ReMuNet

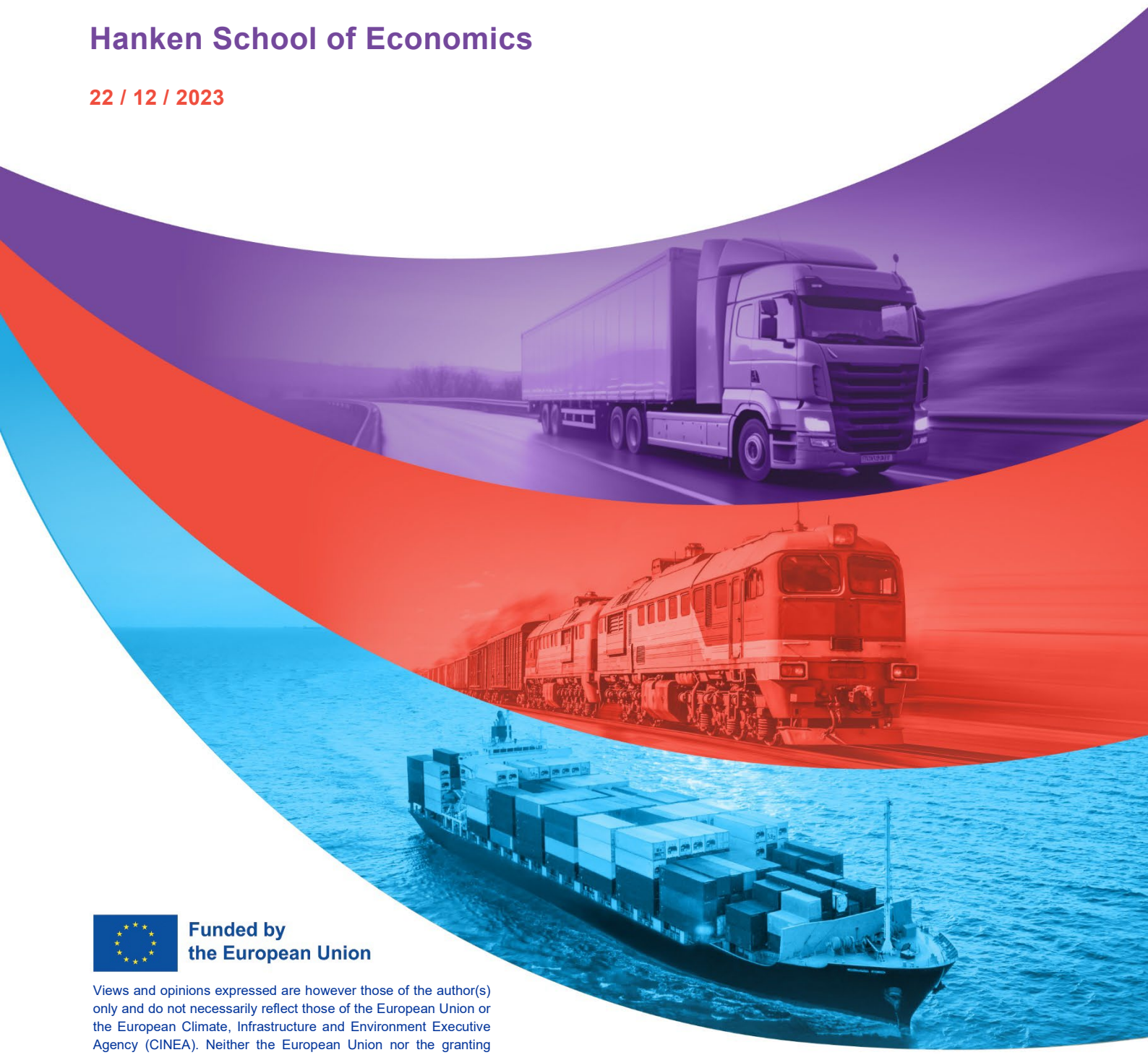
Pioneering resilient and adaptive multimodal transport networks

D1.3

Classification of Disruptive Events

Hanken School of Economics

22 / 12 / 2023



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Executive Summary

The transport network in Europe is facing severe and frequent disruptions due to the dynamic geo-political situation in the region, as well as the effects of climate change. The EU Horizon project Resilient Multimodal Transport Networks (ReMuNet) is focused on improving the resilience of the transport network, considering alternate routing options, and identifying disruptions and ways to mitigate their effects.

