75

LIST OF TABLES

Table 1: The Orchestration Platform Archetype	20
Table 2: Business Model Framework	28
Table 3: Change-log Matrix for adapted Business Models	29
Table 4: Learnings from past Disruptions in Logistics	35
Table 5: Learnings from Cross-Industry Insights in Disruption Management	37
Table 6: Incoterms Explanation.....	39
Table 7: Responsibilities during disruptive Events.....	41
Table 8: Existing or shut down digital Logistics Platforms	47
Table 9: Success Factors of digital Logistics Platforms	49
Table 10: Roles within the existing Ecosystem.....	55
Table 11: Advantages and Disadvantages of the current Ecosystem for the Roles	62
Table 12: Implications on the BM of Infrastructure Operators and Managers	65
Table 13: Implications on the BM of Carriers.....	67
Table 14: Implications on the BM of MTO	68
Table 15: Implications on the BM of Terminal Operators.....	70
Table 16: Implications on the BM of Software Providers and Consulting Companies	70



Table 17: Implications on the BM of Freight Forwarders 71

Table 18: Implications on the BM of DLSP 72

Table 19: Implications on the BM of Consignors 73

Table 20: Implications on the BM of Consignees..... 74

ABBREVIATIONS

API	Application Programming Interfaces
ATC	Air Traffic Control
BM	Business Model
CFR	Cost and Freight
CI	Coopetition Index
CIF	Cost, Insurance and Freight
CIP	Carriage and Insurance Paid To
CPT	Carriage Paid To
DAP	Delivered At Place
DDP	Delivered Duty Paid
DLSP	Digital Logistics Service Provider
DORA	Digital Operational Resilience Act
DPU	Delivered at Place Unloaded
EACCC	European Aviation Crisis Coordination Cell
ECB	European Central Bank
ECM	Entity in Charge of Maintenance
EDI	Electronic Data Exchange
ERA	EU Agency for Railways
ETA	Estimated Time of Arrival
EXW	Ex Works (or Ex Warehouse)
FAS	Free Alongside Ship
FCA	Free Carrier
FMEA	Failure Mode and Effects Analysis

FOB	Free On Board
ICT	Information and Communication Technology
IM	Infrastructure Manager
Incoterms	International Commercial Terms
IWW	Inland Waterway
IOM	Infrastructure Operator and Manager
IP	Interview Partner
IQR	Interquartile Range
ITU	Intermodal Transport Unit
JNS	Joint Network Secretariat
LSP	Logistics Service Provider
MTO	Multimodal Transport Operator
NSA	National Safety Authority
NOP	Network Operations Portal
NSB	North Sea-Baltic
NVO-MTO	Non-Vessel-Operating Multimodal Transport Operator
OCAP	Out of Control Action Plans
RD	Rhine-Danube
RNE	Rail Net Europe
RU	Railway Undertakings
SAIT	Safety Alert IT
SIS	Safety Information System
SME	Small and Medium Enterprises

SRB	Single Resolution Board
TEN-T	Trans-European Transport Network
TIS	Train Information System
TMS	Transport Management System
VO-MTO	Vessel-Operating Multimodal Transport Operator
WP	Work Package

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 enable 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 3.3

The overall objective of ReMuNet's third work package (WP3) is to design a collaborative platform that enables high operational interconnectivity for event-based, synchromodal relay transport. 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 foundation for innovative business model (BM) development, laying the groundwork for the ReMuNet solution to be effectively integrated into existing transport ecosystems.

Task 3.2 begins with a comprehensive analysis of the current ecosystem using Business Ecosystem Mapping to capture the unique features of the North Sea-Baltic (NSB) and Rhine-Danube (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 flows 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 3.3, one of two formal outcomes of Task 3.2, builds on the insights gathered in the ecosystem analysis conducted in D3.2. Key aspect of D3.3 is a comprehensive description of the new ecosystem with ReMuNet being integrated into the European freight transport network. Core element is the development of the digital platform architecture, one of ReMuNet's central modules for promoting physical internet in the logistics sector. A formalised approach of the platform architecture ensures collaborative understanding of the platform features within the whole consortium. With the platform architecture in place, ReMuNet is able to realise its core value proposition: *strengthening the sustainability, efficiency and resilience of multimodal European freight transport networks against disruptive events. It is designed to enable real-time, low-emission, and adaptive route planning through synchromodal relay transport, while fostering seamless collaboration among all relevant logistics stakeholders.* Influencing the whole ecosystem with this new value proposition, business models of key actors change improving not only their own value proposition, but also their customer segments, value creation and profit mechanisms. ReMuNet brings many advantages for the multimodal freight transport sector exemplified with a disruption management process presented in this Deliverable. Through these findings, ReMuNet lays the foundation for a new standard for European multimodal transport, creating an adaptable, value-oriented platform ecosystem that addresses the evolving requirements of the logistics sector and contributes to a more resilient and efficient transport network across Europe.

1.4 From Deliverable 3.2 to 3.3

Deliverable 3.2 analyses the European multimodal transport ecosystem along the North Sea–Baltic and Rhine–Danube corridors, identifying key actors, value flows, and systemic interconnections. It develops a shared framework to address the complexity and inconsistencies of the ecosystem, forming the basis for ReMuNet's integration and problem-solving approach. The analysis identifies four categories of systemic pain points: socio-economic, standardisation and regulatory, technical, and infrastructure-related challenges. It defines platform requirements in six areas (regulation, trust and transparency, data

integration, service tools, disruption management, and sustainability) to ensure alignment with ecosystem needs. The Deliverable provides a roadmap for addressing these challenges, establishes a basis for platform design, and sets the stage for translating requirements into implementable solutions through continued stakeholder engagement.

Deliverable 3.3 builds on the findings of D3.2 and introduces the ReMuNet platform architecture addressing the requirements identified in D3.2. This architecture forms the central aspect of the newly designed multimodal freight transport ecosystem integrating ReMuNet. Further, D3.3 builds on the identified existing ecosystem and designs the cooperative ReMuNet ecosystem, including the actors' potential sustainable business models and new value streams.

1.5 Structure of Deliverable 3.3

Chapter two introduces central theoretical concepts contributing to the understanding of the following research steps. These fundamentals include definitions and approaches for disruption management, digital platform architectures, sustainable business models and a cooperative ecosystem design.

Chapter three describes the research design and methodologies used for synthesising gathered data into new scientific results. Featured frameworks include the K3 notation, the platform navigator, business model theory and the ecosystem design canvas. Desk research, workshops and an online survey were used for data collection and for the validation of findings.

Chapter four presents the results of the disruption management process development. It defines responsibilities during disruptive events and combines expert knowledge with common practices from past disruptions into a three-phase process model, which highlights potentials for improvement by ReMuNet.

Chapter five displays the ReMuNet digital platform architecture with its core service components and the system interaction and data exchange to other systems and platforms ensuring interoperability and standardisation based on the requirements identified in D3.2.

Chapter six combines main results from the previous chapters and shapes the ReMuNet ecosystem with all its key actors, their sustainable business models and all value flows adapted from D3.2. The analysis of cooperation among actors in the new ecosystem closes this chapter highlighting the collaborative advantage with the integration of ReMuNet into the freight transport ecosystem.

Chapter seven concludes all major findings identified in this Deliverable summarising key take aways and discussing the validity of those. In addition, future research plans and outlooks to D3.4 are given.

2. Theoretical Background

Since this Deliverable covers four main topics (disruption management, platform architecture, sustainable business models, and coopetitive ecosystem design), it is initially necessary to establish a theoretical understanding of these areas, which will serve as the foundation for understanding the subsequent chapters.

2.1 Disruption Management

A disruptive event is “any interruption or change, planned or unplanned, in the operations of a transport network, creating effects, such as delays, blockages or closures” (Kulkarni et al., 2023, p. 30). The impact of a disruptive event can be distinguished by its geographical extend or its time duration (Kulkarni et al., 2023). Building upon this definition, disruption management refers to the systematic handling of disruptive events to minimise their operational, financial, and customer-related impacts (Clausen et al., 2010; Hrušovský et al., 2021; Yu & Qi, 2004).

The concept of “disruption management” originated prominently in the 1990s and early 2000s within the aviation industry, where researchers primarily focused on handling unforeseen operational disturbances such as airport closures, adverse weather conditions, and crew or aircraft scheduling conflicts that led to significant delays and cancellations (Yu & Qi, 2004). Disruption management in this early context mainly involved tactical rescheduling and resource allocation to maintain flight continuity and service levels (Clausen et al., 2010; Yan & Lin, 1997).

In recent years, the concept has been extended to encompass multimodal freight transport systems, where disruptions may arise from a variety of sources such as infrastructure failures, port congestions, labour shortages, regulatory changes, or extreme weather events (Ghadge et al., 2020; Ivanov & Dolgui, 2021; von Stamm et al., 2024). In these multimodal networks, disruption management requires not only rapid operational adjustments across different transport modes but also a high degree of information sharing, collaborative decision-making, and the integration of digital technologies such as real-time monitoring, predictive analytics, and decision-support systems (Ivanov & Dolgui, 2021; Marzuoli et al., 2016).

2.2 Digital Platform Architecture

The emergence of digital platforms offers potential benefits for companies to enhance their value proposition (bitkom, 2020; Popova et al., 2024). Digital platforms represent “layered modular technology architectures in business networks” (Kazan et al., 2018, p. 186), which are described with a platform architecture (Blaschke et al., 2019).

The concept of platform architecture emerged from the broader field of systems engineering and modularity theory (C. Y. Baldwin & Clark, 2000). Its primary role is to create the possibility for innovation around a platform as a blueprint defining boundaries and capabilities including the configuration of the platform components (Blaschke et al., 2019; Tiwana, 2013).

2.2.1 Concept Origin and Definition

A platform is defined as

„a business based on enabling value-creating interactions between external producers and consumers. The platform provides an open, participative infrastructure for these interactions and sets governance conditions for them. The platform’s overarching purpose: to consummate matches among users and facilitate the exchange of goods, services, or social currency, thereby enabling value creation for all participants.“

(Parker et al., 2016, p. 177)

It encompasses the set of design principles and structural arrangements that specify the core components (the platform) and the peripheral modules (complementary products or services), as well as the interfaces that govern their interaction (Carliss Y. Baldwin & Woodard, 2009; Gawer & Cusumano, 2002).

Platform architecture has become a central topic in both information systems and strategic management research. Scholars have explored various properties, including modularity (C. Y. Baldwin & Clark, 2000; Kazan et al., 2018), openness (Blaschke et al., 2019; West, 2003), governance (Tiwana et al., 2010), and the interplay between architecture and ecosystem dynamics emphasising the importance of architecture adaptability to changing ecosystem conditions through a flexible yet robust platform governance (Bonina et al., 2021).

2.2.2 Dimensions of Platform Architecture

The taxonomy developed by Blaschke et al. (2019) describes an architecture of digital platforms on four levels:

Infrastructure

Digital platforms are based on digital infrastructures, which are understood as computing and network resources that enable distributed actors to exchange resources. These infrastructures are characterised by their ability to collect, store and exchange digital data across systems and devices. Platforms interact with these infrastructures via three types of access: direct, indirect and open (Blaschke et al., 2019).

Core

Digital platforms are based on a stable set of core technical artefacts that serve as the technological foundation for platform-extending derivatives. These artefacts form an extensible code base that enables third parties to develop complementary products, services, and technologies. The interface between core and periphery is realised via two key mechanisms: openness of access and openness of resources, both of which facilitate innovation by third parties (Blaschke et al., 2019; West, 2003).

Ecosystem

Digital platforms depend on dynamic platform ecosystems (chapter 2.4). Their success depends on the contributions of a critical mass of actors in key roles such as platform owners, partners, end users, and subcontractors, each providing complementary resources (Blaschke et al., 2019). The successful integration of a digital platform into an ecosystem

requires a clear strategy encompassing the platform itself, its network effects and the market requirements (Popova et al., 2024). The taxonomy distinguishes two general forms of ecosystems: private networks and federated networks (Blaschke et al., 2019).

Service

Digital platforms generate value primarily through digital services, marking a significant shift from a product-centric to a service-oriented economy. Unlike traditional bilateral relationships, these services emerge from networked systems that integrate organisational and technological resources to meet user needs. The service provider typically involves both the platform owner and at least one partner, while the user is the service recipient. Such services may occur as single or continuous transactions within actor-to-actor networks. Two key orientations characterise this service dimension: exchange and design (Blaschke et al., 2019).

Besides the dimensions Blaschke et al. (2019) exemplifies the taxonomy on platform archetypes. Using the example of the **orchestration platform** archetype the taxonomy shows central characteristics within the dimensions described previously (table 1). Orchestration platforms are characterised by federated networks which are enabled through cooperative and inclusive platform strategies. They exhibit high levels of access and resource openness, facilitating integration with third-party derivatives. The key governance challenge lies in aligning the technological and business interests of the platform owner and diverse partners. These platforms depend heavily on established digital infrastructures to connect actors and expand market reach (Blaschke et al., 2019).

Table 1: The Orchestration Platform Archetype (based on Blaschke et al., 2019)

Architectural Dimension	Characteristic 1	Characteristic 2	Characteristic 3	Digital Platform Archetype
Service	Exchange Orientation	Design Orientation	-	ORCHESTRATION PLATFORM: Co-opetitive and inclusive platform profiles
Ecosystem	Private Network	Federated Network	-	
Core	Access Openness	Resource Openness	-	
Infrastructure	(Direct Access)	Indirect Access	Open Access	

Within this Deliverable the platform architecture of ReMuNet is introduced as a digital platform orchestrating the multimodal freight transport, especially in the face of disruptions. Thus, the described orchestration platform archetype serves as an orientation for considerations on the platform design in chapter 5.

2.3 Sustainable Business Models

A sustainable business model enables companies to combine economic success with social and environmental responsibility. In contrast to traditional business models, which focus primarily on financial value creation, a sustainable business model additionally aims to make a positive contribution to the environment, society, and the economy along the entire value stream (Gassmann et al., 2013; Lüdeke-Freund et al., 2024). *Gassmann et al.* (2013) define a business model as a holistic picture that shows how a company creates and retains value.

It comprises the dimensions of “who” (target customers), “what” (value proposition), “how” (value creation architecture), and “why” (profit mechanism) (Gassmann et al., 2013).

Sustainability extends this concept to include the combination of economic, ecological and social goals, known as the “triple bottom line” (Lüdeke-Freund et al., 2024). Thus, it integrates sustainability into all dimensions of the business model without neglecting economic profitability. The impact on the environment and society are systematically considered when designing business activities (Lüdeke-Freund et al., 2024).

Business models focusing sustainability, such as circular economy models, sharing economy approaches, and social enterprises combine social inclusion and environmental awareness (Lüdeke-Freund et al., 2024). Resources are used more efficiently, products are designed in a modular way, and social challenges are addressed through the business offering (Lüdeke-Freund et al., 2024). This may lead to sustainable value creation beyond short-term profit maximisation and addressing challenges such as climate change, social inequality, and environmental destruction (Gassmann et al., 2013; Lüdeke-Freund et al., 2024).

2.4 Coopetitive Ecosystem Design

As described in chapter 2.2, orchestrator platforms are characterised by coopetitive networks. For integrating ReMuNet as a digital platform into the multimodal freight transport ecosystem, it is essential to analyse its coopetitive network characteristics. A strategic analysis method specifically designed for examining business ecosystems (as defined in D3.2) taking the aspect of coopetition into account was developed by Wieninger et al. (2019). It will be used to gain insights into ReMuNet’s ecosystem and the coopetition among key stakeholders. The approach consists of three core phases (Wieninger et al., 2019):

1. Business Ecosystem Identification

The first step involves clearly identifying the specific value proposition or the problem from the customer’s perspective. Essential functional components required to deliver this value proposition are identified focusing on structures and activities for customer-oriented benefits rather than on the actors (Adner, 2017; Wieninger et al., 2019)

2. Business Ecosystem Analysis

Central aspect of an ecosystem is its containing roles and their relationships towards each other. This interplay between ecosystem participants is represented by a coopetition index (CI). The CI combines the aspects of competition and cooperation in a single numeric value. The cooperation and competition relationship are both measured by a five-point rating scale (1 = weak, 5 = strong). To create the CI, the difference between the competition and cooperation scales is calculated. Therefore, this index ranges from strongly cooperative (+4) to strongly competitive (-4), enabling precise analysis of strategic dynamics between actors (Wieninger et al., 2019). Consequently ΔCI represents the alteration of coopetition regarding two points of time: the current ecosystem and the newly designed ReMuNet ecosystem.

3. Business Ecosystem Visualisation

Altering from Wieninger et al. (2019), this Deliverable visualises the coopetitive ecosystem analysis using a coloured matrix representing the change of coopetition due to the integration of ReMuNet into the multimodal freight transport ecosystem. The colour scheme highlights groups of actors that are engaged in increased cooperation or competition.

3. Research Design and Data Collection

The overarching objective of this Deliverable is to conceptualise the digital platform architecture of ReMuNet and to systematically analyse its implications for the emerging ecosystem. Central to this effort is the examination and description of a possible future ReMuNet ecosystem, along with the development of a catalogue of sustainable business models highlighting the ecosystem's potentials and improvements. To achieve this goal, the following chapter describes the methodological approaches that were applied based on the theoretical foundations presented previously to design the disruption management process and platform architecture and to develop sustainable and coopetitive business models in the ReMuNet ecosystem (figure 1). Also, a consolidated disruption management process for the freight transport ecosystem is developed and enriched with possible improvements by the ReMuNet platform.

This Deliverable builds directly on the findings of D3.2, which focused on analysing the current state of the ecosystem. In D3.2, existing business models of key stakeholders in the multimodal transport network were examined, the current ecosystem was visualised using value flow models, and role-specific challenges were used to derive requirements for a digital solution aimed at enhancing resilience and sustainability in the transport sector. D3.3 now expands upon this foundation by shifting the perspective toward a future-oriented design of the ReMuNet ecosystem.

The disruption management process is modelled using the K3 method, with validation carried out through expert workshops. The platform architecture is described using the Platform Navigator (Schwind et al., 2011), with its conceptualisation informed by literature research and dedicated consortium workshops. Sustainable business models are investigated based on the frameworks proposed by Gassmann et al. (2013) and Lüdeke-Freund et al. (2024), validated through a quantitative questionnaire, and subsequently embedded into the ecosystem design following Lewrick's (2021) approach. Their degree of coopetition is assessed using the Coopetition Index developed by Wieninger et al. (2019).

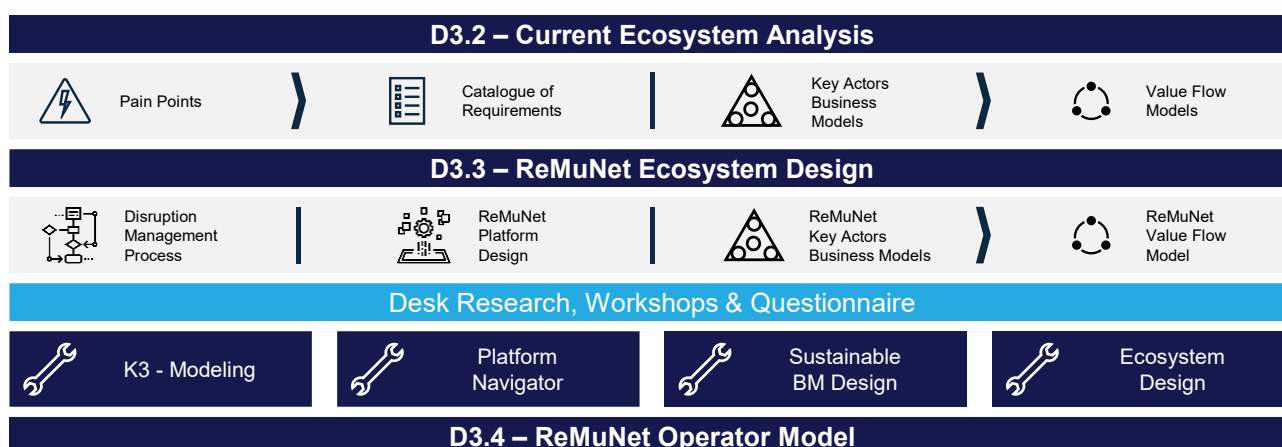


Figure 1: Research Framework

3.1 Designing the Disruption Management Process

The aim of designing the disruption management process is to understand how disruption management is currently handled within the multimodal transport ecosystem, in order to create a foundation for a future-oriented perspective on how the ReMuNet platform could potentially shape this process. A clear understanding of the current state is necessary to identify existing gaps, inefficiencies and coordination problems, which may be addressed by ReMuNet.

To achieve this, a two-stage methodological approach is applied. First, a combination of desk research and the K3 method enables a structured representation of the current disruption management process. Second, expert workshops were conducted to validate and refine this process model, ensuring that the envisioned integration of ReMuNet is grounded in practical expertise and stakeholder needs.

3.1.1 Desk Research & K3 Method

Foundational literature and process reports of past events were gathered in a selective desk research. The handbook for international continuity management developed by RailNetEurope (2021) served as a foundational concept for the first process draft.

The synthesised process was then modelled using the K3 methodology. K3 is a graphical tool for depicting weakly structured collaborative processes (Nielen, 2014). Processes are built with basic shapes allowing high comprehensibility highlighting coordination and collaboration of multiple actors (see figure 2).

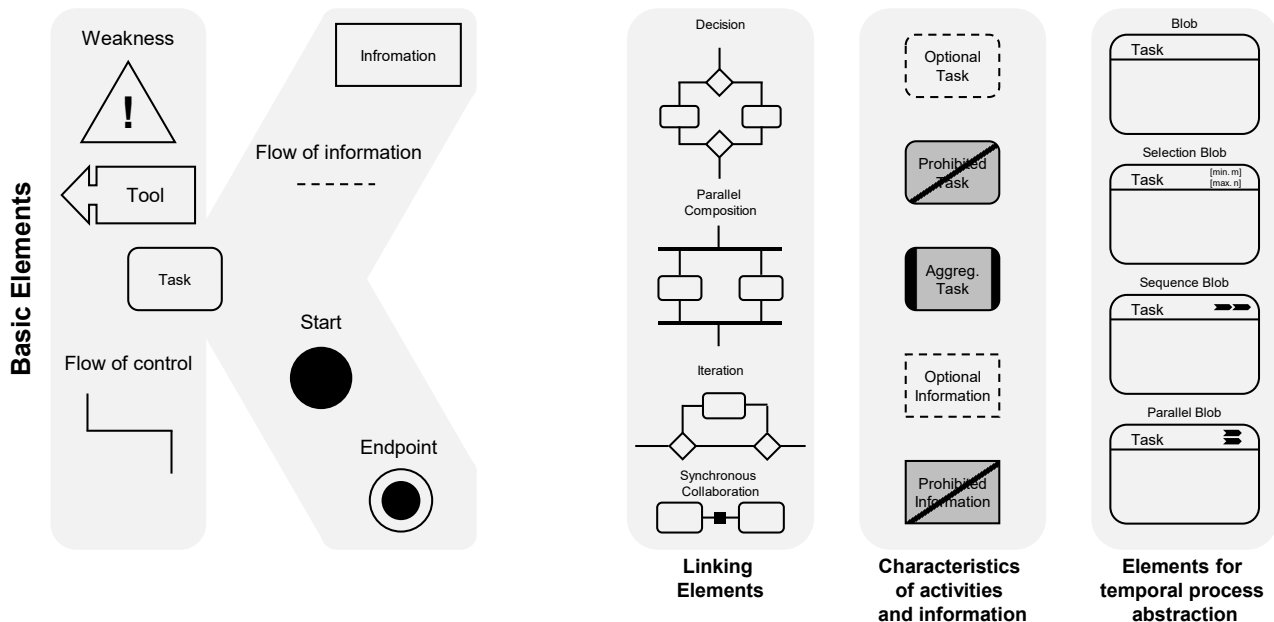


Figure 2: K3-Methodology basic Shapes (based on Nielen, 2014)

3.1.2 Validation-Workshops for Disruption Management Process

To validate and iteratively refine the preliminary desk research results presented by using K3, six validation workshops were held. According to Bell et al. (2019), validation workshops

are a suitable method for reflection and discussion, as well as for ensuring the practicability and applicability of the research results. They were part of an iterative research design, which can help to effectively integrate feedback from practitioners into the results in the context of qualitative research (Bell et al., 2019).

The interviews began after a first conceptual process was designed. Purposive sampling was used to select the participants, ensuring that they either had expertise related to the individual roles identified in the disruption management process or that they themselves fulfilled these roles (an anonymised list of all participants can be found in Appendix 2). This ensured that the participants had sufficient expertise and experience to provide informed feedback, thereby increasing the quality and reliability of the results (Bell et al., 2019).

The workshops were conducted in the form of one-hour interviews, during which a researcher presented the K3 process to the participants. In addition, the assumptions made when creating the process (see chapter 4.2.1) were presented to the participants. Parts of the workshop were open, allowing participants to freely express their comments, while in other parts predefined questions (see Appendix 1) were asked to ensure that the essential topics and issues were covered in all workshops. This led to a semi-structured discussion of the results.

Throughout the workshops, participants' comments were visually noted and displayed, allowing them to follow the researchers' understanding of their feedback and to adjust as necessary. According to Bell et al. (2019), this is a way to increase the credibility and reliability of the research.

All participants were informed in written form in advance of the workshop about its purpose and the use of their contributions, and informed consent was obtained. Furthermore, all participants were asked for their permission to record the workshop in video and sound before the workshop began. For the documentation of the interviews, the integrated transcription function within Microsoft Teams was utilised. Following each session, the automatically generated transcript was carefully reviewed, manually corrected, and subjected to a thematic analysis. Upon completion of the final transcript, all video recordings were permanently deleted in line with applicable data protection regulations and confidentiality standards formulated in the project's data management plan to safeguard the privacy and integrity of the interview participants.

3.2 Designing the Platform Architecture

The Platform Navigator, developed by Wortmann et al. (2022), provides a research-based framework organised into five key development phases: Ideate, Design, Monetise, Scale, and Manage (figure 3).

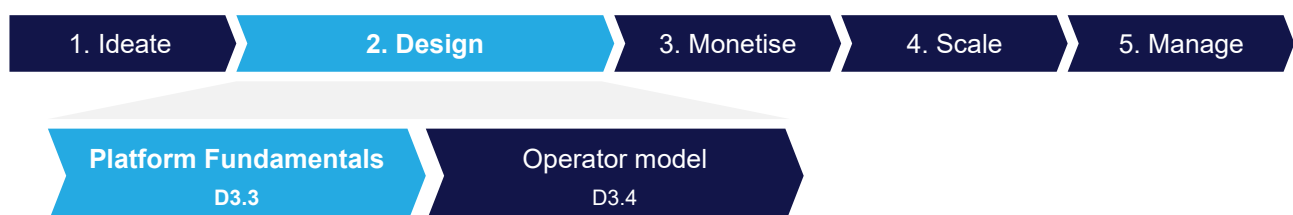


Figure 3: Platform Design Methodology (based on Wortmann et al., 2022)

Ideate focuses on categorising the platform in principle, which was already done at the start of the project. ReMuNet combines primary activities of a value creation platform and a value exchange platform. Support activities within ReMuNet can be categorised as a technology and data platform (Wortmann et al., 2022).

This Deliverable focuses on the **Design** phase of the framework. This phase serves as the methodological basis for defining the architectural logic, the value proposition, and the governance structure of a platform, which are decisive for the subsequent phases of platform development (Wortmann et al., 2022).

The design phase can be divided into two steps:

1. The *platform fundamentals* include the formulation of a central value proposition that serves as the basis for the relevance and acceptance of the platform. The value proposition must be precisely defined and can focus on enabling network effects, democratising access, establishing ecosystems or facilitating disruptive interactions (Wortmann et al., 2022).

With the central value proposition formulated, the platform ownership must be decided. From a methodological perspective, the choice between ownership models such as single ownership and consortial governance has a direct impact on stakeholder alignment, trust and the ability to catalyse network effects (Wortmann et al., 2022). This step requires an analysis of the broader ecosystem and strategic intentions of the platform, especially in markets characterised by interdependence and cooperation. Therefore, D3.3 lays the foundation for this decision by designing the ecosystem, which will allow the decision to be justified in D3.4.

2. The *operator model design* outlines the central value creation activities of the platform orchestrator and defines the roles, responsibilities, and operating processes. The operator model design will be covered in D3.4 and will not be discussed in this Deliverable.

Furthermore, phase 3 **Monetise** in the form of a monetisation strategy is also developed in D3.4. Phase 4 **Scale** is addressed in D5.4 in the form of public and private roadmaps and strategies for scalability. Finally, phase 5 **Manage** focuses on managing and sustaining the platform in the long term.

3.2.1 Desk Research

To establish the foundational design of the platform, desk-based research was undertaken to identify best practices and failure factors associated with both operational and defunct digital platforms. Due to the limited availability of scientific sources, the scope of the research was broadened to include online resources such as blogs, industry magazines, and official platform descriptions.

The initial phase of the research focused on identifying existing scientific logistics platforms, as well as both active and discontinued commercial platforms. Subsequently, the factors contributing to the success or failure of these platforms were compiled. Identified failure factors were then reformulated into corresponding success factors. Based on this analysis,

a consolidated list of success factors was created. To enhance clarity and facilitate interpretation, the success factors were categorised into eight distinct categories.

3.2.2 *Consortium Workshops for Platform Architecture*

After defining the success factors of a digital platform, the functional platform architecture was designed. Since the architecture of the ReMuNet platform is largely determined by the consortium partners, the development and elaboration of the platform architecture took place jointly within the consortium. During this process, attention was paid to the ongoing alignment and integration of interests and requirements for the upcoming work packages WP 4 and WP 5, so that the technical implementation would be aligned with the subsequent project phases.

Purposive sampling was used to select participants, so that only technical partners of the ReMuNet consortium and representatives of relevant work packages (WP 4 & WP 5) were present. The selection criteria focused on expertise on the one hand and responsibility for implementation in relation to platform development on the other. All participants were informed about the objective, procedure and documentation in advance. The consent of all participants to be recorded was obtained.

Two full-day on-site workshop formats were chosen as the method for participatory development. Workshop 1 was more exploratory in nature, focusing on a rough conceptualisation and coordination of the partners' interests. It was a moderated format for the creative collection of requirements and ideas. Whiteboards were used to visualise concepts. A high degree of openness and participation was expressly desired, in line with the principles of exploratory, qualitative research (Bell et al., 2019).

Workshop 2, on the other hand, was more detailed, with the aim of developing the final platform architecture and task distribution. There was a structured process based on a prepared agenda in PowerPoint. This was shown in parallel to the workshop so that results on architecture development were permanently recorded and displayed for better tracking. In addition, a mutually agreed video and audio recording of the workshop was made for quality assurance and to clarify any possible questions that might arise later. A follow-up meeting was held a week later to finally confirm the developed functional platform architecture. The one-week-delay ensured that each participant had time to reflect on the results.

The advantages of this approach were its high practicality and coordination with other work packages and workflows through the active involvement of the implementation partners. In addition, this approach promoted ownership and commitment through participatory decision-making (Bell et al., 2019). Furthermore, traceability and transparency were increased through a structured approach and documented results that were shared with the participants (Bell et al., 2019).

3.3 Designing sustainable and cooperative Business Models

This subchapter outlines the methodological approach used to identify and validate potential changes to the actor's business models and to integrate such business models into the overall ReMuNet ecosystem design.

The methodological process follows a structured, three-phase approach. In a first step, existing business models and industry-specific trends were analysed through desk research and examined in the context of the ReMuNet vision during an internal workshop. Based on this foundation, a second step involved the design and distribution of a quantitative questionnaire to validate the potential business models with key stakeholders across the ecosystem. The third and final step focused on embedding the validated business models into the broader ecosystem design. This was done by assessing their cooperative potential and situating them within the ecosystem model based on Lewrick's (2021) framework.

3.3.1 Desk Research & internal Workshop

With ReMuNet as new central element in the multimodal transport ecosystem, new and adapted business models for all stakeholders could be enabled. The methodological approach for the analysis of business model changes will be grounded on the business model framework proposed by Gassmann et al. (2013). The analysis builds on the results from D3.2 and insights gathered from an internal workshop.

Gassmann et al. (2013) distinguish between four central dimensions of a business model, which are represented in the so-called Magic Triangle (table 2):

Table 2: Business Model Framework (based on Gassmann et al., 2013)

Who? Target customers	Who is the company addressing? Who are the target groups or users of the offering?
What? Value proposition	What does the company offer? Which products or services solve a problem or fulfil a need?
How? Value creation	How is the offer created? Which resources, processes and partners are involved?
Why? Profit mechanism	Why is the business model financially viable? How is money earned and what are the sources of revenue?

In this context, Gassmann's model was utilised to develop a structured method for analysing and updating business models in an internal workshop. The method is comprised of five sequential steps. These steps are as follows: Analysis, Description, Comparison, and Documentation & Visualisation of the business model.

1. Analysis

This phase was already completed in D3.2. The current multimodal freight transport ecosystem has been analysed focussing on its roles. Business models have been derived from multiple expert interviews and a quantitative online survey including the different value streams between the different actors.

2. Description

The following phase involved the implementation of Gassmann's framework across the four dimensions and defining the key questions required to build a theoretical framework and structured analysis template. The following key questions were addressed:

- Who: Have customer groups or their requirements changed?
- What: Are there new services or service improvements?
- How: Are there new partners, technologies, or processes?
- Why: How is the change creating value?

3. Comparison

Using the framework developed in the previous phase, a comparison was made between the current business models from D3.2 and the new adapted models using a matrix. The matrix highlights differences and potentials for improvement for each involved role.

4. Documentation & Visualisation

The results were finally documented and visualised for each role using Gassmann's business model framework. Consequently, the assumed changes to the business model were documented in a change log matrix (table 3).

Table 3: Change-log Matrix for adapted Business Models (based on Gassmann et al., 2013)

Dimension	Current	Assumed Change
Who? <i>Target customers</i>	Who is the company addressing? Who are the target groups or users of the offering?	New target groups or users
What? <i>Value Proposition</i>	What does the company offer? Which products or services solve a problem or fulfil a need?	New or improved value proposition
How? <i>Value creation</i>	How is the offer created? Which resources, processes and partners are involved?	New or improved possibilities in delivering value to the customer
Why? <i>Profit mechanism</i>	Why is the business model financially viable? How is money earned and what are the sources of revenue?	New or improved revenue streams
Sustainability	New or improved way to increase sustainability	

3.3.2 Business Model Validation Questionnaire

In order to design the ecosystem around ReMuNet, a quantitative online questionnaire was developed to validate pre-established hypotheses about how the existing business models (D3.2) would change if a digital platform such as ReMuNet were integrated into the ecosystem. The aim was to assess the probability of specific impact assumptions, differentiated according to the roles of the actors in the network. The survey engaged 24 stakeholders from the ecosystem, who could each select up to two roles, resulting in 32 roles being represented in total.

The questionnaire begins with a contextual introduction that allows even participants unfamiliar with the subject matter to gain an understanding of the topic. It explains the functionality of the ReMuNet platform to ensure a uniform understanding of the platform's possible mechanisms of action and to create a fundamental basis for evaluating the hypotheses. This approach follows the requirement for context-related comprehensibility emphasised in qualitative research (Bell et al. 2019).

Following this introduction, participants were asked to indicate which role within the multimodal transport network they primarily identified with. Depending on the role they chose, participants were then presented with a specific set of hypotheses about how the specific business models of the respective players could change with the introduction of ReMuNe (Appendix 3). To ensure that all dimensions of a business model were covered by the hypotheses, they were assigned to the four dimensions of the magical triangle according to Gassmann et al. (2013), supplemented by a fifth dimension "Sustainability" in accordance with the sustainability approach for business models by Lüdeke-Freund et al. (2024).

The hypotheses were evaluated on a five-point Likert scale from very unlikely to very likely, which is widely used in social science research to measure attitudes and assessments (Bell et al., 2019). Following the closed-ended scale questions, participants were given the opportunity to freely formulate their own hypotheses or comments. This semi-structured approach allowed for a high degree of comparability of results, while openness to new hypotheses made it possible to capture additional or previously unconsidered perspectives and promoted the content validity of the survey (Bell et al., 2019). Further, the combined use of structured and open questions, as well as the linkage to a theoretical frame of reference (business model dimensions according to Gassmann et al. (2013)), enables a methodologically robust and practically relevant validation of the hypotheses (Bell et al., 2019).

Since many actors in this industry have more than one role, participants were given the opportunity to specify a second role with which they also identify. If this was the case, the process described above was repeated with a second, role-specific set of hypotheses. If no second role was selected, the questionnaire came to the end of the survey.

At the end of the survey, participants could voluntarily leave additional comments or questions. They also had the option of providing an email address to receive the final Deliverable or to be contacted in case of any queries. The questionnaire was completely anonymous, and participation was voluntary. In advance of the survey, participants were informed about the purpose of the research and the anonymous evaluation, which corresponds to the principle of informed consent (Bell et al., 2019).

The sample was generated using purposive sampling by specifically addressing relevant roles in the network. The link to the online questionnaire was distributed via email, the ReMuNet consortium, the ReMuNet industry board, ReMuNet synergy projects and their networks.

For the analysis, descriptive statistics were applied, including the calculated median, percentage agreement, and interquartile range, to determine which assumptions could be accepted or rejected, as further detailed in the evaluation in chapter 6.6. The open-ended

responses were subjected to a qualitative content analysis to identify new topics or clusters of hypotheses and are included in the evaluation.

3.4 Designing the coopetitive Ecosystem

The methodology employed for the ecosystem design is based on *Business Ecosystem Design* by Lewrick (2021). In his work, Lewrick proposes an iterative design approach in which the ecosystem is continuously re-evaluated and refined. For the ReMuNet project, however, this approach was adapted into a linear process due to resource constraints. The ecosystem was developed in the following three stages (based on Lewrick, 2021):

1. Strategic Foundation

The foundation for the ecosystem design is formed by a set of strategic decisions regarding the domain in which the ecosystem is intended to deliver value, the way this value is to be created, and the strategy by which it is to succeed in competition with existing ecosystems (Lewrick, 2021). To support this, the configuration of the ecosystem across multiple dimensions has been derived. In addition, both the value proposition and the ecosystem vision have been developed and refined based on the initial proposal.

2. Current Ecosystem Information

In Deliverable 3.2, the value flows within the ecosystem were documented, and the actors and their corresponding business models were thoroughly analysed. Building on this, the advantages and disadvantages of the current ecosystem from the perspective of each actor have now also been identified. Furthermore, the overarching value proposition has been refined into a detailed core value proposition.

3. Ecosystem Redesign

During the ecosystem redesign, the first six steps of Lewrick's Ecosystem Design Canvas were followed (figure 4). The results of this process have been documented in chapter 6.

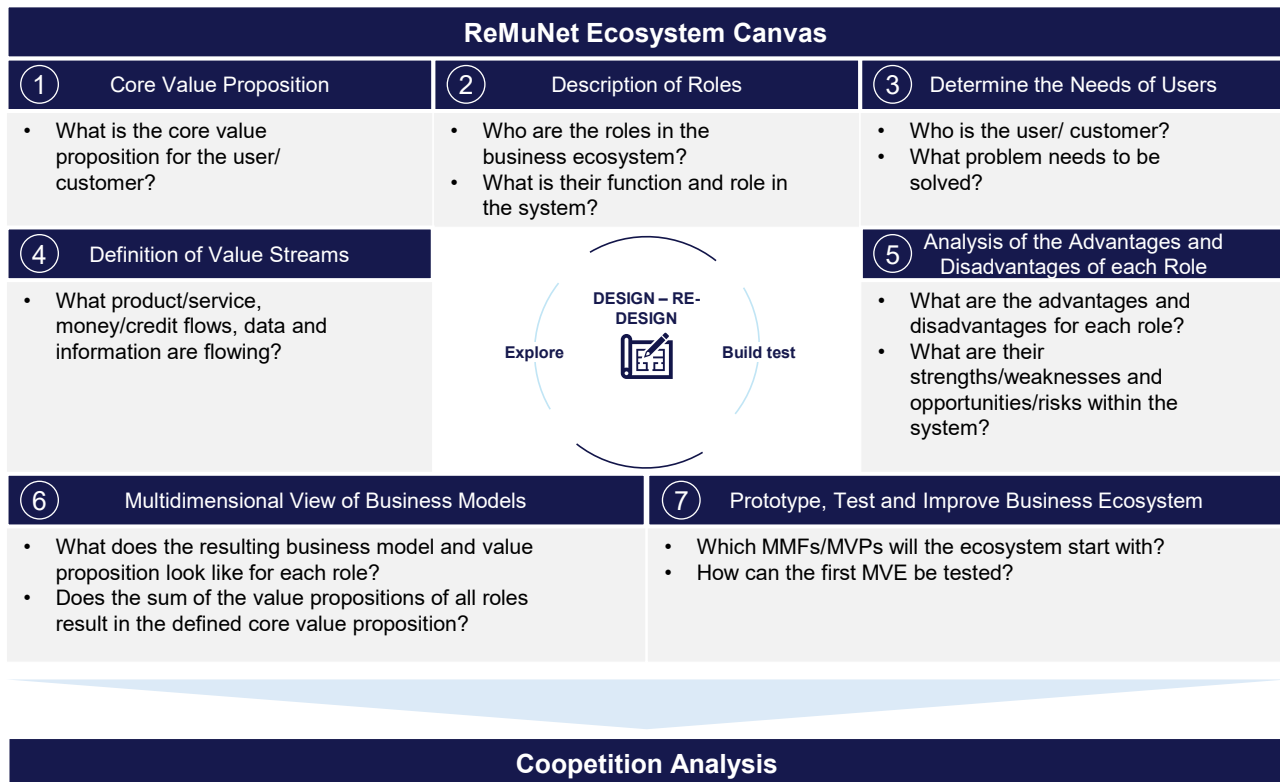


Figure 4: Ecosystem Design Canvas (based on Lewrick, 2021)

After the ecosystem redesign, the adapted ReMuNet ecosystem has been analysed using the CI (figure 4), which is based on the methodology developed by Wieninger et al. (2019) described in chapter 2.4. The methodology is used to support the value flow model visualisation as presented in D3.2 and extended in this Deliverable and portray cooperation and competition between entities and their respective replaceability, thus offering a practical and strategic insight into the ecosystem.

4. Disruption Management Process

This chapter provides an examination of the disruption management process in multimodal freight transport, focusing particularly on both the associated flow of information and responsibilities during disruptive events. The aim is to understand how disruptions are currently handled, who communicates with whom, and how these processes could be improved. Based on best practices and a proposed disruption management process by RailNetEurope (2021). The process was refined and a first draft was created, which was later adapted based on the results of the validation workshops. This analysis lays the groundwork for identifying how and where the ReMuNet platform could be integrated to support and optimise disruption management.

4.1 Best Practices in Disruption Management

The following chapter presents best practices in disruption management derived from past disruptions and cross-industry experience.

4.1.1 *Lessons learned from past Disruptions*

By understanding past disruptions, it is possible to identify weaknesses and patterns but also successful responses, that can be used to improve the handling of future disruptions.

Great Belt Bridge

On 2 January 2019, a passenger train collided with a semi-trailer being transported on an oncoming freight train on the Great Belt Bridge in Denmark. The collision was due to the semi-trailer being inadequately secured on a pocket wagon (Hansen et al., 2021).

Immediately after the incident, a comprehensive crisis and safety management system was initiated. Subsequently, Danish emergency services used the nationwide safety network SINE as internal means of communication (Hansen et al., 2021). Furthermore, the Safety Alert IT (SAIT) and the Safety Information System (SIS) were used to both disseminate all relevant information (e.g., essential date and incidents, warnings etc.) and inform all affected and involved roles (Joint Network Secretariat, 2022).

After disruption clearance, the Joint Network Secretariat (JNS) Normal Procedure Task Force coordinated the exchange of information, the publication of investigation results, and the development of new safety measures. Communication guidelines were established, and experience was systematically processed (Joint Network Secretariat, 2022). In addition, safety measures regarding loading recommendations and the locking procedure of semi-trailers were integrated into technical specifications for railway operations (Joint Network Secretariat, 2022).