One of the four core objectives of the ReMuNet project is to develop a standardized methodology to describe multimodal transport networks. The proposed standard is derived from existing approaches and developed together with critical stakeholders to ensure Europe-wide practicability and acceptance. This allows for the standard to be easily transferred into appropriate regulatory frameworks ensuring more efficient communication and operational stakeholder interconnectivity. The first task towards this core objective is **Task 1.3: Creating a typology of disruptive events**, which is addressed in this report. Building on existing typologies, for example classifications of disasters, this report analyzes disruptive events in European transport networks for a better understanding of the disruptions, the potential reactions to them and the actions to prevent them from occurring and to mitigate their effects.

As a first step in this research, the team at HUMLOG Institute (Hanken School of Economics) conducted an interview study to 1) define disruptive events from the perspective of logistics operators and key stakeholders, 2) to identify frequently occurring and severe disruptive events and 3) to understand standard practices of managing these disruptive events. One of the key findings from this study was that although stakeholders have different definitions for disruptions, their thoughts on disruptions converge to thematic groups such as viewing disruptions as blockages, delays, or change in business-as-usual. The other important result included the viewpoints of participants on what they considered to be the vulnerable link in the EU transport network, and a majority highlighted the railways. The analysis revealed that railways were considered critical for achieving the goals of sustainability and yet, they were sensitive to infrastructural damage and irregularities in energy pricing. Another insight offered was that the managers often prioritized impact and response of disruptions over an analysis of root-causes. This is because of the financial pressures that govern the operational practices.

The viewpoints of various stakeholders including terminal operators, freight forwarders, software system developers, rail, road, and shipping operators, government agencies, and consultants are considered in defining the key terminology related to disruptions in the EU multimodal freight network. The typology developed here highlights ten different categories of causes, as well as dimensions of disruptive events, and their impacts on individual actors, nodes, links, the entire transport network, and cascading effects on supply chains and society. This study is an important exercise to achieve the ultimate goal of the project: **the building of a collaborative platform and taking the first steps towards an Artificial Intelligence (AI) based self-learning transport network to promote synchro-modal relay transport across European rail, road, and inland waterways to improve network resilience, reduce emissions, and boost corridor efficiency during disruptive events**.

The terminology and classifications developed in this qualitative study will be a critical input to the mathematical models that follow in subsequent work packages.

1. Introduction

As natural catastrophes multiply in the wake of climate change, the risks of pandemics and geopolitical conflicts are omnipresent, the threat of disruptive events to the European transport network grows ever greater. With increasing complexity of global supply chains and closely timed transport schedules, the vulnerability of European trade to disruptive events will continue to increase unless transport networks become more resilient (Kiebler et al., 2021). ReMuNet identifies and signals disruptive events and assesses their impact on multimodal transport networks. This report is part of WP 1, which includes the development of a typology of disruptive events as T1.3. Building on existing literature, this report analyses disruptive events in European transport networks to enhance the understanding of the events and the reactions to them as a basis for being able to prevent them from occurring or to mitigate their effects.

An important contribution of this analysis will be the compilation of different perspectives of disruptions of the various stakeholders in the multimodal EU transport network. Apart from interviews, the research team also engaged with industry partners in the EU and masters' students of a supply chain course at Hanken School of Economics through focus groups on categories and root causes of disruptive events. Participants identified multiple disruptive events in the last 5 years in the EU and in small groups of 5-8 people, discussed the causes, impact, and response for each event. At the end of the discussion, each group came up with a list of categories in which these disruptive events can be placed.

The typology will create better understanding of disruptive events occurring in the European transport network, offering insights into effective mitigation strategies and improved disruption management. Further, the results from the qualitative study will help build the foundation for an AI-based platform to be developed later in the project, providing crucial information for disruption modelling.