Gotthard Tunnel

On 10 August 2023, a freight train derailed in the Gotthard Base Tunnel because of a broken wheel. Due to repair works, one tunnel tube remained closed for about one year leading to a disruption of the cross alpine traffic (Joint Network Secretariat, 2025).

Immediately after the accident, the Swiss Federal Railways (SBB) stopped traffic and informed all relevant stakeholders about the disruption and the closure. All relevant information was summarised in a few slides and promptly made available to the corridor coordinator (IP05). Both goods and passenger traffic was rerouted via alternative routes such as the Gotthard Mountain route, the Lötschberg, and the Brenner Pass (SBB News, 2023). Furthermore, a JNS task force was established to enable a rapid and well-structured exchange of information between participating actors. The JNS task force also took the charge of accident analysis and general coordination at European Level. Members of the task force were the EU Agency for Railways (ERA) as neutral moderator and chair, as well as experts from railway undertakings (RU), IM, the Entity in Charge of Maintenance (ECM), and National Safety Authority (NSA) (Joint Network Secretariat, 2025). RU, IM, and NSA shared relevant safety information using systems such as SAIT and SIS (Joint Network Secretariat, 2025). In addition, emergency protocols, email, telephone, and MS Teams were used to exchange information in a secure manner (IP05).

Initial results of SAIT and SIS were published by JNS in April 2024. Following these findings, the ECM carried out an immediate check of similar wheelsets. Identified risks were automatically reported to RU, NSA, and ERA. In addition, maintenance intervals were adjusted and the NSA of other countries checked for similar safety risks. Based on expert opinions, mandatory safety checks and new requirements were introduced (GCU Bureau, 2002, 2022). Finally, EU requirements also mandate ECM to assess the risk of comparable components (Joint Network Secretariat, 2025).

Rastatt

On 12 August 2017, the track bed sank significantly in Rastatt under the Rhine Valley railway line as the tunnel boring machine broke down and water entered the construction site (Deutscher Bundestag, 2017). This incident resulted in a seven-week closure of the line (Railway Gazette International, 2018).

After identifying the disruption, the emergency shutdown of the line within the Rhine-Alpine Corridor was activated. In parallel, the external communication process was initiated with an official statement of the IM (W. Wolf, 2017), followed by the establishment of rail replacement transport using both different modes of transport and alternative routes (Spiegel, 2017). Communication took place via telephone, mail and messaging services (e.g., MS Teams, Signal etc.) (IP05). In addition, DB Netz offered daily conference calls and bilateral discussions to communicate with involved RU (EEIG Corridor Rhine-Alpine EWIV, 2017). However, the speed of information dissemination was criticised (Manager Magazin, 2017), along with insufficient (international) coordination and communication, limited flexibility in transport management, regulatory and technical barriers to seamless international transport and missing standardised procedures (Henker, 2018).

As a result, the railway sector published the “Handbook for International Contingency Management”. This handbook outlines processes for IM focusing on internal and public communication, rerouting plans, and allocation rules. This suggests that, in the event of a comparable major disruption, IM are likely to respond more quickly and coordinate more effectively than before (Henker, 2018).

Learnings from past Disruptions

Table 4 summarises the key findings from the previously analysed disruptions, outlining essential strategies and their practical implementation to improve transport logistics.

Table 4: Learnings from past Disruptions in Logistics

Category	Success Factor / Learning	Examples from Past Disruptions
Standardised Procedures	Standardised documentation and procedures ensure rapid, reliable, and transparent disruption management	SAIT/SIS, and JNS procedures for standardised reporting and incident management
Rapid Communication	Clear and direct communication channels between all involved and affected stakeholders	Immediate warnings and updates via SAIT/SIS and JNS tools
National & International Cooperation	Close collaboration between authorities, infrastructure managers, and railway companies nationally and internationally	Information exchange through ERA, NSA, OTIF, OSJD; establishment of a joint task force for disruption management
Regular Training & Prevention	Continuous training and preventive maintenance minimise errors and failures	Mandatory training, load securing audits, and regular technical inspections
Early Warning & Digital Systems	Integration of automated early warning systems and centralised digital reporting platforms	Sensor-based damage detection; digital reporting and alert systems (e.g., SAIT/SIS, centralised platforms)
Proactive Crisis Planning & Alternative Routes	Pre-planned diversion routes and clear disruption management teams with defined responsibilities	Pre-established rerouting plans and defined disruption management processes
Transparency & Public Communication	Open and timely communication to the public and media	Publication of investigation results and ongoing safety measures
Financial Incentives & Compensation	Motivation to avoid disruptions through proper compensation for closures	Calls for compensation during diversions and avoidance of additional costs for infrastructure managers and companies

4.1.2 Cross-Industry Insights in Disruption Management

To develop a comprehensive and broadly applicable process for the management of disruptions, the analysis also includes industries not directly related to ReMuNet, such as aviation and banking. This broader perspective offers valuable insights into established approaches for managing disruptions effectively.

Aviation

Air traffic is regularly confronted with various types of disruptions. These can have both external and internal causes. External causes include extreme weather conditions or geopolitical events such as the closure of airspace due to military conflicts (Moore, 2025). Besides that, internal causes of disruptions in air traffic are often capacity bottlenecks, strikes or technical problems (Koenen, 2024; Simillon, 2017).

For European air traffic, EUROCONTROL plays a leading role in dealing with disruptions. The pan-European organisation supports civil and military aviation stakeholders and works

closely with member states as well as with air navigation service providers, airports, and airlines (Deutsches Zentrum fuer Luft- und Raumfahrt e. V., 2025).

EUROCONTROL has an established system for dealing with disruptions and crises in European air traffic. In the event of major incidents such as military conflicts or Air Traffic Control (ATC) failures, EUROCONTROL works together with partners to maintain operations. Real-time data is provided on an ongoing basis via the Network Operations Portal (NOP), enabling quick, efficient responses during European air traffic disruptions. In the event of incidents, the European Aviation Crisis Coordination Cell (EACCC) is activated, which coordinates the response and works together with the European Commission, air navigation service providers, airports, and airlines (Eurocontrol, 2025a).

This ensures rapid, coordinated responses and a unified, effective approach in emergencies. In addition, EUROCONTROL develops technical and operational standards to implement both European and international requirements and create a level playing field in air traffic (Eurocontrol, 2025b).

Banking Sector

Europe has set up various mechanisms in the banking sector to respond to disruptions and ensure the stability and digital resilience of the financial system. One of them is the Digital Operational Resilience Act (DORA), which focuses on Information and Communication Technology (ICT) risk management (BaFin, 2025a), regular penetration testing (BaFin, 2025c), and the monitoring of ICT third-party risks (BaFin, 2025b). In addition, an EU-wide monitoring framework for critical ICT service providers has been introduced (BaFin, 2024).

Another tool for crisis resilience are the European Central Bank's (ECB) stress tests, where the ability of banks to respond to cyber-attacks is tested. The tests include the activation of emergency plans, communication with partners and authorities, and cooperation with IT service providers (European Central Bank, 2024).

Furthermore, the EU's resolution framework for banks ensures orderly recovery in case of failure, avoiding taxpayer-funded bailouts and placing losses on shareholders and creditors (European Council, 2025). Key elements are the Single Resolution Mechanism, which is responsible for large and cross-border banks (Deutsche Bundesbank, 2020), and the Single Resolution Board (SRB), which decides independently on resolutions (European Union, 2025). The Single Resolution Fund provides funds for emergencies and is financed by the banks themselves (Single Resolution Board, 2022).

In the event of a crisis, resolution instruments, including bailing, company sales, bridge banks, and bad banks are used (European Council, 2025).

Learnings from Cross-Industry Insights in Disruption Management

Table 5 summarises the key findings from the cross-sector insights into disruption management. The scenarios highlight the importance of centralised crisis coordination, the availability of real-time information systems, general digital resilience, and robust financial mechanisms.

Table 5: Learnings from Cross-Industry Insights in Disruption Management

Category	Success Factor / Learning	Examples from Past Disruptions
Standardised Procedures	Development and enforcement of technical and operational standards at European level to ensure a uniform response mechanism	EUROCONTROL standards for European air traffic management; SRB resolution procedures for failing banks
Rapid Communication	Provision of real-time situational updates via centralised digital platforms	EUROCONTROL's NOP enabling all aviation stakeholders to access situational awareness in crises
National & International Cooperation	Cooperation between supranational bodies and national authorities for aligned decision-making and crisis response	Coordination of aviation crises via EACCC and cooperation with European Commission; cooperation between ECB, SRB and national authorities in banking resolutions
Regular Training & Prevention	Conducting regular cyber crisis exercises and penetration testing to identify vulnerabilities	ECB stress tests involving activation of emergency plans and simulation of cyber-attacks in banks
Early Warning & Digital Systems	EU-wide monitoring frameworks for ICT risks and service providers, supported by digital platforms	DORA implementation, central monitoring of third-party ICT risks, and information sharing mechanisms across EU financial institutions
Proactive Crisis Planning & Alternative Routes	Availability of predefined emergency plans and resolution strategies for key infrastructures	Resolution plans for failing banks via SRB; EUROCONTROL's operational crisis protocols and fallback procedures during airspace closure or ATC failure
Financial Incentives & Compensation	Bank-funded emergency financing mechanisms to avoid burdening public finances	SRF financed by banks to ensure private-sector responsibility in crisis response
Crisis Management Structures & Coordination	Establishment of institutionalised crisis coordination bodies and processes to enable rapid, structured action in emergencies	EACCC in aviation managing cross-border disruptions; SRB as central actor for banking resolution
Resilience through Regulation	Legal and regulatory frameworks designed to strengthen system-wide resilience against digital and financial disruptions	DORA in the financial sector; SRM with predefined instruments such as bailing or bridge banks in case of crisis

4.2 Disruption Management Process Design

Disruption management processes vary depending on the severity of the incident. In most serious cases, an investigation is launched immediately to determine the cause of the disruption. However, IP07 notes that there is a lack of harmonised rules and procedures across countries, which can lead to an inconsistency in the responses. There are generally three process pathways following a disruption:

1. Wait for normal operations to resume
2. Secure capacity on the same or an alternative corridor within the same mode
3. Shift to a different mode of transport.

The feasibility of rerouting rail lines is often constrained by technical compatibility. A major problem is the railway profile, which refers to infrastructure requirements for handling

specific loading units. This can prevent rerouting even when an alternative corridor is available. The ability to facilitate interoperability between assets, as well as the establishment of standardised protocols, are identified as key factors in enabling a transition towards alternative modes of transportation. In future, the use of routing algorithms and machine learning tools also has the potential to offer innovative rerouting solutions that extend beyond human capacity (D1.2).

4.2.1 *Process Assumptions*

The disruption management process is founded on a series of fundamental assumptions, drawing from the ICM handbook (RailNetEurope, 2021) and the experiences through major past disruptions (chapter 4.1.1). The proposed framework is defined by these core principles in terms of its scope and operational context. The following points outline the specific conditions and roles of the stakeholders that were considered during the design process.

- The process is based on data from rail transport due to better information availability but can be applied to other modes of transport, as insights on transferability were gathered through the validation workshops.
- With a focus on major disruptions, the process covers situations that typically involve emergency responses and substantial changes to normal operations. Therefore, “proceeding as normal” is not a viable option for the infrastructure manager and is only included in the process for the purpose of formality and completeness (figure 6).
- The task force holds significant decision-making authority and includes all key stakeholders. It is led by the IM.
- The four relevant transport roles, Carrier, Freight Forwarder, MTO, and RU, are divided into the operational (Carrier) and organisational (Freight Forwarder, MTO, RU) aspects of the transport process. This distinction is based on the functional similarities and overlaps of these roles within each area.

4.2.2 *Incoterms*

In the context of the disruption management process in multimodal transport, it is relevant to consider the International Commercial Terms (Incoterms), as the understanding of the various Incoterms improves the assessment of potential liability issues and the impact of disruptions on the responsibilities of the involved actors. The Incoterms are established as globally recognised, uniform contract and delivery terms. They standardise commercial transactions and thus enable the tasks, cost distribution, risk distribution and due diligence obligations between the contracting parties to be clearly defined (IHK Region Stuttgart, 2020).

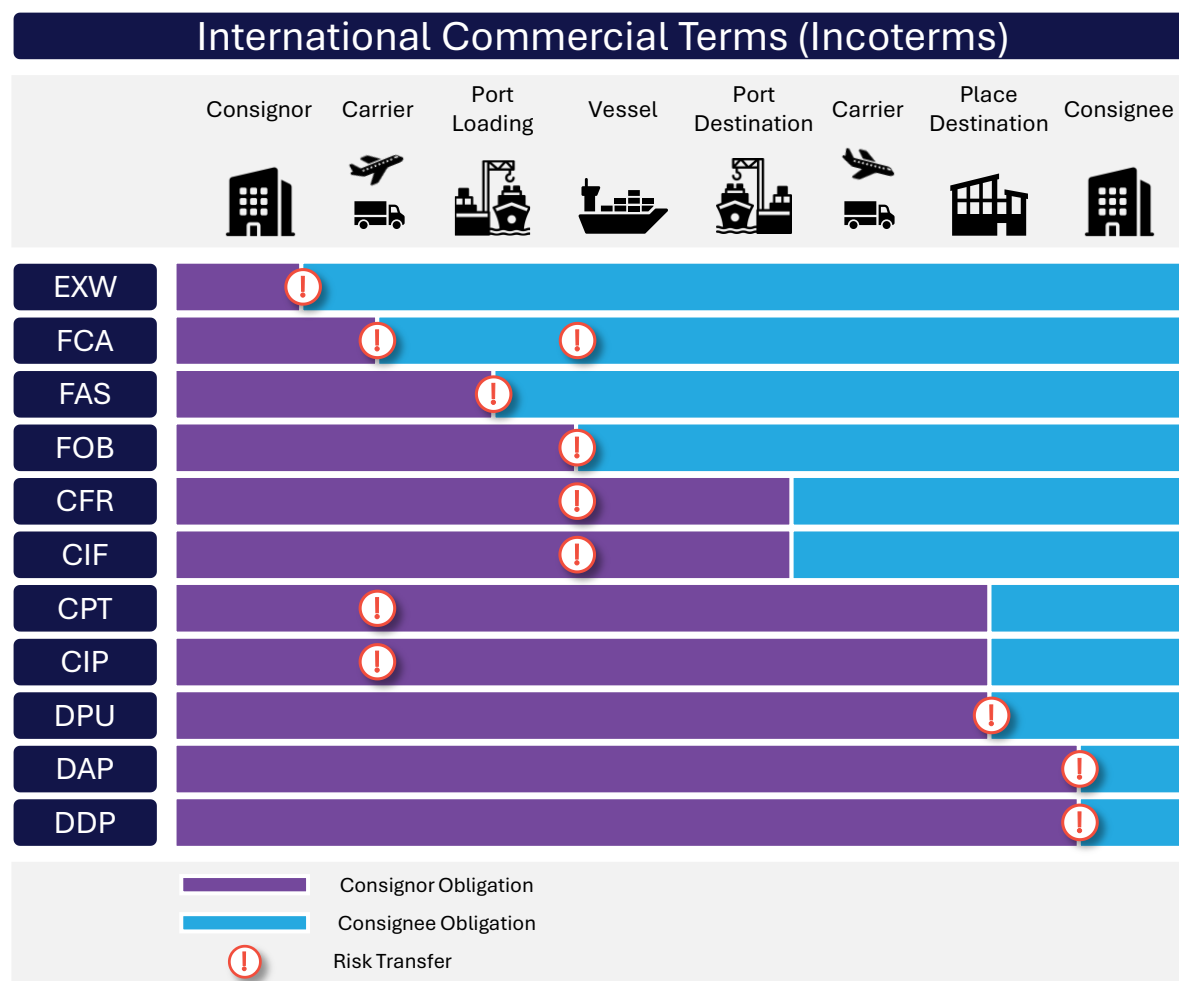


Figure 5: Overview of Incoterms (based on Munich Business School, 2025)

All types of Incoterms are explained subsequently in table 6 and illustrated in figure 5. All information is sourced from IncoDocs (2025).

Table 6: Incoterms Explanation (based on IncoDocs, 2025)

Incoterms	Explanation
EXW – Ex Works (or Ex Warehouse)	Under EXW, the seller makes the goods available to the buyer at the seller's premises, or another agreed location such as a factory or a warehouse. The seller is not responsible for loading the goods onto any pick-up vehicle or clearing the goods for export.
FCA – Free Carrier	FCA signifies the seller's obligation to deliver the goods to a designated carrier, or another party as nominated by the buyer, at the seller's premises or an alternative agreed location. Risk transfers to the buyer once the goods are handed over at that specific point.
FAS - Free Alongside Ship	FAS means that the seller delivers when the goods are loaded onto the buyer's nominated vessel at the agreed port of shipment. The risk of loss or damage passes to the buyer once the goods are placed alongside the ship
FOB - Free On Board	FOB means the seller delivers when the goods are loaded onto the buyer's nominated vessel at the agreed port of shipment. Once on board, the risk and responsibility transfer to the buyer
CFR - Cost and Freight	CFR signifies the seller is responsible for delivering the goods onto the vessel or ensuring that they are already on board. Once the goods are on the vessel, the risk of loss or damage transfers to the buyer. The seller must arrange and pay for transportation and freight charges required for the delivery to the destination port

CIF - Cost, Insurance and Freight	Similar to CFR, as the seller delivers the goods on board and covers transport to the destination port. Additionally, the seller must provide minimum insurance for the goods during transit. The buyer assumes risk once the goods are on board and should arrange additional insurance if more coverage is needed
CPT – Carriage Paid To	With CPT, the seller delivers the goods to a carrier or another party of their choice at an agreed place. The seller covers the cost of transportation to the named destination, but the risk transfers to the buyer once the goods are handed over to the carrier.
CIP – Carriage and Insurance Paid To	Similar to CPT, the seller is responsible for arrangement and payment for transport to the destination. Additionally, the seller must provide minimum insurance coverage for the goods during transit. If the buyer wants a more comprehensive coverage, they must arrange it separately with the seller.
DPU – Delivered at Place Unloaded	DPU signifies that the seller is responsible for delivering the goods, once unloaded, to the buyer at the specified destination. The seller assumes full responsibility for any risks and costs associated with delivering and unloading the goods at the specified location.
DAP – Delivered At Place	Under DAP, the seller delivers when the goods are made available to the buyer on the arriving transport vehicle, ready for unloading at the named destination. The seller assumes all risks and costs up to that point.
DDP – Delivered Duty Paid	With DDP, the seller delivers the goods ready for unloading at the named destination and takes full responsibility for export and import clearance, including payment of all duties and taxes. The seller bears all costs and risks until the goods are delivered.

4.2.3 Responsibilities during disruptive Events

The following table 7 provides an overview of the key roles involved in disruption management and their main responsibilities. The individual activities will be discussed in more detail in the following subchapters, which describe the disruption management process across its three main phases.

Table 7: Responsibilities during disruptive Events

Role	Responsibility	Source
IM	Initiates necessary operational actions, activates protocols, informs stakeholders, coordinates rerouting and capacity coordination, and restores operations	RailNetEurope (2021); Europäisches Parlament and Rat der Europäischen Union (2016); Directive 2012/34/Eu of the European Parliament and of the Council of 21 November 2012 establishing a single European railway area (2012); IP07
Carrier	Manages disruptions via Task Force; coordinates rerouting and planning with IM; ensures communication and real-time planning	RailNetEurope (2021); Overdijkink (2019); IP07
Corridor Coordinator	Leads corridor coordination; aligns actions, addresses international issues with IMs and other stakeholders	RailNetEurope (2021)
MTO, Freight Forwarder, RU	Has limited control, depends on IM and carrier decisions, but participates in the Task Force	IP07
Governmental entities	Request evaluations, initiate improvements to enhance system resilience	RailNetEurope (2021)
Terminal Operator	Manages loading and unloading operations; coordinates necessary schedule adjustments	D3.2; IP02

4.2.4 Phase I – Task Force Assembly

The disruption management process is structured into three major phases: task force assembly, mitigation, and evaluation. Each phase is depicted using the K3 notation (chapter 3.1.1) and described, following the insights from the desk research and the validation workshops.