1.1 Research questions

The main goal of this research is to create a typology of disruptive events. The sub-aims of the research presented in this report are as follows:

1) To define disruptive events from the perspective of logistics operators and key stakeholders,

2) To identify frequently occurring and severe disruptive events and

3) To understand standard practices of managing these disruptive events.

A qualitative study involving interviews with stakeholders and focus groups was planned to address the research goals. To guide the discussions with participants of the study, a set of research questions (RQs) was identified. These research questions were then further developed into an interview guide (described later in the report). The following table shows the RQs.

Table 1: Research questions

	Research question
1	What are the categories of disruptive events based on their causes?
2	What disruptive events are specific to which transport mode?
3	What are examples of each category of disruptive events?
4	Apart from cause, what are other ways of classifying disruptive events?
5	What is most relevant for the disruptive event: cause, effect, reaction, or something else?
6	What type of disruptions have been most impactful in recent times?
7	What types of disruptions will gain / lose importance in the next 5 years?

This report is structured as follows: first, a description of the review of state-of-the-art is presented, where knowledge gaps are identified, and relevant terminology is highlighted. Next, the focus groups are described, along with an analysis of key outputs in Section 3. This is followed by a detailed description of the interview process and analysis of the interview metadata in Section 4. Sections 5 and 6 address the main tasks in the deliverable by presenting the analysis on disruption definitions and classification. Section 7 presents some other interesting insights observed in the qualitative study. The report concludes with a summary of the key points in the discussion in Section 8. The interview guide used in the study is presented in the appendices of this report.

2. Literature review

Two create a typology, the two key topics discussed in this report are 1) the definition of disruptions or disruptive events in the context of transport networks and 2) classification or categorization of disruptive events, especially those affecting the EU multimodal transport network. The qualitative study began with an analysis of existing literature on the definitions and classifications of disruptive events. Some of the previous, related work on both these topics is presented in this section. The ideas that are relevant to the study at hand are identified, while knowledge gaps in existing literature are also highlighted.

2.1 Defining disruptions and disruptive events

Disruptions within a transport network, are a major threat for a network's reliability and efficiency (Ambulkar et al., 2015), (Bode et al., 2011), (Bode & Macdonald, 2017), (Craighead et al., 2020), (Burgholzer et al., 2012). The definition of disruption as per the Cambridge dictionary is an ‘action of preventing something, especially a system, process or

event, from continuing as usual or as expected'. Craighead et al., (2007) define supply chain disruptions as *unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain*. Ambulkar et al (Ambulkar et al., 2015) extend this definition to include the impact and '..and *can have severe negative consequences on the financial, market and operational performance of the firm'*.Bugert and Lasch (2018) describe disruptions as originating from *unforeseen triggering events in combination with consequences which jeopardize normal business activities and the flow of material*. Another perspective is offered by El Baz and Ruel (2021), who define disruptions as *events that occur with low frequency but have a high impact*. There have been some efforts made by various others to define disruptions, if not extensively, at least in the context of their research. Many authors have acknowledged the multi-dimensionality of the term and the lack of consensus. Another article (Katsaliaki et al., 2022) that conducts a literature review of supply chain disruptions and resilience, avoids defining disruptions altogether, instead diving straight into causes and impact. Indirectly, Katsaliaki et al. (2022) define disruptions through their causes.

As observed from the multiple references cited above and analysis of the review papers, one common theme for academic definitions of disruptions is the emphasis on uncertainty (unplanned, unexpected) and the high impact associated with it. Through the work presented in this report, **we propose to expand the definition of disruptions to include even planned or expected events** that may have a high impact as well. The role of cause and impact in defining disruptions and other aspects to be considered in the terminology are discussed further in this report.

Vulnerability in the road transportation system is a susceptibility to incidents, or disruptive events, that can result in considerable reductions in network serviceability (Berdica, 2000)(Berdica, 2002). This definition emphasizes that there is an initiating disruptive event, that the fundamental purpose of the transport system is hurt (its ability to provide transport services to the users), and that the adverse consequences are significant (Mattson and Jenelius, 2015).