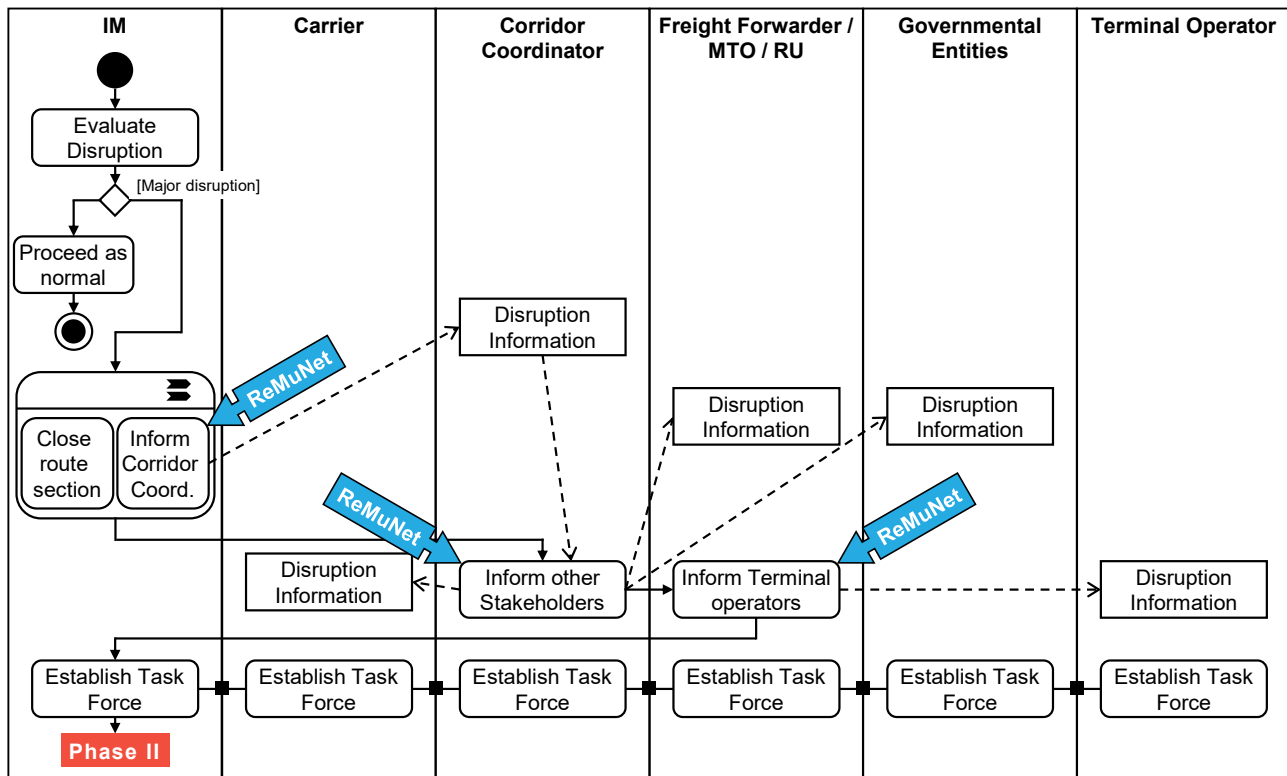


Figure 6: Phase I - Task Force Assembly

The disruption management process is initiated with an evaluation indicating the disruption as a “major disruption” as assumed in the previous section. As a result, normal operations cannot be maintained, and the IM closes the affected section. The IM then provides the initial information to the Corridor Coordinator, who processes and consolidates it before forwarding it to the relevant partners (IP05). Terminal operators will be informed by a MTO or a RU (IP02). This process must take into account regional differences and potential language barriers (IP05). According to the interviewees, this distribution of real-time information in the initial stages could be improved using a digital and automated platform such as ReMuNet resulting in higher resilience across the whole network (IP02; IP04; IP05; IP06).

Subsequent to the first stage of communication, a dedicated task force will be established. This task force includes all direct roles of the multimodal transport process. It is responsible for disruption management and the communication of status updates. Possible channels for initial communication include telephone, email, MS Teams or Signal, but vary greatly (IP05; IP06).

4.2.5 Phase II – Mitigation

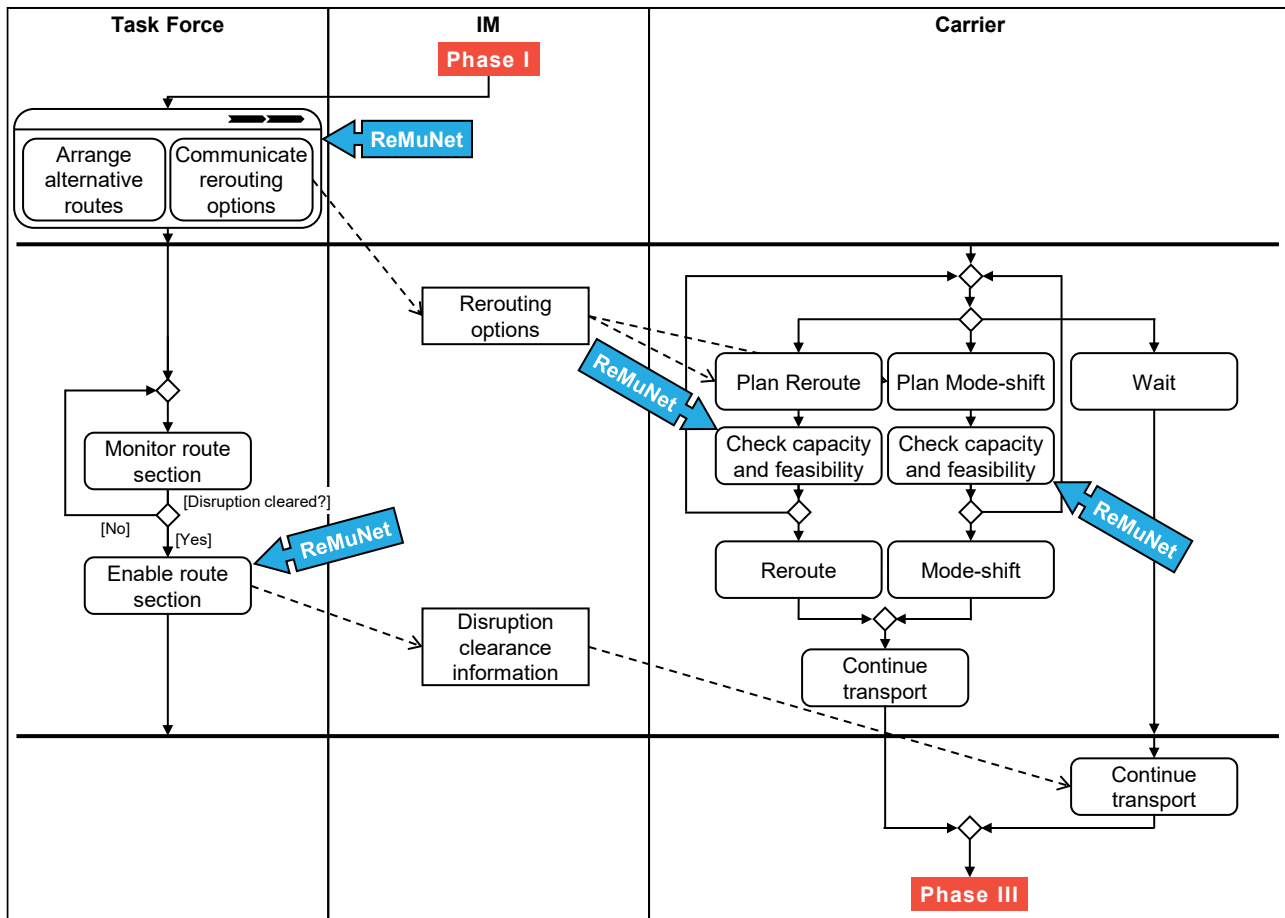


Figure 7: Phase II - Mitigation

The task force organises alternative routes and communicates the rerouting and/or modal shift options to the Carrier. Status messages can be sent via the Rail Net Europe (RNE) Train Information System (TIS) (IP02; IP05). RNE TIS provides an overview including status messages and tracking of disruptions (IP05). Information is usually communicated via email, telephone, MS Teams, Electronic Data Interchange (EDI) or RNE TIS (IP01; IP02; IP04; IP05).

Upon receiving the options from the task force, the carrier has three possible courses of action:

1. waiting,
2. rerouting, or
3. shifting the transport mode.

International rerouting differs significantly from national rerouting due to regulation and must be considered when planning a new route (IP05). If the carrier decides on rerouting or a modal shift, the transport of goods is rescheduled along the new route or transferred to the new mode of transport, allowing the shipment to proceed and the rerouting phase to be successfully completed. If the proposed options are either not feasible or if there is no available capacity, other options have to be checked. For Inland Waterway (IWW) the most

common choice is to wait out the disruption due to missing alternatives (IP01). In parallel, the task force monitors the condition of the blocked route. Once the disruption has been resolved and the section has been reopened by the task force, the relevant information is shared with both the IM and the carrier. Once the task force has reopened the route, the transport of goods continues.

According to the interviewees ReMuNet could improve the rerouting process by automatically optimising routes based on capacities and available route calculation bundling information streams on a central platform available for all players (IP03). An automated process as such might prevent unnecessary and time-consuming discussions and decision-making processes (IP03).

4.2.6 Phase III – Evaluation

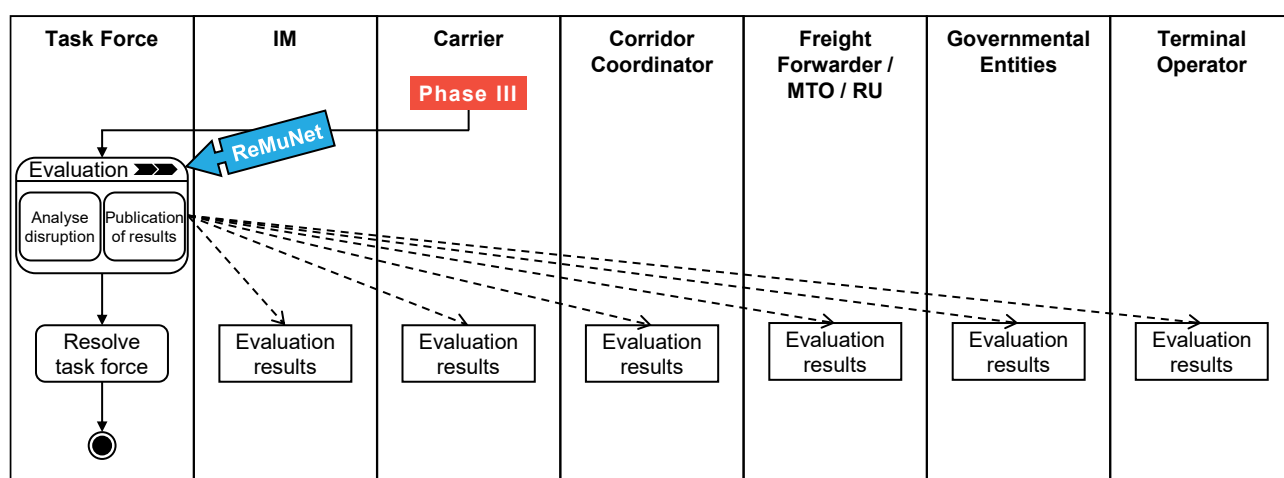


Figure 8: Phase III - Evaluation

The third and final phase of the disruption management process involves a comprehensive evaluation, including an analysis of the disruption and the actions taken. The IM and the corridor coordinator take the lead in this process (IP05). Additionally, internal audits may be conducted to assess performance and evaluate the effectiveness of the implemented measures (IP06). The relevant information that the task force collects during the analysis phase include:

- The general course of action, including an assessment of the underlying cause, the time required to resolve the issue, and the overall impact and scale of the disruption,
- cost and performance indicators,
- the impact on resources and capacities,
- the impact on customers and suppliers,
- the evaluation of resilience measures, and
- potential lessons learned and optimisation potential.

These results are summarised in a final report and then made available to all stakeholders involved in the task force and send out to involved ministries (IP05). The evaluation report serves as a learning tool for each disruption to strengthen network resilience.

Once the analysis has been completed and the results published, the task force is dissolved. This marks the end of the disruption management process. It is important to note that the conclusion of the process does not imply that all effects have been resolved. For instance, accumulated shipments still need to be cleared and processed (IP04).

According to the interviewees ReMuNet could improve the evaluation process and effectiveness analysis with automated optimisation and greater integration of systems such as RNE TIS (IP01; IP02). However, this requires harmonisation and standardisation of all processes, particularly at the regulatory level through legislation (IP05).

5. ReMuNet Platform

The following chapter describes the development of the functional architecture of the ReMuNet platform. To this end, the requirements identified in D3.2 and success factors of digital platforms in transport logistics are first analysed. Based on these foundations and the joint collaboration with the consortium (see chapter 3.2.2), the functional platform architecture is subsequently developed.

5.1 Success Factors for digital Platforms in Transport Logistics

The present chapter identifies key success factors of transport logistics platforms through desk research, synthesising insights from both scientific and non-scientific sources. While academic literature provides theoretical frameworks and empirical analyses on digital platforms, business reports, industry white papers, and expert opinions contribute practical perspectives on market dynamics and technological advancements.

5.1.1 *Insights from D3.2*

In D3.2, the following ten requirements for the ReMuNet platform have been identified based on pain points derived from expert interviews:

- Address sustainability
- Protect sensitive data
- Neutral non-profit operator model
- Standards for transport document
- Handle double bookings
- Easy integration for small and medium enterprises (SMEs) and “big players”
- Enable real-time network capacity
- Costs and CO₂-tracking
- Integrate alternative routing tools
- Disruption signalling policy/system integration as well as process and responsibilities in case of disruption.

While logistics experts provide deep domain knowledge about supply chain operations, transportation challenges, and industry-specific workflows, they often have limited expertise in platform economy principles and digital platform design. Therefore, their insights are crucial for understanding operational needs, but they may lack familiarity with key aspects of successful platform-driven business models. As a result, solely relying on expert-driven requirements may lead to a platform that optimises logistics processes but fails to leverage the scalability, interoperability, and ecosystem-driven value creation seen in successful logistics platforms. Combining expert logistics knowledge with insights from platform-based solutions ensures a more holistic and effective approach to logistics platform development.

5.1.2 Success Factors of digital Platforms in Transport Logistics

The rapid evolution of the logistics sector has led to the emergence of numerous digital platforms aimed at optimising supply chain operations. These platforms integrate key stakeholders, technologies, and processes to enhance efficiency, reduce costs, and improve service quality (Rožman et al., 2019; Steffen et al., 2022).

Desk Research on existing or shut down digital Logistics Platforms

The following overview presents a curated selection of scientific and real-world logistics platforms. These platforms represent a diverse range of approaches to digitalising and optimising logistics operations, including data integration, coordination of multimodal transport, real-time tracking, and collaborative supply chain management. By examining this selection of comparable platforms, this Deliverable identifies common features and success factors that can inform the development and implementation of future solutions. Table 8 presents a detailed overview of the digital platforms identified during the research. Due to the limited availability of scientific literature on specific logistics platforms, non-academic sources such as industry reports, case studies, and expert opinions have been incorporated to supplement the analysis.

Table 8: Existing or shut down digital Logistics Platforms

FEDeRATED	FEDeRATED is a European initiative creating a secure, open data network for logistics and mobility. It provides a standardised framework to improve interoperability and efficiency, supported by a Master Plan and industry collaboration to ensure broad adoption and a smarter, connected transport system. (Roos, 2024)
Clusters 2.0	CLUSTERS 2.0 is a European initiative connecting logistics hubs to boost efficiency and sustainability. It aims to enhance coordination and performance across European logistics hubs and clusters, creating a hyper-connected, efficient, and sustainable transport network. It also focuses on developing low-cost and low-impact transshipment solutions that support regional and European development while minimising local disruptions. (Cordis, 2020)
SETO	SETO is a Horizon project that aims to modernise transport enforcement by creating a digital platform that integrates data from multiple sources, enabling faster, fairer, and more efficient decision-making. By leveraging technologies like blockchain and focusing on soft enforcement, SETO reduces administrative burden, enhances safety and sustainability, and supports a more competitive and socially responsible transport sector across Europe. (SETO, 2023)
Transporeon	Transporeon is a cloud-based, neutral platform that connects shippers, carriers, and logistics providers. It offers real-time tools for freight sourcing, execution, visibility, and auditing, along with many value-added services like rate benchmarking and autonomous quoting to improve efficiency and collaboration. (Transporeon, 2025; Priestman, 2023; Schwind <i>et al.</i> , 2011)
Uber Freight	Uber Freight is a tech-driven logistics platform that uses AI and data analytics to optimise freight transport. It offers instant pricing, real-time tracking, and seamless load booking through a broad carrier network. With an AI-optimised system, it enhances visibility and data-driven decision-making. Following its acquisition of Transplace, Uber Freight now provides end-to-end logistics solutions, though this has raised concerns about carrier reliability when freight forwarders use independent carriers. (The Cooperative Logistics Network, 2021; Krishnan, 2022; Uber Freight, 2024)
Convoy	Convoy's success came from its advanced automation, real-time data, and efficient load matching in a fragmented trucking market. However, its failure was driven by a high cash burn, inability to secure funding during a freight recession, and challenges scaling

	profitably. Despite strong technology and market fit, these financial and market pressures proved critical. Flexport's 2023 acquisition and 2024 relaunch aim to address these issues. (Acquired Podcast, 2019; Avila, 2024; Bellan, 2023; The Brand Hopper, 2022; Cheng, 2023)
Flexport	Flexport is a tech-driven logistics platform offering freight forwarding, customs brokerage, and trade finance. It uses data and real-time tracking to optimise supply chains and improve transparency. While growth is boosted by strategic marketing, challenges include handling physical documents and balancing data acquisition with effective use. (Flexport; Manley; Scale)
Loadsmart	Loadsmart is a freight platform that optimises booking and routing, reducing costs by up to 20 %. Backed by an experienced team and partnerships with UPS and Maersk, it offers automated booking and a customer-focused approach. Despite achieving profitability, Loadsmart faces challenges with competition, regulatory compliance, stakeholder management, scalability, and supply chain disruptions. (Canvas Business Model, 2025a; Loadsmart, 2025; Sharkey, 2021)
Sennder	Sennder is a digital freight forwarder optimising freight matching, routing, and real-time tracking. Through strategic acquisitions, it has expanded into key European markets and supports employee growth via the Sennder Academy. However, it faces strong competition, regulatory changes, supply chain disruptions, limited geographic coverage, and a heavy reliance on a few major clients. (Canvas Business Model, 2025b; Reuters, 2024; Sennder, 2019a, 2019b)
DSV A/S	DSV A/S is a global logistics provider with scalable infrastructure, multimodal transport solutions, and strong operational efficiency. The €14 billion acquisition of DB Schenker expands its global network and strengthens data-driven transparency. While financially strong, DSV faces integration risks and increasing demands to reduce emissions. (DSV; DSV; Moody's Ratings, 2024; Vizologi; Welt, 2024; World Benchmarking Alliance)
Amazon Fulfillment	Amazon FBA offers end-to-end logistics services, including storage, shipping, and returns, supported by a vast network and multi-channel capabilities. It enables efficient inventory management but faces challenges like labour strikes, tech reliance, data selling concerns, and rising competition from platforms like Temu and Shein. (Lindsey, 2018; Matsakis, 2024; Muhit, 2024; Starks Jr, 2022; Trangle, 2024; Young, 2024)
Shopify Fulfillment Network	The Shopify Fulfillment Network offered integrated logistics for Shopify merchants and was seen as a trusted, neutral partner. However, it faced challenges such as software integration issues, high capital costs, and a poor fit with Shopify's core software business. Its asset-light 4PL model struggled in the low-margin logistics industry, while strong competition from Amazon added further pressure. (Choudhary, 2023; Shopify; Starks Jr, 2022; Stone, 2022)
TradeLens	TradeLens was a blockchain-based logistics platform aimed at improving transparency and collaboration in global shipping. It was discontinued due to limited stakeholder participation caused by concerns over data access, protection, and neutrality, stemming from private ownership. High operating costs, technical limitations, and lack of legal recognition for digital documents also hindered its success. (Sethuraman, 2023)
Shippo	Shippo offers predictive and real-time shipment tracking, fast carrier onboarding, and precise monitoring, including global port congestion and emissions calculations. It boasts high data quality and strong customer satisfaction but is primarily concentrated in Europe. Compared to larger competitors, Shippo is smaller and has weaker marketing presence outside Europe. (Gowans, 2024; Shippo; Shippo)

Success Factors of digital Logistics Platforms

Based on the platforms analysed in the previous section, several success factors can be identified, which can be divided into eight categories (table 9):

- Technological excellence & seamless integration
- Real-time data-driven decision making
- Customer centricity & user experience

- Operational efficiency & cost reduction
- Trust transparency & neutrality
- Network effects & strategic partnerships
- Scalability & market expansion
- Innovation & continuous improvement

Table 9: Success Factors of digital Logistics Platforms

Category	Success Factors
Technological Excellence & Seamless Integration	• Unified platform integration (Transporeon) • Integration with existing systems and tools (Smith & Grierson, 2024) • Communication between information systems (Nicoletti, 2020) • Real-time data sharing (Transporeon, 2025) • Closed user groups (Schwind et al., 2011) • Comprehensive transaction support (Zemmrch & Hofmann, 2022)
Real-Time Data-driven Decision Making	• Data-driven decision-making (Smith & Grierson, 2024; Transporeon, 2024) • Accurate data ingestion (Scale) • Large data pool (Zintel et al., 2021) • Increased visibility of processes (Nicoletti, 2020) • Improved traceability (Nicoletti, 2020) • Integration of micro and macro optimisation (Smith & Grierson, 2024) • Optimised routing (Sennder, 2019a) • Integration of route optimisation into information and trading processes (Schwind et al., 2011) • Real-time data (Sethuraman, 2023) • Real-time tracking and analytics (Shippeo)
Customer-Centricity & User Experience	• Customer-centric approach (Canvas Business Model, 2025a) • Guarantee of defined quality level (Zemmrch & Hofmann, 2022) • Low hardware limitations (Nicoletti, 2020) • Low introduction and implementation costs (Nicoletti, 2020)
Operational Efficiency & Cost Reduction	• Cost control (Sethuraman, 2023; Uber Freight, 2024) • Reducing costs for shippers (Loadsmart, 2025) • Low payback time (Nicoletti, 2020) • Efficient load matching (Acquired Podcast, 2019) • Efficient inventory planning (Lindsey, 2018) • Process automation (Canvas Business Model, 2025a; Transporeon, 2024) • Streamlined process (The Cooperative Logistics Network, 2021)
Trust, Transparency & Neutrality	• Neutral trusted entity (Schwind et al., 2011; Sethuraman, 2023; Starks Jr, 2022) • Neutral marketplace (Priestman, 2023) • Trust in participating entities (The Cooperative Logistics Network, 2021) • Security (Schwind et al., 2011; Sethuraman, 2023) • Transparency (excluding pricing) (The Cooperative Logistics Network, 2021; Schwind et al., 2011; Sethuraman, 2023) • Recognition of the pricing mechanism (Schwind et al., 2011) • Knowledge of the reputation of participants (Schwind et al., 2011)

Network Effects & Strategic Partnerships	• Critical mass of users (Schwind et al., 2011) • Network effects (Zintel et al., 2021) • Partnerships (Canvas Business Model, 2025a; Zintel et al., 2021) • Pilot projects (Hellsmark et al., 2016) • Cooperations (Burgert, 2019; Sethuraman, 2023) • Decentralised control (Sethuraman, 2023)
Scalability & Market Expansion	• Scalability (Canvas Business Model, 2025a; DSV; Smith & Grierson, 2024) • Global reach (DSV; Sethuraman, 2023; Transporeon) • Market expansion (Reuters, 2024; C. D. Wolf, 2024; Zintel et al., 2021) • Multimodality (Vizologi) • Broad access (Sethuraman, 2023) • Clear positioning (Zintel et al., 2021) • Solid and resilient technological groundwork (Zintel et al., 2021)
Innovation & Continuous Improvement	• Constant innovation (Canvas Business Model, 2025a) • Continuous improvement (Moraga & Piñango, 2023) • Strategic marketing (Gowans, 2024; Manley) • End-to-end platform (Krishnan, 2022) • Value-added services (Schwind et al., 2011) • Balancing freight capacity (Uber Freight, 2024) • On-time arrival (Convoy, 2025) • Effective management of stakeholders (Canvas Business Model, 2025a) • Awareness of the product (Zemmrch & Hofmann, 2022) • Understanding of business model (Zemmrch & Hofmann, 2022)

5.2 ReMuNet Platform Architecture Design

Based on all the results, the functional platform architecture of ReMuNet was created, which was approved by all stakeholders involved in the development process (figure 9).

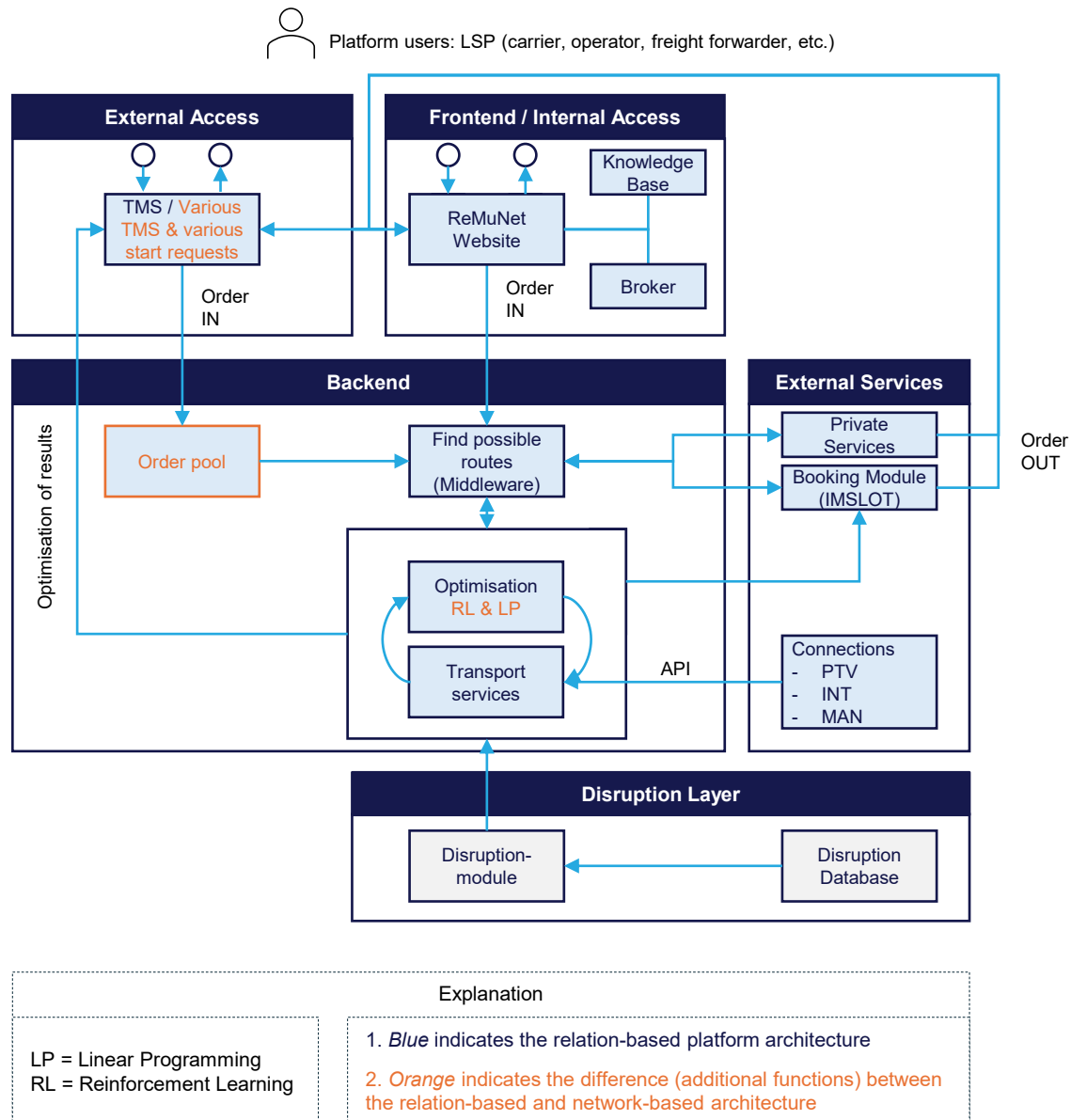


Figure 9: ReMuNet's Platform Architecture Design

5.2.1 Core Value Proposition and Vision of ReMuNet

ReMuNet aims to be a digital, AI-powered, open and collaborative platform that strengthens the sustainability, efficiency and resilience of multimodal European freight transport networks against disruptive events. It is designed to enable real-time, low-emission, and adaptive / agile route planning through synchromodal relay transport, while fostering seamless collaboration among all relevant logistics stakeholders. This is achieved by establishing standardised data models and integrating a self-learning optimisation algorithm, which enables the calculation of resilient, disruption-aware transport routes. These routes

support involved actors in efficiently rerouting and shifting between transport modes in response to disruptions.

The architecture of the ReMuNet platform can be divided into two approaches:

1. a relationship-based architecture and
2. a network-based architecture (in figure 9 distinguished by orange colour).

The two approaches differ in terms of the optimisation approach and booking process.

The **relation-based approach** optimises booked transports within different types of platforms (e.g. TMS, IMSLOT, MANSIO) that have a fixed start and fixed destination, considering an individual optimum for the respective transport. This means the individual bookings, for which the platform's algorithm finds the respective optimum, is handled by individual transport management systems (TMS). With this approach, the user is presented with a selection of different route optimisations based on certainty of arrival, CO₂ impact, time, or costs, from which they can choose. This can be classified as the preliminary stage of the network-based approach.

The **network-based approach**, by contrast, is a more complex approach which intendeds to optimise the entire network. In this case, the optimisation does not refer to a single start-destination relation, but rather transfers process orders from multiple TMS, into an open, collaborative order pool (ReMuNet platform). Through this, it is possible to determine a network-wide optimum based on all orders, to maximise the overall resilience of the network, rather than determining an optimum for an individual transport. Subsequently in this case, ReMuNet automatically rebooks for all users if necessary (e.g., in the event of a detected disruption).

5.2.2 Core Service Components

The architecture of the ReMuNet platform considers five main components: external access, front end/ internal access, back end, external services, and a disruption layer.

External access includes the integration of systems such as different TMS or launch systems from third-party service providers (e.g., IMSLOT, MANSIO, Transporeon). These systems serve as one of the two initial points of entry for transport orders into the backend of the platform.

The **front end/internal access** is a web interface of the ReMuNet platform. Through this interface, users can access a knowledge base and a broker component. The knowledge base offers access to reference materials like a glossary, while the broker discloses transport options. The front end also supports different user roles with varying interface requirements and decision-making permissions, which in turn determines which modules are visible and which actions are permitted.

The **backend** constitutes the core of the platform. Here, transport orders are processed through the middleware component with the overarching goal to "find possible routes" and to optimise any number n of individual transports for a network optimum. In the relation-based approach, the order is forwarded directly to the middleware for processing. In the relation-based approach, the order is forwarded directly to the middleware for processing

and solved preferably by linear programming. In the network-based approach, the order first enters a central order pool, from where subsequent processing steps are initiated in order to pursue the network-wide optimum through the application of reinforcement learning and/or linear programming.

Within the backend, an optimisation module handles intelligent route planning based on various optimisation models (linear programming and/or reinforcement learning). The module needs to retrieve transport service data through APIs connected to **external services** and databases (e.g., PTV, INT, MAN).

As part of the overall platform structure, a **disruption layer** is also included. Its role in processing and responding to external disruption information is critical. The integration of the disruption module will be further specified in the further course of the project.

5.2.3 *System Interaction and Data Exchange*

Interaction with the system begins with the intake of transport orders, either via external access (like TMS) or through internal access via the platform's web interface. Depending on the routing approach, orders are either processed directly to the middleware (relation-based approach) or collected and routed through a central order pool before entering the middleware (network-based approach).

Once in the middleware, possible routes are determined and passed on to the optimisation module, which then relies on API connections to the external databases to gather relevant transport data. The resulting optimised routes is either communicated directly back to the external access or transmitted via external booking services to be made available through the ReMuNet website.

A key aspect of the system interaction is the disruption layer, which includes a dedicated disruption module. This module processes incoming reports from a connected disruption database. Real-time data on disruptions, such as road closures, strikes, or severe weather, is integrated into the transport services and optimisation logic. This enables dynamic responses like re-routing or rebooking, allowing the system to adjust to changing conditions efficiently and intelligently, while feeding into the optimisation module to enhance results through linear programming or reinforcement learning, depending on the selected optimisation approach.

6. Mapping of the new ReMuNet Ecosystem

Building on the insights from D3.2., this Deliverable aims for mapping the new ReMuNet ecosystem by following the research design described in chapter 3.4.

This chapter presents the individual ReMuNet ecosystem components based on the Ecosystem Design Canvas by Lewrick (2021) (figure 10), including the core value proposition, the description of actors, the determination of user needs, the definition of value streams, the advantages and disadvantages for actors, and a multidimensional view of the sustainable business models of all actors. Finally, in addition to the Ecosystem Design Canvas, a coopetition analysis is presented.

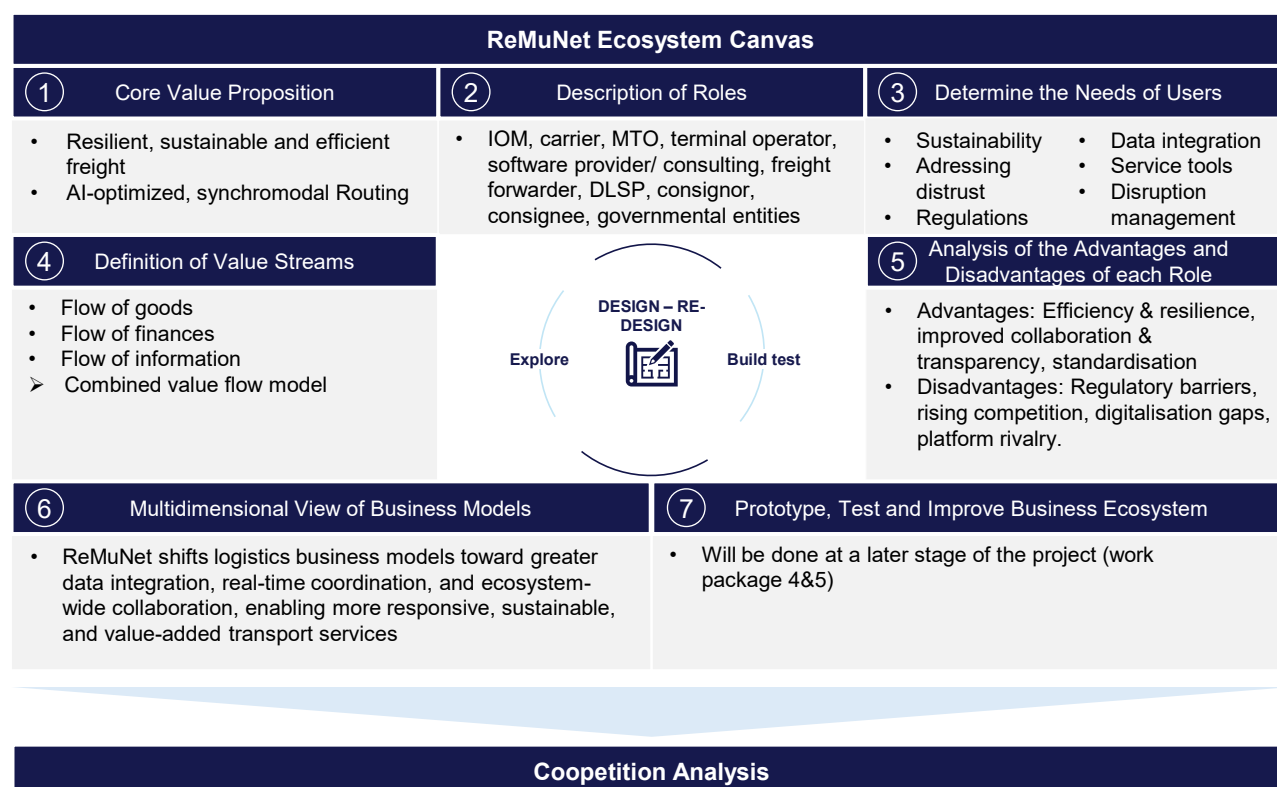


Figure 10: ReMuNet Ecosystem Canvas and Coopetition Analysis (based on Lewrick, 2021)

6.1 Core Value Proposition

The core value proposition of ReMuNet, as outlined in chapter 5.2.1, is to provide an AI-powered, synchromodal platform that enhances the resilience, efficiency, and sustainability of multimodal European freight transport. Rather than restating the detailed formulation presented earlier, this chapter applies the same proposition to the ReMuNet ecosystem. In this context, ReMuNet supports all relevant stakeholders in coordinating responses to disruptions, optimising multimodal routes, and fostering a coopetitive and sustainable environment.

6.2 Description of Roles

Based on Deliverable 3.2, 1.2 and 1.1 the actors within the system have been identified and described for the (re)design of the ecosystem (table 10).

Table 10: Roles within the existing Ecosystem (based on D1.1, D1.2 and D3.2)

Roles	Description
Infrastructure Operator and Manager (IOM)	IOMs develop, maintain, and manage transport networks, enabling carriers and terminals to move goods, vehicles, and passengers efficiently.
Carrier	Carriers transport goods between supply chain nodes via road, rail, inland waterways, and short sea shipping.
MTO	A MTO, also known as an intermodal or combined transport operator, integrates multiple transportation modes under a single contractual framework.
Terminal Operator	Terminals enable shunting, transshipment, and modal shifts.
Software Provider / Consulting	Logistics software providers support logistics actors with advanced digital solutions. Specialised support and consulting firms offer tailored models to address the unique challenges of freight transport operations.
Freight Forwarder	Freight forwarders act as logistics intermediaries, arranging shipments for consignors and handling tasks like carrier contracting, transit oversight, and value-added services such as warehousing, documentation, and packaging.
(Digital) Logistics Service Provider ((D)LSP)	DLSPs play a pivotal role in the multimodal transport ecosystem, specialising in orchestrating logistics operations using advanced digital solutions, without owning physical assets.
Consignor	The consignor initiates transport by providing goods and usually contracting freight forwarders or transport operators.
Consignee	The consignee starts the consignment by ordering from the consignor and receiving the goods.
Governmental Entities	Governmental entities regulate, oversee, and enforce policies to ensure safe, efficient, and compliant multimodal transport systems.

6.3 Determination of User Needs

According to Lewrick (2021), the concept of “user needs” is determined by addressing two central questions: who the user is and which problem is to be solved for them. For the purposes of this Deliverable, and in order to maintain terminological consistency with D3.2, the term “stakeholder requirements” is applied instead. This adaptation does not alter the underlying meaning but aligns the terminology with the broader, multi-stakeholder context of ReMuNet, in which the identified needs are understood and operationalised as requirements.

The stakeholder requirements identified for ReMuNet are organised into six overarching categories, as illustrated in figure 11. These categories are derived from the findings of D3.2 and D1.1, with D3.2 building on and extending the results of D1.1.

A central stakeholder need for the platform concerns the integration of **sustainability** into transport operations. This includes the prioritisation of green routes, the use of environmentally friendly infrastructure, and the provision of tools for monitoring and reporting

emissions (D3.2). The need for advanced analytics and forecasting tools, as identified in the earlier stakeholder needs analysis, supports this objective by enabling assessment and optimisation of environmental performance (D1.1).

Stakeholder Requirements					
Sustainability	Addressing Distrust	Regulations	Data Integration	Service Tools	Disruption Management
Environmentally friendly routing Green infrastructure utilisation Emission tracking and reporting	Protecting sensitive data (data governance & data management plan) Robust cybersecurity Neutral non-profit platform operator model	Standards for transport documents Handling of double bookings and terms & conditions Handling of regulations on border crossing	Facilitated data exchange and collaboration Easy integration for all stakeholders Real-time tracking of network capacity, costs, and CO ₂ values Data standardisation and automation	Alternative route optimisation (route identification, decision parameters, booking module development) Advanced analytics and forecasting tools	Disruption signalling and integration (partnerships with data providers, reporting feature) Terms and regulations for disruption handling (rerouting process specifications, contractual agreements etc.)

Figure 11: Stakeholder Requirements (based on D3.2)

Another requirement relates to **addressing distrust** between platform participants. Stakeholders require strong safeguards for sensitive data, supported by a robust data governance framework and clear management plans (D3.2). Additionally, a neutral, non-profit operator model with transparent governance structures is essential to create confidence in the platform's long-term intentions (D3.2). This connects directly to the need for facilitated data exchange and collaboration (D1.1), as trust is a prerequisite for open data sharing, and such sharing is in turn necessary for the platform to deliver value to all stakeholders. **Regulatory** complexity presents another challenge for stakeholders. They need standards for transport documentation, to navigate regulations for cross-border movements, and to address contractual issues such as double bookings (D3.2, D1.1). Further, the ability to **integrate and exchange data** effectively is fundamental to platform functionality. Stakeholders need easy integration pathways, real-time connectivity, and access to clean, reliable data (D3.2). This is closely related to the needs for data standardisation and automation, as well as integrated digital solutions (D1.1), which together point towards an open, flexible, and interoperable platform architecture. Such an approach could facilitate participation from both small and large actors, reducing technical and organisational entry barriers. In addition to robust data integration, stakeholders require **service tools** that transform information into actionable insights. The optimisation of alternative routes and decision-support capabilities are core examples of these tools (D3.2). The provision of advanced analytics and forecasting capabilities, as emphasised in the earlier analysis (D1.1), underpins these functionalities by allowing stakeholders to evaluate operational alternatives and choose optimal solutions in complex, time-sensitive contexts. Finally, **disruption management** emerges as a critical functional area. Stakeholders need timely disruption signalling, integration with relevant data providers, and clearly defined rerouting procedures supported by contractual arrangements (D3.2).

6.4 Definition of Value Streams

Building on the value flow models based on den Ouden (2012) from D3.2, the flows of goods, information, and finances have been adapted in line with the findings of D3.3, reflecting the assumptions on how these flows would change if a platform such as ReMuNet were integrated into the existing ecosystem.

Compared to the mapping presented in D3.2, several adjustments have been made. The role of the freight forwarder has been incorporated into the Carrier/MTO category, as both entities perform broadly operational functions. Furthermore, the role of the (digital) logistics service provider ((D)LSP) has been redefined to encompass the Carrier/MTO/Freight Forwarder group as well as Software Provider and Consulting roles. This reflects the (D)LSP's position as an overarching entity representing all actors involved in the provision of logistics services. In this role, the (D)LSP remains the primary interface with the consignor, maintaining responsibility for direct communication and coordination. Nevertheless, the most significant change is the introduction of ReMuNet as a key actor within the ecosystem, specifically tasked with orchestrating general transport and managing transport operations during times of disruption (figure 12).

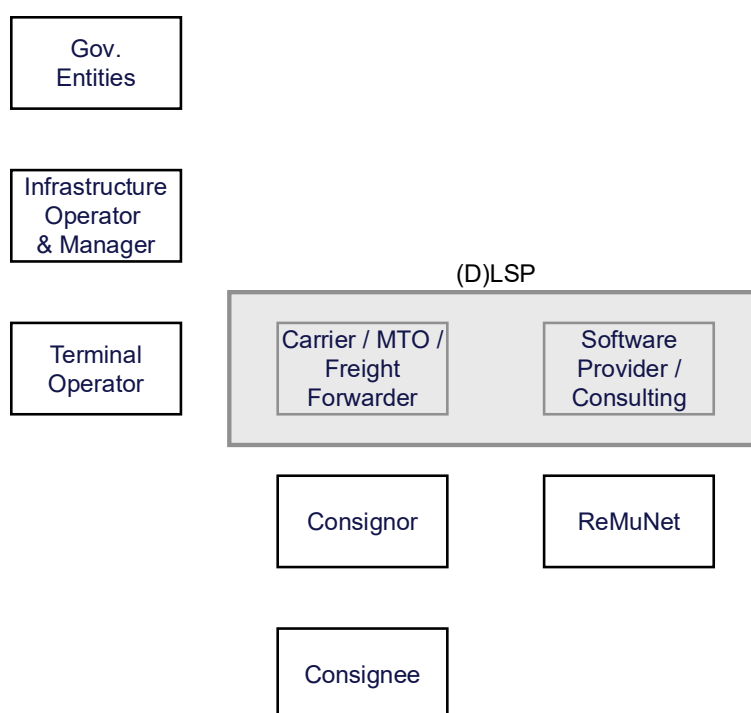


Figure 12: New Ecosystem Landscape

6.4.1 Flow of Goods

Figure 13 illustrates the flow of goods within the revised ecosystem. As ReMuNet operates as a digital service provider that supports and standardises the flow of information and services, it does not influence the physical flow of goods. For this reason, the flow of goods remains the same as in the previous ecosystem, as described in Section 4.3.1 of D3.2. Goods are exchanged between the consignor as initiator, the carrier for executing the

transport, the terminal operator for transshipment, and finally the consignee as receiver of the goods.

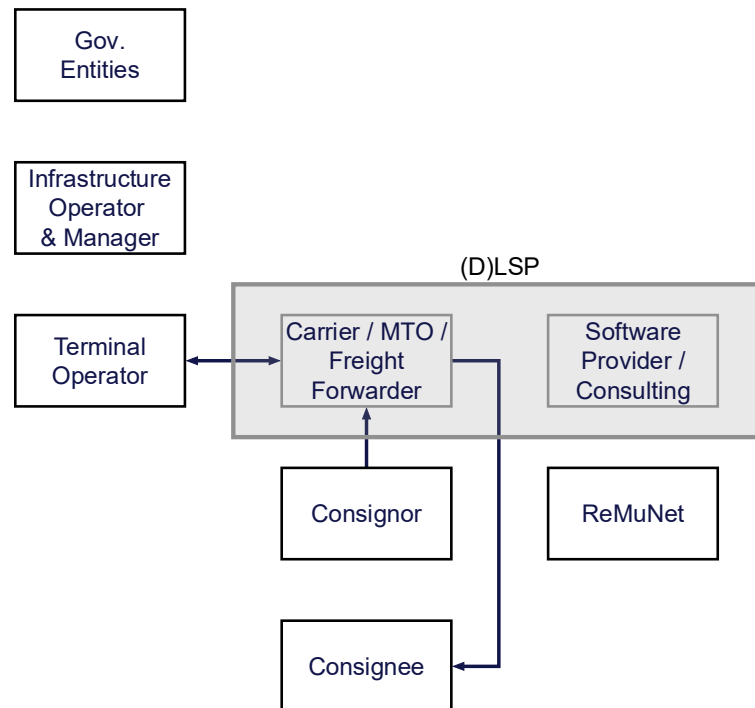


Figure 13: Flow of Goods

6.4.2 Flow of Finances

As ReMuNet follows a non-profit approach, no changes can be determined in the flow of finances after its integration into the revised ecosystem compared to the flow presented in D3.2 (figure 14). Nevertheless, the topic of monetisation will be discussed again in D3.4.

Summarising, the flow of finances follows the flow of goods. It is only extended by financial flows between:

- Carrier, MTO, or freight forwarder and governmental entities (e.g., tax, customs fees, emissions fees, etc.),
- Carrier, MTO, or freight forwarder and terminal operator as well as infrastructure operator and manager (e.g., usage fees, service fees etc.) and
- Carrier, MTO, or freight forwarder and service provider and consulting (e.g., service fees, licence fees, consulting etc.).

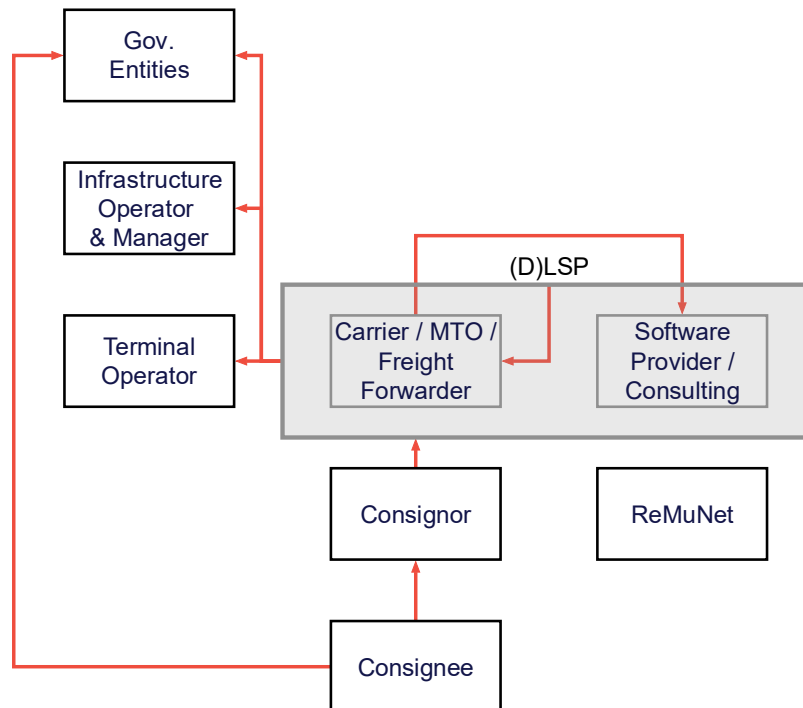


Figure 14: Flow of Finances

6.4.3 Flow of Information

The flow of information shows all relevant information within the revised ecosystem (figure 15). The information is clustered using the same four different types of information from D3.2

- infrastructure and real time,
- transport and shipping documents,
- logistics documents and information, and
- financial documents and information

in order to improve the clarity of the generated flow and to enable comparability to D3.2. The integration of ReMuNet introduced a fifth category of information called “disruption information”. This category includes all information related to reporting and managing disruptions in the (multimodal) transport sector.

Within the revised ecosystem, ReMuNet acts as a central, standardised information hub (IP01) through which transport orders can be (automatically) optimised and booked. The infrastructure operator and manager, carrier, MTO, and freight forwarder as well as software provider and consulting supply real time data and/or disruption information. In case of a major disruptive event, these data will be disseminated to all roles participating in the task force.

Furthermore, ReMuNet uses optimisation algorithms to generate revised routes and issues updated transport orders based on these routes to the MTO or freight forwarder or directly to the carrier. The adapted transport and logistics planning information is subsequently transmitted to the (D)LSP, the infrastructure operator and manager, and ideally terminal

operator. Additionally, governmental entities transmit transport authorisations and safety certificates directly to ReMuNet.

The infrastructure operator and manager, as well as the terminal operator, send traffic reports directly to ReMuNet, while software provider and consulting transmit traffic and weather reports that can be used for a predictive disruption analysis. Infrastructure and maintenance documents are now sent by the infrastructure operator and manager the carrier, MTO and freight forwarder as well as to governmental entities. Furthermore, the sustainability balance sheet and the status report are transmitted from the carrier, MTO and freight forwarder to ReMuNet.

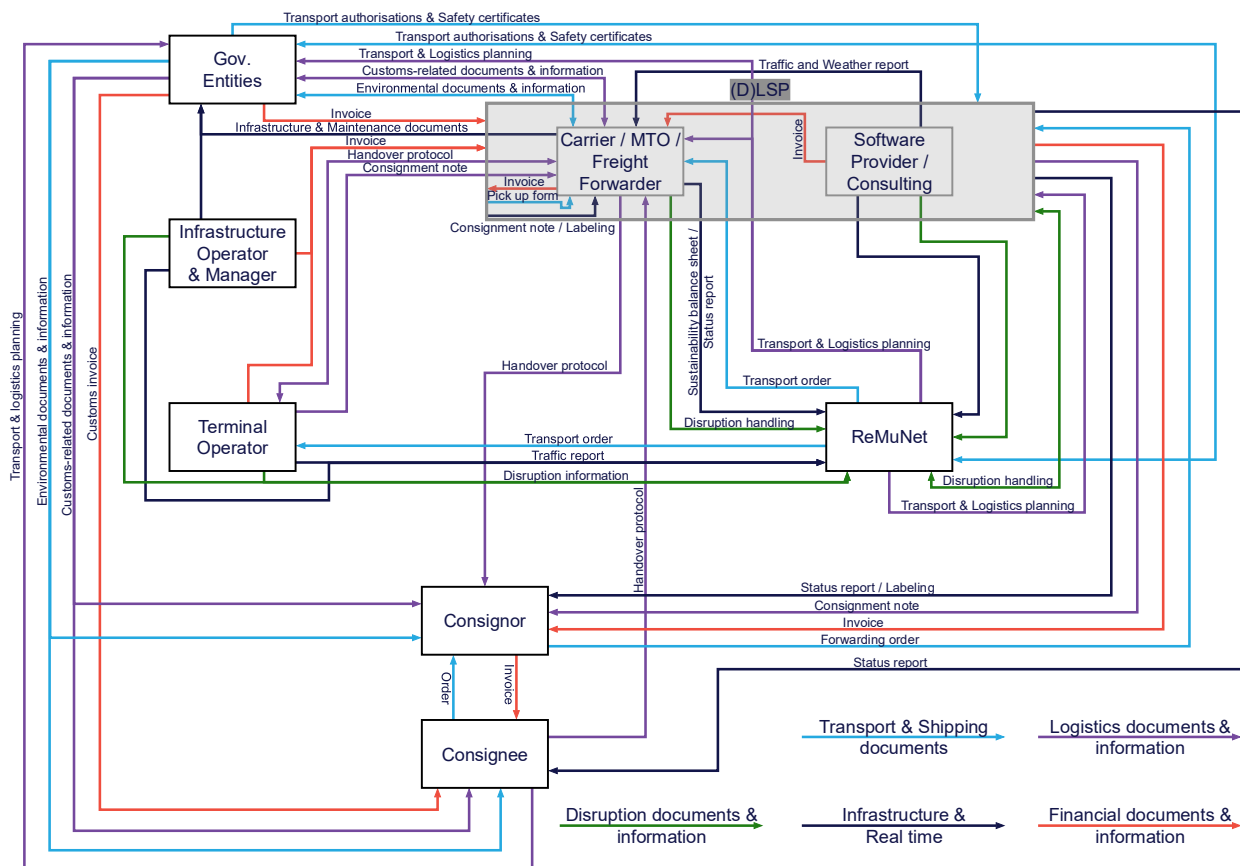


Figure 15: Flow of Information

6.4.4 Combined Value Flow Model

The combined value flows are presented in figure 16. This model consolidates the information provided in the individual value flow models for goods, finances, and information, and illustrates the ecosystem in a way that simplifies the representation of its complexity while increasing the level of detail. To achieve this, visual elements are used to indicate both the type of flow and the intensity of exchange between roles: blue lines represent information, red lines represent finances, and dark blue lines represent goods. The thickness of each line corresponds to the volume exchanged, with thicker lines indicating a higher quantity of shared information, goods, or financial transactions.

The most significant change is due to the introduction of ReMuNet into the ecosystem. ReMuNet, as a central information hub, is clearly identifiable, as every role directly involved

in the transport process either exchanges information with or receives information from ReMuNet.

In addition to the new role of ReMuNet, the carrier, MTO, freight forwarder, and (D)LSP are the central actors of the revised ecosystem. This can be attributed to their function as primary communicators with the consignee, as well as their role in bridging digital planning with physical logistics operations.

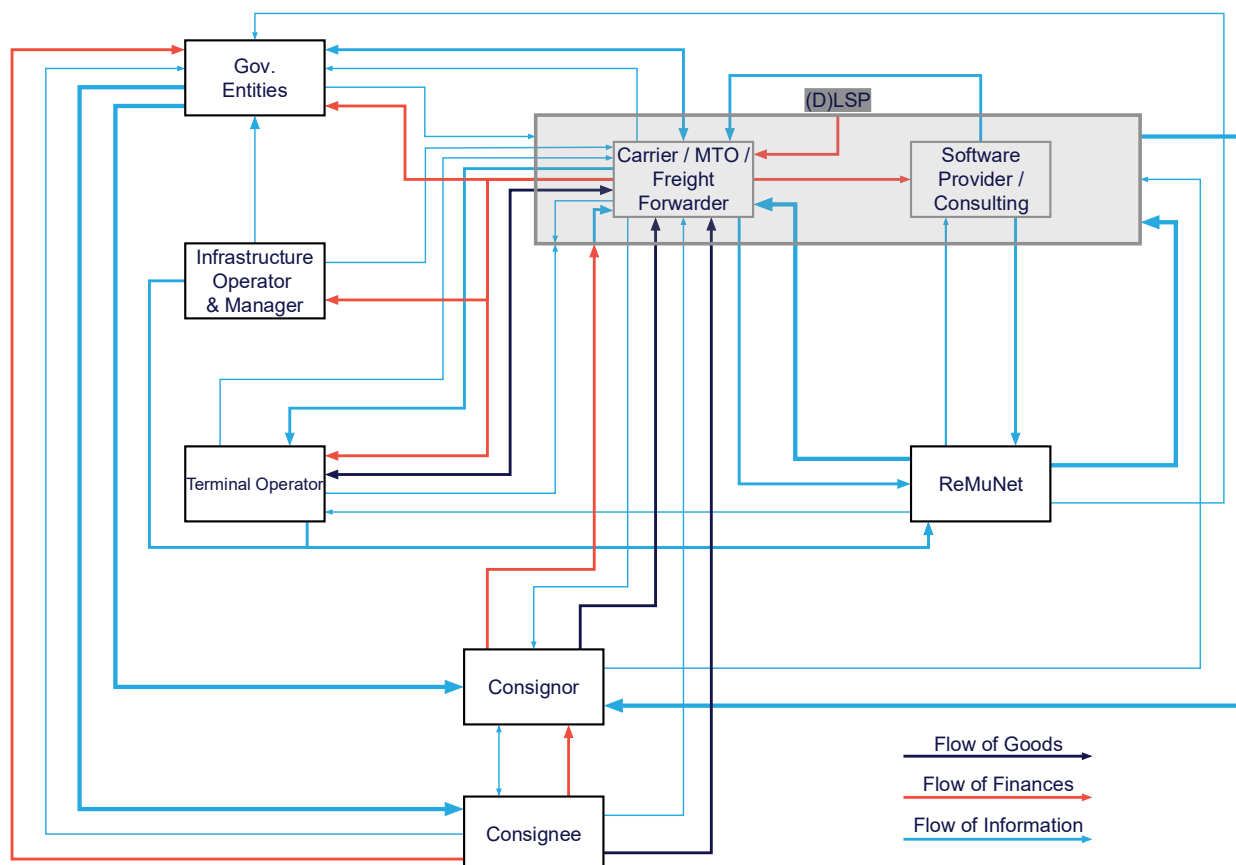


Figure 16: Combined Value Flow Model

6.5 Advantages and Disadvantages for Actors

The envisioned ReMuNet ecosystem is designed to enhance cooperation, transparency, and efficiency across all involved actors. By integrating real-time data, improving interoperability, and fostering stronger connections between stakeholders, the new ecosystem aims to address many of the inefficiencies and fragmentation issues present in the current system (see D3.2). Nevertheless, certain challenges remain, such as potentially increased competition, varying levels of digital integration, and the need for consistent stakeholder engagement. The following table 11 summarises the key advantages and disadvantages for each role within the new ecosystem. The information is based on findings from D3.2, D1.1, and the conducted validation workshops.

Due to the overarching role of the (D)LSP, the subsidiary roles of the carrier, freight forwarder and MTO are analysed in terms of advantages and disadvantages in order to make more specific statements regarding the potential of each role.

Table 11: Advantages and Disadvantages of the current Ecosystem for the Roles

Role	Advantages	Disadvantages
Infrastructure Operator and/or Manager	- The rising demand for intermodality and sustainable driven transport alternatives highlights their strategic importance. - They have a central role in network operations and management especially in the event of disruptions. - With a centralised data management system, capacities become transparent and communication with other roles improves due to higher data quality and completeness. Also, status updates of various infrastructure managers become available enabling a clear status report of the whole infrastructure network and increasing cooperation among different stakeholders.	Im struggle with regulatory fragmentation especially across borders. Non standardised legal frameworks hinder international shipping and rerouting.
Carrier/ MTO/ Freight Forwarder	- They have a central role on the operational side of the freight transport ecosystem. - The availability of real-time data is an advantage for communication with other actors especially when mitigating disruptions. - Increasing cooperation and information transparency further improve multimodal operations and collaboration with other roles. - The availability of detailed transportation data assists in the estimation of arrival times and capacity forecasts. Also, sustainability reports become more detailed and easier to create. - New digital solutions offer possibilities for enhancing existing business models and value creation systems with new service offerings.	- Various regulatory frameworks complicate transport operations especially at border points and network nodes. - Due to greater availability of transportation services, the competition among this group of actors might rise (chapter 6.7). - Some actors might not be integrated due to the lack of digitalisation.
Terminal Operator	- Enabler of multimodal transportation through access to multiple transport modes. - Through increased cooperation and improved data availability, terminal operators will be more closely involved in incident management. - Real-time data availability supports smooth operations especially with carriers and increases the accuracy of arrival and departure time estimations.	-/-
Software Provider/ Consulting	- The demand for digital solutions rises and offers great potentials for consulting services and digital products. - Software providers benefit from the development of software solutions that can be integrated into ReMuNet.	ReMuNet may compete with other logistics platforms offered by software providers.

Consignor and Consignee	- Increased efficiency and network resilience reduce transportation times resulting in improved throughput times and shorter procurement cycles for producing companies. - Improved disruption management reduces economic losses due to delays or lost goods. - Real-time data availability supports smooth operations especially with carriers and increases the accuracy of arrival and departure time estimations.	-/-
Governmental Entities	- Great influence on processes and level of standardisation. - ReMuNet emphasises the need for standardised regulatory frameworks to improve efficiency, particularly for cross-border shipments.	-/-

6.6 Multidimensional View of Business Models

The introduction of the ReMuNet platform into the existing ecosystem is expected to entail changes not only at the ecosystem level but also within the individual business models of the respective roles. To capture potential shifts in these business models, a total of 87 assumptions were formulated, based on previous findings. These assumptions were subsequently validated through a survey, as described in chapter 3.3.2, involving 24 stakeholders from the ecosystem. Since respondents could identify with up to two roles, the survey ultimately reflected 32 represented roles (figure 17).

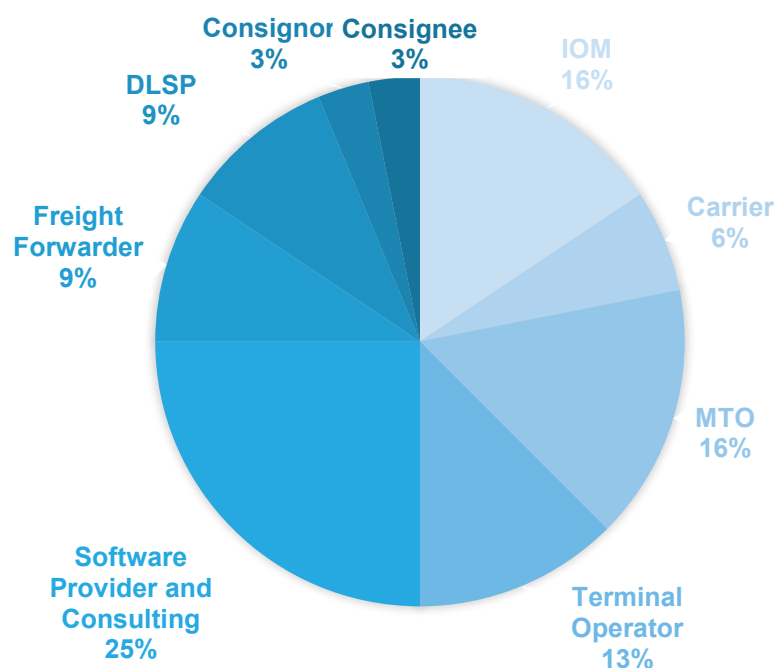


Figure 17: Distribution of Roles participated in the Survey

For the analysis, only those assumptions were retained that received a minimum level of agreement of more than 50 %, meaning at least 50 % of respondents evaluated them as either “likely” or “very likely.” Assumptions rated by at least 50 % of respondents as “neither

likely nor unlikely”, “unlikely” or “very unlikely” were excluded. Additionally, to ensure consensus and stability in the responses, only assumptions with an interquartile range (IQR) of less than or equal to 1 were included.

Following the application of these criteria, 36 of the original 87 assumptions remained and are presented in the subsequent chapters. The tables are structured by role and are organised according to the business model dimensions defined by Gassmann et al. (2013), complemented by the sustainability dimension according to Lüdeke-Freund et al. (2024). Each table includes the corresponding element of the current business model (derived from D3.2 and D1.1) alongside the changes identified in the survey. If no assumption is indicated in a specific cell, it can be inferred that the corresponding business model dimension for that role remains unchanged in the ReMuNet ecosystem.

For the “current” business models, the sustainability dimension is always left empty, as the sustainability aspect according to Lüdeke-Freund et al. (2024) represents an extension to Gassmann’s framework from D3.2 and, in comparison to D3.2, is also intended to indicate how the sustainability aspect of the business model changes with the introduction of ReMuNet into the ecosystem.

6.6.1 *Infrastructure Operator and Manager*

For Infrastructure Operators & Managers (IOM), the target customers traditionally include carriers responsible for freight movement and terminal operators managing loading, unloading, and transshipment at logistics hubs. With the introduction of ReMuNet, this customer base is expected to expand, as SMEs and local logistics actors will increasingly rely on IOM infrastructure due to improved access (80 % agreement).

The value proposition remains centred on enabling freight transport and supporting the movement of vehicles and goods by managing transportation networks, facilities, and related retail and real estate activities. No changes were identified in this dimension.

In terms of value creation, IOM have traditionally provided, developed, operated, and maintained key infrastructure such as ports, rail lines, roads, and terminals, alongside responsibilities including road asset management, vehicle load control, setting performance standards, bridge management, facilitating self-regulation for heavy vehicles, and implementing systems for abnormal loads. Following the introduction of ReMuNet, value creation processes are expected to evolve through the progressive integration of real-time data collection and sharing into operational workflows (agreement from over half of respondents).

The profit mechanism continues to be driven by carriers’ dependence on reliable, well-maintained infrastructure to ensure timely and efficient delivery of goods, and by the requirement for terminal operators to be directly connected to such infrastructure to facilitate smooth intermodal transfers. No change is anticipated here.

From a sustainability perspective, IOM are expected to strengthen their performance by reducing downtime and extending the lifespan of assets, a shift supported by more than half of the respondents (table 12).

Table 12: Implications on the BM of Infrastructure Operators and Managers

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Why? Target Customers	Carriers and terminal operators	Increased reliance on IOM infrastructure
What? Value proposition	Enabling of freight transport and support of the movement of vehicles, passengers, and goods	-/-
How? Value creation	Providing, developing, operating, and maintaining key infrastructure (e.g., ports, rail lines, roads, terminals)	Integration of real-time data collection and sharing of processes
Why? Profit mechanism	Driven by the other stakeholders' dependence on reliable, well-maintained infrastructure	-/-
Sustainability	-/-	Reduction of downtime and extension asset lifespans

6.6.2 Carrier

For Carriers, the target customers traditionally include freight forwarders, who organise shipments and manage bookings and documentation across carriers; multimodal transport operators (MTO), who deliver end-to-end services under a single contract by combining transport modes; and digital logistics service providers (DLSP), who utilise technology platforms to connect shippers with carriers and manage freight in real time. No change in this customer base is anticipated with the introduction of ReMuNet.

The value proposition currently focuses on the physical transportation of goods between supply chain nodes using the most suitable transport mode. This involves consolidating goods into intermodal transport units (ITU) and operating either as common carriers, serving multiple clients flexibly, or as contract carriers, serving specific clients under long-term agreements. With ReMuNet, this value proposition will expand to include the provision of more accurate, emissions-transparent transport services.

In terms of value creation, carriers deploy a range of transport modes to meet shipment requirements, maintain compliant and efficient fleets, and ensure operational readiness, whether contracted directly by consignors or via intermediaries such as freight forwarders. The introduction of ReMuNet is expected to enhance these processes by enabling carriers to leverage disruption alerts to respond more swiftly to unforeseen events, thereby minimising service interruptions. Furthermore, relaying freight between actors at exchange points might become a core operational process.

Under ReMuNet, faster reaction capabilities could allow carriers to make more informed and timely decisions, reducing delivery delays and enhancing cost efficiency. They are expected to increasingly monetise their flexibility and responsiveness during disruptions, while reduced dependence on traditional freight forwarders will improve margin control.

From a sustainability perspective, the platform's transparency could enable carriers to better benchmark and optimise their environmental performance (

table 13).

Table 13: Implications on the BM of Carriers

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Who? Target Customers	Freight forwarders, MTO, and DLSP	-/-
What? Value proposition	Physical transportation of goods between nodes in the supply chain	Provision of more accurate emissions-transparent transport services
How? Value creation	Deployment of various transport modes to meet shipment requirements, own and maintain a fleet of compliant and efficient transport assets, and ensure operational readiness.	- Leveraging ReMuNet's disruption alerts to react more swiftly to unforeseen events - Relaying freight between actors becomes a core operational process
Why? Profit mechanism	Carriers choose transport modes based on specific advantages as a profit mechanism	- Faster reaction capability to make more informed, timely decisions - Faster reaction capability to reduce delivery delays and enhance overall cost efficiency - Increased monetisation of flexibility and responsiveness during disruptions - Reduction of dependence on traditional freight forwarders
Sustainability	-/-	Enhanced benchmark and optimisation of environmental performance

6.6.3 Multimodal Transport Operator

For Multimodal Transport Operators (MTO), the target customers currently include consignors and freight forwarders responsible for managing cargo movement. With the introduction of ReMuNet, this customer base is expected to broaden, enabling MTO to engage with a wider range of customers and partners requiring orchestrated end-to-end transport services.

The value proposition currently focuses on providing seamless, end-to-end transportation under a single contract, integrating multiple transport modes from origin to destination. Under ReMuNet, this proposition could be enhanced through the provision of seamless orchestration, documentation, and digital handovers via ReMuNet APIs and interfaces.

In terms of value creation, MTO currently operate and maintain networks of carriers and strategic partners, and, depending on the type, own transport assets across different modes. This includes vessel-operating MTO (VO-MTO) with their own fleets and non-vessel-operating MTOs (NVO-MTO) that organise services without owning transport assets. Following ReMuNet's introduction, MTOs could join the platform to optimise capacity utilisation across their multimodal networks.

The profit mechanism is currently based on streamlining logistics, reducing handovers, paperwork, and delays between transport segments, thereby delivering faster and more efficient operations for clients. In a ReMuNet ecosystem, MTO could generate revenue not only from static contractual arrangements but also from managing resilient, low-emission multimodal chains. From the sustainability perspective, more efficient route planning and reduced buffer times, enabled by ReMuNet, could minimise unnecessary transport emissions (table 14).

Table 14: Implications on the BM of MTO

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Who? Target Customers	Consignors and freight forwarders	• Broader range of customers or partners in need of orchestrated end-to-end services
What? Value proposition	Seamless end-to-end transportation under a single contract using multiple transport modes	• Seamless orchestration, documentation, and digital handover
How? Value creation	Operating and maintaining networks of carriers, strategic partners, and, depending on the type, own transport assets across different modes	• Joining the ReMuNet platform to optimise capacity utilisation
Why? Profit mechanism	Streamlining logistics, reducing handovers, paperwork, and delays between transport segments	• Managing resilient, low-emission multimodal chains, not just static contracts
Sustainability	-/-	• More efficient route planning and reduced buffer times

6.6.4 Terminal Operator

For Terminal Operators, the target customers currently include carriers, freight forwarders, and MTO, with the core function of facilitating cargo handling and coordination at transport hubs. With the introduction of ReMuNet, terminals could extend their role by serving ecosystem partners not only operationally but also through data and capacity-sharing interfaces.

The value proposition focuses on enabling smooth modal transfers, secure transshipment, warehousing, and efficient cargo flows across different transport modes within a single hub. Under ReMuNet, this proposition could be enhanced through terminal operations based on planned usage forecasts and disruption data, thereby increasing overall reliability and reducing operational costs.

In terms of value creation, terminal operators currently run facilities equipped with infrastructure and machinery such as cranes, ramps, and yards, while managing essential processes including shunting, vertical and horizontal transshipment, customs procedures, and maintenance. With ReMuNet, cooperation with MTO, carriers, IOM could become more API-driven and standardised, enabling greater integration and efficiency across the ecosystem.

The profit mechanism, which relies on ensuring efficient intermodal transfers, minimising delays, and offering value-added logistics services such as storage, documentation, and equipment use, is expected to remain unchanged. Similarly, no changes are anticipated in the sustainability dimension (

table 15).

Table 15: Implications on the BM of Terminal Operators

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Who? Target Customers	Carriers, freight forwarders, and MTO	Serving ecosystem partners also through data and capacity-sharing interfaces
What? Value proposition	Smooth modal transfers, secure transshipment, warehousing, and efficient cargo flows	Operating based on planned usage forecasts and disruption data
How? Value creation	Operating terminals equipped with infrastructure and machinery and managing key processes	More API-driven and standardised cooperation with MTO, carriers, and IOM
Why? Profit mechanism	Ensuring efficient intermodal transfers, minimising delays, and offering value-added logistics services	-/-
Sustainability	-/-	-/-

6.6.5 Software Provider and Consulting Companies

For Software Providers and Consulting companies, the target customers remain logistics service providers, to whom they deliver digital tools and expert consulting tailored to freight transport operations. Their value proposition continues to centre on optimising transport processes through customised software and strategic guidance. Currently, value creation is achieved by combining advanced digital platforms, such as TMS and analytics tools, with logistics expertise to design, implement, and refine tailored solutions based on data, key performance indicators, and specific client requirements. With the introduction of ReMuNet, these companies could integrate the platform directly into their solutions via APIs, embedding its data feeds and routing capabilities into their service offerings. The profit mechanism remains unchanged, with revenue derived from helping clients reduce costs, improve transit times, and enhance service quality through efficient, scalable, and insight-driven logistics management solutions. No changes are anticipated in the sustainability dimension (table 16).

Table 16: Implications on the BM of Software Providers and Consulting Companies

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Who? Target Customers	Logistics service providers	-/-
What? Value proposition	Optimisation of transport processes	-/-
How? Value creation	Combining advanced digital platforms with logistics expertise to design, implement, and refine tailored solutions	Integration of the ReMuNet platform directly into solutions via API
Why? Profit mechanism	Helping clients cut costs, improve transit times, and enhance service quality	-/-
Sustainability	-/-	-/-

6.6.6 Freight Forwarder

For Freight Forwarders, the current target customers are consignors requiring transport solutions, with collaboration taking place with other forwarders or MTO for complex or specialised shipments. With the introduction of ReMuNet, freight forwarders could collaborate more directly with platform-integrated actors such as terminals, MTO, and IOM (table 17).

The value proposition is currently to organise the movement of cargo between two locations, orchestrating transport using either their own assets or those of third-party carriers. In the future, this proposition could expand to include digital booking, documentation, and real-time tracking aligned with platform standards. Freight forwarders might also use ReMuNet to access live capacity, plan resilient routes, and manage bookings across multiple modes, meeting end-customer expectations for digitally supported, resilient, and green logistics solutions as a standard.

In terms of value creation, freight forwarders currently handle tendering and contracting processes, negotiating with carriers, terminal operators, and infrastructure providers to secure transport capacity and ensure service quality. No changes are expected in the core processes of this dimension.

The profit mechanism is currently based on providing expertise and coordination capabilities that many customers lack internally. With ReMuNet, enhanced agility could deliver superior capacity utilisation across transport networks. The platform might also minimise delays and overhead, boosting overall efficiency and service reliability.

Table 17: Implications on the BM of Freight Forwarders

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Who? Target Customers	Consignors needing transport solutions and collaboration with other forwarders or MTO	More direct collaboration with platform-integrated actors like terminals, MTO and IOM
What? Value proposition	Organising the movement of cargo between two locations	- Offering digital booking, documentation and real-time tracking more aligned with platform standards - Using ReMuNet to access live capacity, plan resilient routes and manage bookings across modes - Meet expectations of increased digitally supported, resilient, and green logistics solutions
How? Value creation	Handling tendering and contracting processes, and negotiating with stakeholders	-/-
Why? Profit mechanism	Provision of expertise and coordination	- Enhanced agility delivers superior capacity utilisation across transport network - Minimising time delays and overhead
Sustainability	-/-	- Avoiding waste through optimised route planning, cargo consolidation and minimisation of empty-leg runs - Facilitating informed decision-making, and providing clients with transparent data on environmental impact

From a sustainability perspective, ReMuNet could enable freight forwarders to avoid waste through optimised route planning, cargo consolidation, and minimisation of empty-leg runs. They might also unlock value by providing clients with transparent data on environmental impact, facilitating informed decision-making and supporting higher environmental standards.

6.6.7 Digital Logistics Service Provider

For Digital Logistics Service Providers (DLSP), the target customers currently include consignors, to whom they provide full digital coordination of shipments. They also support freight forwarders and MTO by enhancing their orchestration and planning capabilities. With the introduction of ReMuNet, DLSP could progressively support public-private collaboration by offering scalable digital infrastructure without physical dependencies.

The value proposition is currently to provide integrated digital solutions for managing and optimising transport operations across the entire supply chain. In the future, DLSP could expand this by offering new service solutions through integration of their services into the ReMuNet platform.

In terms of value creation, DLSP currently leverage cloud-based platforms, digital twins, and other emerging technologies to generate real-time visibility and predictive insights into the transport ecosystem. No changes are anticipated in this dimension. The profit mechanism is currently based on enabling logistics partners to operate more efficiently, scale faster, and unlock new capabilities, without requiring physical assets or in-house IT development. No changes are anticipated here, as well as in the sustainability dimension (table 18).

Table 18: Implications on the BM of DLSP

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Who? Target Customers	Consignors, freight forwarders and MTO	Supporting public-private collaboration without physical dependencies
What? Value proposition	Offering integrated digital solutions to manage and optimise transport operations across the full supply chain	DLSP offer new service solutions via integration of their services into the ReMuNet platform.
How? Value creation	Leveraging cloud-based platforms, digital twins and other emerging technologies	-/-
Why? Profit mechanism	Enabling logistics partners to operate more efficiently, scale faster, and unlock new capabilities	-/-
Sustainability	-/-	-/-

6.6.8 Consignor

For Consignors, it should be noted that in the survey only one respondent identified with this role; while all results should be interpreted with caution, the findings for this role in particular should not be considered representative.

The consignors' target customers currently consist of consignees, who rely on timely deliveries to meet production schedules, inventory requirements, or personal demands. No change is anticipated in this dimension.

The current value proposition is to ensure that goods are transported to consignees in a predictable and reliable manner, allowing recipients to schedule their production runs or inventory needs effectively. In this dimension, there is no change is anticipated as well.

In terms of value creation, consignors currently coordinate production and transport logistics, maintain accurate static freight data (e.g., weight, quantity, hazard information), and, where possible, select climate-friendly transport options. No changes are foreseen in this dimension.

The profit mechanism currently depends on many consignors differentiating themselves in the marketplace through unique selling propositions, such as superior product quality, competitive pricing, or specialised niche offerings, which in turn rely on consistent delivery performance. With ReMuNet, improved estimated time of arrival (ETA) accuracy could enable consignees to plan their production schedules and inventory requirements more effectively, thereby improving the coordination of the entire supply chain.

From a sustainability perspective, consignors could actively select low-emission routes and carriers via ReMuNet, thereby reducing their transport footprint (table 19).

Table 19: Implications on the BM of Consignors

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Who? Target Customers	Consignees	-/-
What? Value proposition	Ensuring that goods are transported to consignees in a predictable, reliable manner	-/-
How? Value creation	Coordinating production and transport logistics, maintaining accurate static freight data, and selecting climate-friendly transport options where possible	-/-
Why? Profit mechanism	Distinguishing themselves through unique selling propositions	Improved ETA accuracy to plan production schedules and inventory requirements more effectively
Sustainability	-/-	Selecting low-emission routes and carriers, reducing their transport footprint

6.6.9 Consignee

For Consignees, as with consignors, it should be noted that in the survey only one respondent identified with this role; while all results should be interpreted with caution, the findings for this role therefore cannot be considered representative.

The target customers in this context are not applicable, as consignees are the final recipients of freight within the logistics chain and do not serve other customers. Nevertheless, with the introduction of ReMuNet, consignees could become internal beneficiaries of improved logistics.

The consignees' value proposition is currently to transform incoming freight into finished goods and supply these to external businesses, thereby creating added value beyond the logistics process. No changes are foreseen in this dimension.

In terms of value creation, consignees currently synchronise production planning with transportation requirements, defining shipment specifications and schedules to ensure that inbound materials arrive just in time for manufacturing. With ReMuNet, they could use improved predictive arrival information to dynamically adjust production lines or labour allocation.

The profit mechanism is currently based on converting raw materials into differentiated products through specialised processes, generating value via production efficiency, quality, and market responsiveness. With ReMuNet, optimised disruption handling could reduce the need for safety stock, lower operational costs, and increase working capital efficiency. No sustainability-related changes are anticipated for consignees as a result of ReMuNet's introduction into the ecosystem (table 20).

Table 20: Implications on the BM of Consignees

Dimension	Current (D 3.2 & D 1.1)	Assumed Change
Who? Target Customers	Not applicable	Becoming internal beneficiaries of improved logistics
What? Value proposition	Transforming incoming freight into finished goods, supplying these to external businesses	-/-
How? Value creation	Synchronising production planning with transportation requirements and defining shipment specifications and schedules	Using improved predictive arrival information to adjust production lines or labour allocation dynamically
Why? Profit mechanism	Converting raw materials into differentiated products	- Optimised disruption handling reduces the need for safety stock - Optimised disruption handling lowers operational costs and increases working capital efficiency
Sustainability	-/-	-/-

6.6.10 Governmental Entities

As described in chapter 6.2 and in D3.2, governmental entities are not profit-driven and therefore they do not follow a defined business model. However, they contribute to the ecosystem by defining regulations and directives. By setting the legal rules for the freight transport network, the governmental entities enable the value proposition of other stakeholders. These kind of actors are described as enablers of an ecosystem (den Ouden, 2012). A comprehensive list of representative entities is included in D3.2.

6.7 Coopetition Index for ReMuNet Ecosystem

When analysing the ReMuNet ecosystem, the CI should be taken into account. This index measures the amount of cooperation in relation to competition between stakeholders of an ecosystem (chapter 2.4). Within the CI, ΔCI determines the alteration of that value between two different states of time. One being the CI value in the current ecosystem, the other being the value in the ReMuNet ecosystem.

The calculated values for ΔCI in figure 18 represent estimations based on the implications on the business models in chapter 6.6 and divide them into discrete value ranges. A negative ΔCI signifies either a strong or a slight change towards competition between two actors depending on the influence of ReMuNet's involvement on the relationship between the two actors. Positive values respectively signify a strong or a slight change towards cooperation though the integration of ReMuNet into the ecosystem. No change in coopetition between two stakeholders is represented by a ΔCI of zero. The value is unidirectional, which means that it is calculated only once for each actor-to-actor relationship. Finally, the change in coopetition is considered not only between two different actors but also within a group of the same actor.

Due to the overarching role of (D)LSPs, the subordinate roles of carriers, freight forwarders and MTOs are analysed in relation to the CI in order to make more specific statements regarding the potential of each role.

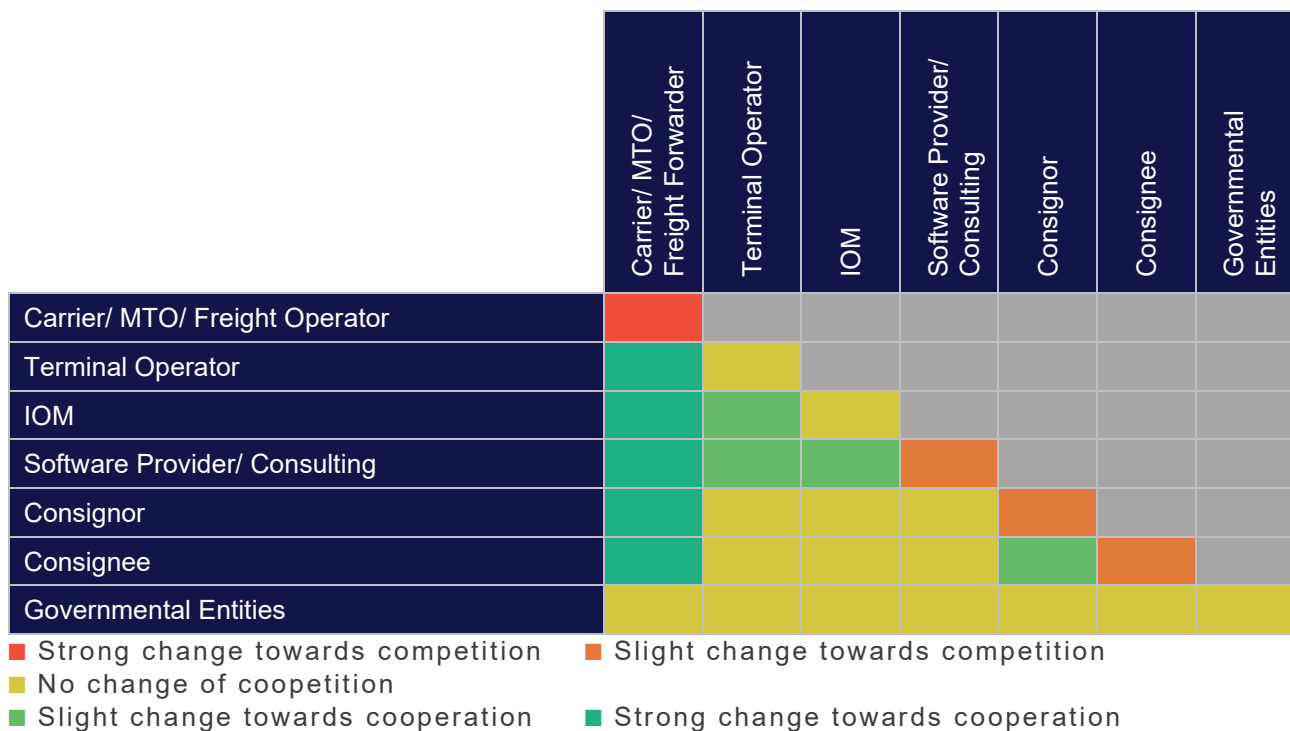


Figure 18: Coopetition Index Matrix

A **strong change of coopetition towards competition** (■) can be observed among carriers. The integration of the ReMuNet platform offers several advantages for the value proposition of each carrier (chapter 6.5). Especially the improved efficiency in the operational business enables competitive advantages compared to other competitors, as the transport business is a key component of the core value proposition of carriers. ReMuNet brings great advantages in optimising these business aspects resulting in a strong change of coopetition towards competition.

The **slight change towards competition** (■) mostly affects roles at the edges of the transport process such as consignors, consignees and software providers. Those roles might be affected by transportation improvement, but do not include the transportation in their core value proposition. So, the effect will be noticeable, but not that great compared to

actors directly associated with freight transport. Nonetheless, consignors and consignees can profit from digital platforms as they optimise efficiency along their supply chain. With lower throughput times resulting from shorter procurement times paired with higher confidence of delivery dates, competition among actors at the end of the transport chain rises. In the case of software providers, the slight change towards competition is closely connected to the required adaption of their services to make them accessible via a digital platform such as ReMuNet, as increased interoperability will become even more important in the logistics sector.

No change in coopetition (■) can be expected between roles interacting with enabling roles such as governmental entities. Also, relationships between roles that do not interact directly within the transportation process will not change regarding coopetition. The interplay among terminal operators and IOM will not be affected by ReMuNet, resulting in no change of coopetition.

ReMuNet as an orchestrating digital platform not only improves efficiency, resilience, and sustainability of the freight transport ecosystem, but also streamlines the information flow among stakeholders, offers communication standards and enables availability of real-time information. These improvements result in higher cooperation among actors within the network. A **slight change of coopetition towards more cooperation (■)** with the integration of ReMuNet will be visible between roles that offer software solutions, infrastructural capacities and shifting capabilities. The availability of data and improved communication (e.g., by defining standards, establishing a direct, communication-based connection to other stakeholders, implementing a translation tool etc.) enabled by ReMuNet slightly improve the harmonisation of capacities between terminal operators and IOM (IP05). Also, software providers can adjust their digital offerings to the needs based on data available through ReMuNet. The relationship between consignor and consignee is also affected towards more cooperation. Real-time data enables confident prediction of delivery times, leading to harmonious business relationships between shipper and customer. Long-term contracts strengthen partnerships and form the foundation of integrating suppliers into the customers' procurement systems.

Finally, a **strong shift of coopetition towards cooperation (■)** can be observed in the interplay of all roles (besides governmental entities) and carriers, MTO, and freight forwarders. ReMuNet not only strengthens the exchange of information but also offers digital solutions and mitigation tools for disruption management in freight transport. The transparency of capacities and capabilities of multiple players merged on a central orchestration platform supports adapting transportation plans and handling unforeseen events collectively and collaboratively (IP01; IP05; IP07).

7. Conclusion and Outlook

D3.3 builds on insights from D3.2 and extends its ecosystem analysis by designing a value creation system with ReMuNet as central actor. A disruption management process, as an integral part of ReMuNet's service offering, reveals potentials for improving collaboration and data exchange with a digital platform. In addition, business models for the variety of affected parties benefit from various advantages that lead to revised business models and an updated ecosystem. At the core of the new ecosystem is ReMuNet with its digital platform architecture, which includes core components of services and system interactions with external data sets and services.

A disadvantage of the current ecosystem is the lack of a uniform and effective disruption management process. An idealised process for handling disruptive events is proposed in chapter 4. The handbook for international contingency management (RailNetEurope, 2021) serves as the foundation for the process design. An initial draft including best practices from past disruptions and from cross-industry examples was refined with industry insights from numerous experts during online workshops. The result is a three-phase process model as a concept of the current state of the art disruption management. Starting with the assembly of a task force, the process includes role-specific activities and responsibilities, and the flow of information using multiple communication channels. The mitigation phase features the three options available to the carrier adjusting its transportation plans: waiting, rerouting and mode-shifting. An evaluation after cleared disruption concludes the process.

Current weaknesses of the process, such as the lack of data availability and quality, missing collaboration and unstandardised internal procedures, can be addressed with ReMuNet functionalities. A centralised database grants access to vital information regarding disruptive events, status reports of infrastructure and terminal operations, and real-time updates of carriers. Additionally, the mitigation phase benefits from optimised route alternatives, capacity overviews and forecasts based on machine learning.

The developed process model faces some limitations. The fundamental literature used for initially drafting the process focuses on rail transportation. Although experts from different transport modes were consulted, transferability can ultimately not be guaranteed. Fragmented internal processes hinder the integration of the proposed process. Nonetheless, ReMuNet promotes standardisation by offering an open platform for sharing and accessing information and enabling collaboration among all involved stakeholders.

Enabler for these potentials is the digital ReMuNet platform. Its architecture is described in chapter 5. The digital platform design recognises the requirements for addressing the stakeholder challenges and pain points identified in the ecosystem analysis as part of D3.2. Paired with success factors of prominent industry and research platforms, the ReMuNet architecture was iteratively detailed in multiple consortium workshops. It included two approaches: a relationship-based approach and a network-based approach differing in the amount of optimisation included in the booking and overall transport orchestration process. The core service components include external access, front end/ internal access, back end, external services, and a disruption layer, which are described in detail in chapter 5.2.2. The digital platform not only functions as a centralised database and brokerage or booking

platform but also integrates external services ensuring interoperability and accessibility to a wide range of information and digital solutions in the realm of multimodal freight transportation and disruption mitigation. This approach emphasises collaboration among logistics players and open data exchange in real-time with high quality using standardised communication formats.

The platform architecture is described on a research basis which limits the applicability for real world scenarios. According to the proposal ReMuNet will feature experiments and use case scenarios at a later stage of the project. Also, critical components as the frontend and backend will be detailed in D3.7 and D3.8. Besides these descriptive limitations, apart from the platform architecture “a common understanding and regulatory support are equally needed” to address all pain points in the current ecosystem, as a survey participant mentions. A platform can only promote common practices by offering a centralised collaboration medium for information exchange and capacity optimisation. Regulations especially cross-border related should be harmonised and simplified in order to optimally integrate ReMuNet into the multimodal freight transport ecosystem according to chapter 6.

The digital platform is grounded in the core value proposition of ReMuNet as a digital, AI-powered platform that strengthens the sustainability, efficiency and resilience of multimodal European freight transport networks against disruptive events. Following the user needs derived from D3.2, the ecosystem’s value streams are revised with ReMuNet as newly integrated actor. Resulting advantages reach from higher integration of players in processes, such as disruption management, over higher data quality and availability with a centralised database in place and improved collaboration to AI-based route and capacity optimisation. These advantages lead to updated business models of key actors in the freight logistics network, which result in changed relationships between roles expressed by changing coopetition.

The presented ecosystem design is limited in a few aspects, which will be addressed in the subsequent D3.4, which will include the detailed ReMuNet business and operator model enriching the value stream on financial activities with monetarising and scaling strategies. Assumed advantages and changes in coopetition need to be validated in a later stage of the project since the ecosystem design resembles a theoretical concept based on scientific literature enriched with expert insights and opinions.

Including sustainability as core anchor of the new business models and enabling higher collaboration, ReMuNet envisions an efficient, sustainable and resilient ecosystem. The ReMuNet platform makes a key contribution in implementing the concept of physical internet (PI) in the logistics sector marking a milestone in digital innovation.

Concluding WP3, D3.4 will feature the ReMuNet business model and operator model. D3.5 introduces the Fit4ReMuNet transformation methodology. D3.6 already discussed standardised digital handover protocols for multimodal relay transport. Finally, D3.7 and D3.8 will detail the platform components of the frontend and the backend.

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Appendix

A1: Interview Guide

Preparing the Interview

As part of pre-interview exercises, the following aspects of data protection are considered:

1. The interviews will be conducted online using MS Teams and a digital concept board (Mural).
2. The concept boards will be processed and summarised reports will be made publicly available as part of project reports without individual identifiers. Interviewee consent will be sought before beginning the interview. The content developed in the interview is worked out together on a digital whiteboard and prepared in a summarized form and sent to the participants. All records with identifiers will be stored in secure locations at FIR, accessible only to the team. These records will be available for up to 1 year after completion of the project. Results will be published anonymously and consolidated.
3. The terms of confidentiality and the format of the interview will be explained at the start of the interview. The interviewee will be given the opportunity to ask clarifying questions.
4. The meeting will be recorded using MS Teams and written notes on the digital whiteboard. The in-built transcription tool will be used to create first version of the transcript. This will be revised by the interviewers by listening to the recording

List of Interview Questions

#	Guiding Questions Phase 1
1	Were all relevant roles and activities taken into account in the process?
2	Is the process correctly represented?
3	Is the timing of the task force appropriate? And who will initiate it (infrastructure manager)?
4	How often does a route get closed? How is the information passed on?
5	Was a task force formed? If so, was the actor involved? Who were the participants?
6	To what extent could a digital platform such as ReMuNet support Phase 1 and make it more resilient?
7	What would phase 1 ideally look like? (Communication, etc.)
	Guiding Questions Phase 2
8	Is the process correctly represented?
9	How does the flow of information (including communication) work in the current process?
10	How is the disruption process tracked?
11	Assessment of the percentage distribution of the three options: rerouting, mode shift and waiting + what role do costs play?
12	What would phase 2 ideally look like (communication, etc.)?
13	To what extent could a digital platform such as ReMuNet support Phase 2 and make it more resilient?

#	Guiding Questions Phase 3
14	Is the process correctly represented?
15	Distribution of results + who receives them + general communication?
16	To what extent could a digital platform such as ReMuNet support Phase 3 and make it more resilient?
17	What would phase 3 ideally look like?
	Guiding Questions General Part
18	What is the overall timeline for the process?
19	What are currently the biggest challenges in communication?
20	Transferring the process from rail to other modes
21	Further comments

A2: List of Interviewees

IP	Role & Nationality	Business Activities	Why the interview partner was selected
01	Applied Research <i>Austria</i>	Conducts applied research in digital transformation, production, and visual computing.	The research institute has a high reputation for its expertise in applied transport and logistics research. With its focus on digitalisation, supply chain management and operational resilience, it is ideal for gaining insights into the management of disruptions in complex transport ecosystems.
02	Terminal Operator & Carrier <i>Austria</i>	A major trimodal logistics hub, integrating water, rail, and road for international trade. Handles cargo, warehousing, and terminal services.	As a major Terminal, it has extensive experience in coordinating multimodal transport and handling operational challenges, making it well positioned to provide practical insights into disruption management and resilience within complex transport networks.
03	DLSP <i>Germany</i>	Provides a digital platform connecting shippers and carriers to optimise freight management.	Its role in connecting shippers, carriers, and logistics providers offers valuable insights into how disruptions are monitored, managed, and mitigated across complex supply chains.
04	MTO <i>Switzerland</i>	Runs a European intermodal rail network with daily shuttle trains. Provides sustainable logistics services and operates key terminals.	The operational knowledge and expertise in coordinating complex logistics chains connecting multiple countries across Europe make it an ideal source of insights into strategies for managing disruptions and maintaining efficiency and reliability in multimodal transport networks.
05	Corridor Coordinator <i>Germany</i>	Operates one of Europe's largest rail freight networks, offering multimodal logistics across multiple countries. Coordinates disruption management processes involving multiple stakeholders across Europe.	Having a central position in European rail freight operations and expertise in handling operational challenges and implementing strategies to mitigate disruptions makes it an ideal source for understanding how resilience and efficiency are maintained in complex rail and multimodal transport systems.
06	MTO <i>Germany</i>	Operates a European trimodal logistics network linking seaports and inland hubs via barge, rail, and truck. Provides terminal services, container transport, and leasing.	The experience in managing barge, rail, and truck operations across multiple European countries offers important perspectives on addressing challenges and enhancing the overall resilience of transport systems.
07	Industry Association <i>Belgium</i>	Represents European combined transport operators, promoting road-rail freight solutions.	This institution was selected for its role in representing and supporting combined road-rail transport across Europe. Its overview of intermodal operations and policy expertise provides valuable insights into managing disruptions and improving resilience in multimodal transport networks.

A3: Survey - List of Assumptions

Infrastructure Operator and Manager

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	1: IOMs will begin serving not only carriers but also digital platforms like ReMuNet as key data users 2: SMEs and local logistics actors will increasingly rely on IOM infrastructure due to improved access via ReMuNet.
What?	3: IOMs will increasingly maintain and operate infrastructure based on real-time usage metrics and insights from past disruptions to enhance system reliability 4: IOMs will provide network-wide standardised interfaces for seamless integration into synchromodal route planning platforms
How?	5: IOMs will leverage routing plans and disruption data supplied by ReMuNet to optimise the management of their real-estate assets 6: IOMs will progressively integrate real-time data collection and sharing processes into their operations 7: IOMs will increasingly participate in capacity management and relay-point optimisation in the multimodal ecosystem
Why?	8: IOMs will differentiate themselves through better disruption handling
Sustainability	9: IOMs will enhance sustainability by reducing downtime and extending asset lifespans 10: The platform encourages better capacity utilisation of existing infrastructure, reducing the need for resource-intensive expansions by IOMs

Carrier

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	11: New platform-based partnerships will allow carriers to reach end customers they previously accessed only through intermediaries
What?	12: Carriers will offer more flexible, real-time-available capacity into a shared multimodal network 13: Carriers will provide more accurate emissions-transparent transport services
How?	14: Carriers will leverage ReMuNet's disruption alerts to react more swiftly to unforeseen events, minimising service interruptions 15: Carriers will integrate their fleet and capacity data into ReMuNet, enabling dynamic orchestration and booking 16: Carriers will collaborate more closely with other carriers in different modes to enable synchromodal transport 17: Fleet management will be increasingly driven by real-time routing suggestions and disruption data from the platform 18: Relaying freight between actors (e.g., handovers at exchange points) becomes a core operational process
Why?	19: The faster reaction capability (by the use of ReMuNet) enables carriers to make more informed, timely decisions 20: The faster reaction capability (by the use of ReMuNet) reduces delivery delays and enhances overall cost efficiency 21: Carriers will generate increased revenue from participating in orchestrated relay chains, even for partial routes 22: Carriers will increasingly monetise flexibility and responsiveness during disruptions 23: ReMuNet reduces dependence on traditional freight forwarders, improving margin control

Dimension	Assumptions on BM Alterations through ReMuNet
Sustainability	24: Shared relay transport increases vehicle utilisation and reduces empty runs, improving resource efficiency 25: Platform transparency allows carriers to better benchmark and optimise their environmental performance

Multimodal Transport Operator

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	26: ReMuNet enables a broader range of customers or partners in need of orchestrated end-to-end services
What?	27: MTOs will shift from static transport chains to modular, on-demand relay services that can be dynamically reconfigured 28: MTOs will provide seamless orchestration, documentation, and digital handover via ReMuNet-APIs and interfaces
How?	29: MTOs will rely on ReMuNet to access and orchestrate live carrier capacity across modes 30: MTOs join the ReMuNet platform to optimise capacity utilisation across their multimodal networks 31: Own-asset operators will use ReMuNet to optimise asset utilisation
Why?	32: The faster reaction capability (by the use of ReMuNet) enables more informed, timely decisions, cutting delivery delays and reducing costs 33: MTOs will earn from managing resilient, low-emission multimodal chains, not just static contracts
Sustainability	34: More efficient route planning and reduced buffer times minimise unnecessary transport emissions. 35: MTOs maintain value by reducing resource consumption across their multimodal transport networks

Terminal Operator

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	36: Terminals will increasingly serve digital orchestration platforms like ReMuNet as indirect clients via data integration 37: Terminals serve ecosystem partners not only operationally but also through data and capacity-sharing interfaces
What?	38: Terminals maintain and operate based on planned usage forecasts and disruption data to increase overall reliability and reduce operational costs 39: Digitalised handover and documentation processes will become part of their core offering
How?	40: Terminals will leverage ReMuNet's routing plans and real-time disruption analytics to optimise terminal capacity and resource allocation 41: Terminals will digitise core processes and share capacity and availability data with ReMuNet 42: Cooperation with MTOs, carriers, and infrastructure operators will be more API-driven and standardised
Why?	43: By offering superior disruption handling and tightly controlled management of freight carriers via ReMuNet, terminals can distinguish themselves through enhanced service resilience

Dimension	Assumptions on BM Alterations through ReMuNet
Sustainability	44: Terminals increase their sustainability by minimising time lost in transshipment processes 45: Terminals unlock value by providing actionable insights and data analytics that enable stakeholders to make informed decisions 46: Terminals increase their sustainability by optimising operational flow to reduce energy consumption

Software Provider and Consulting

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	47: SPnC will integrate the ReMuNet platform as a core ecosystem partner and thus expand their service offering for LSPs
What?	48: SPnC will deliver plug-in solutions that enable seamless integration into the ReMuNet data and orchestration environment
How?	49: SPnC will integrate the ReMuNet platform directly into their solutions via APIs, embedding its data feeds and routing capabilities
Why?	50: Revenue comes progressively from subscriptions, licenses, or usage-based models for ReMuNet-compatible software modules
Sustainability	51: When integrating ReMuNet, SPnC increase sustainability by avoiding waste through optimised processes and streamlined resource utilisation

Freight Forwarder

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	52: Freight Forwarders will collaborate more directly with platform-integrated actors like terminals, MTOs and IOMs
What?	53: Freight Forwarders will offer digital booking, documentation and real-time tracking more aligned with platform standards 54: Forwarders will use ReMuNet to access live capacity, plan resilient routes and manage bookings across modes 55: End customers will expect increased digitally supported, resilient, and green logistics solutions as a standard
How?	56: Freight Forwarders will leverage ReMuNet's dynamic routing algorithms to react more swiftly to network disruptions 57: Freight Forwarders will coordinate more efficiently with other ecosystem players using shared standards, APIs, and real-time data
Why?	58: The enhanced agility (by the use of ReMuNet) delivers superior capacity utilisation across their transport network 59: The use of ReMuNet minimises time delays and overhead, boosting overall efficiency and service reliability
Sustainability	60: Freight forwarders increase sustainability by avoiding waste through optimised route planning, cargo consolidation and minimisation of empty-leg runs 61: Freight Forwarders unlock value by facilitating informed decision-making, providing clients with transparent data on environmental impact

Digital Logistics Service Provider

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	62: DLSPs will increasingly serve ReMuNet itself and other digital platforms as integration and optimisation partners 63: DLSPs will progressively support public-private collaboration by offering scalable digital infrastructure without physical dependencies
What?	64: DLSPs offer new service solutions via integration of their services into the ReMuNet platform
How?	65: DLSPs that incorporate ReMuNet into their solution can respond more quickly to detected disruptions thanks to optimised dynamic routing algorithms
Why?	66: The accelerated responsiveness (by the use of ReMuNet) directly reduces time delays, ensuring more punctual deliveries and enhanced service reliability
Sustainability	67: DLSPs increase sustainability by making green transport offerings accessible through their platforms, empowering shippers and carriers to seamlessly choose and implement eco-friendly logistics solutions 68: Using ReMuNet lead to a faster response to identified disruptions thanks to its optimised dynamic routing algorithms

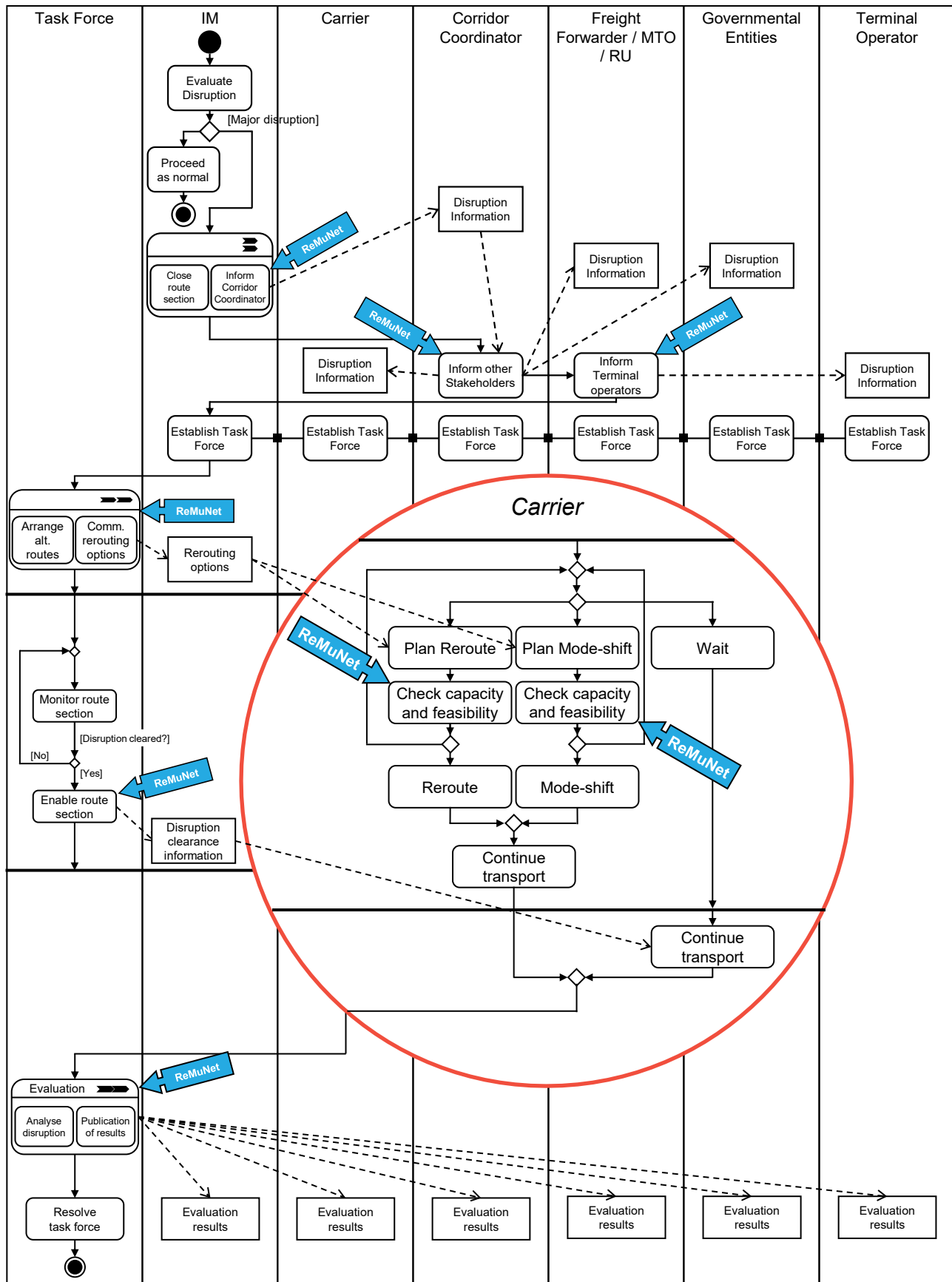
Consignor

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	69: Consignors continue to serve business clients or consumers but now do so through a more resilient, visible, and multimodal delivery chain enabled by ReMuNet
What?	70: ReMuNet's real-time tracking and predictive analytics help to make ETA more accurate 71: Consignors offer enhanced delivery reliability and reduced disruption risk by participating 72: Consignors better differentiate themselves with logistics-related service offerings (e.g., green delivery, guaranteed lead times, delay transparency)
How?	73: Operational planning is increasingly based on live capacity, congestion and emissions data 74: Consignors will collaborate more directly or indirectly with ecosystem actors like DLSPs, MTOs and IOMs
Why?	75: Improved ETA accuracy enables consignees to plan their production schedules and inventory requirements more effectively, thereby improving the coordination of the entire supply chain 76: More reliable and predictable delivery enhances customer satisfaction 77: More reliable and predictable delivery supports repeat business 78: More reliable and predictable delivery increases brand value
Sustainability	79: Consignors increase sustainability by avoiding waste through precise alignment of production schedules with outgoing shipments 80: Consignors can actively select low-emission routes and carriers, reducing their transport footprint

Consignee

Dimension	Assumptions on BM Alterations through ReMuNet
Who?	81: Consignees become internal beneficiaries of improved logistics
What?	82: Consignees turn timely, precise deliveries into competitive advantage
How?	83: Consignees use improved predictive arrival information to adjust production lines or labour allocation dynamically
Why?	84: Consignees' increased efficiency and responsiveness become key profit drivers, enabled by timely logistics 85: Optimised disruption handling reduce the need for safety stock 86: Optimised disruption handling lower operational costs and increase working capital efficiency
Sustainability	87: Consignees increase sustainability by avoiding waste through just-in-time inventory management and optimised production planning

A4: Disruption Management Process



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 utilization, suggests transshipment points and optimizes capacity allocation, minimizing 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 incentivize 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

 RØDE KORS	DANSK RØDE KORS (DANISH RED CROSS)	DRC
	ILMATIETEEN LAITOS	FMI
 Alliance for Logistics Innovation through Collaboration in Europe	ALLIANCE FOR LOGISTICS INNOVATION THROUGH COLLABORATION IN EUROPE	ETP-ALICE
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