2.2 Information and material flows in transport networks

The ReMuNet project is focused on improving resilience in the face of disruptions for the EU multimodal transport network. The work aims to be inclusive of the diverse set of stakeholders of the transport network. These stakeholders are not just freight forwards, cargo owners or fleet operators, but also managers of logistical information, software developers (for example, online booking portals and network planning software) and other processors of data for various uses. It can be said that there are two flows integral to the multimodal transport network: one is the actual flow of materials involving the transport vehicles (modes) and nodes (terminals and warehouses) and the other is the flow of information required to organize the material flow. Although a detailed discussion of these two flows is beyond the scope of this report, a short summary of some related literature is presented here for readers who wish to acquaint themselves with the relevant terminology.

The information layer is also referred to as semantic layer or intelligence flows. The study of flow of materials, on the other hand, is also described as transport flows, freight chains or simply transport networks. Further in the report, there is a description of these layers by some participants of the qualitative study. Since there is no formal definition for these terms, the general concept behind the interaction of data and transport is described by individuals in their own ways.

Almotairi et al. (2011) examine how information and communication technology supports maritime container transport in Sweden's hinterland rail transport and identify a notable gap between increasing IT capabilities and business integration processes among companies, which could lead to inefficiencies also in the physical layer. Larioui (2020) explores the integration of semantic web technologies and multi-agent systems to manage multimodal transportation. Their study emphasizes the importance of the information layer for improving interoperability and communication among various agents in the transportation network, stressing the importance of the information layer for overall performance and to improve decision-making and enhance route planning. Reis & Macefo (2019) map information flows of freight transport chains and evaluate their complexity. They characterize information flows according to involved agents, timing, content, and message type, highlighting the importance of information flows for the seamless integration, and functioning of transport chains. Based on such prior studies, it is therefore essential to consider both physical and information flows in this report on disruptive events as disruptions in either can have serious consequences that challenge the resilience of transport networks.

2.3 Classification of disruptive events

To create a typology, we examined how previous literature has classified disruptive events. While investigating classification of disruptive events, the starting reference point chosen is that of **classification of disasters**, described in humanitarian operations literature. This seemed an intuitive approach, since every disaster, by its very definition, is a disruption to the normal functioning. Figure 1 shows two such classification approaches. These approaches are based on two dimensions, 1) *causes* (classified either natural or man-made), and *time* (sudden-onset and slow-onset).

	Natural	Man-made
Sudden-onset	Earthquake Hurricane Tornadoes	Terrorist Attack Nuclear Chemical Leak
Slow-onset	Famine Drought	Political Crisis Refugee Crisis

(a) Van Wassenhove, 2006

	Natural	Man-made
Sudden-onset	Earthquake Landslide Flood Drought	Bush fire Industrial fire Water pollution
Slow-onset	Soil erosion Coastal erosion	Influx of refugees /returnees

(b) Kovács & Spens, 2009

Figure 1: Classification of disruptions

In the first approach, the disasters are classified as either natural or man-made. For both these categories, there are again two alternatives: sudden-onset and slow-onset disasters. Each disaster is classified in one of the four boxes as shown in (a). This classification approach was extended as shown in (b), where some disasters were placed across the categories. For example, floods are natural events that may have human causes (such as a human activity triggering it). The ReMuNet project aims to model in detail the wide range of disruptions faced by diverse stakeholders in the EU multimodal transport network. For this purpose, the above classification approaches lack the necessary granularity required to be of value to the project.

Examining prior literature on distributive events in transportation networks, disruptive events have been classified according to their respective *causes*. Jenelius & Mattsson, (2015) classify between internal and external causes of disruptions and between accidental events and intentional interferences, as presented in Figure 2. Internal causes may originate from mistakes and accidents caused by staff or users, technical failures, components that break down, faulty constructions, overload, etc. External causes may be related to natural phenomena including various degrees of adverse weather and natural disasters: heavy rains, snowfalls thunderstorms, floods, wildfires, landslides, tsunamis, volcanic eruptions, earthquakes, etc. External causes also include antagonistic actions ranging from sabotage, terrorist attacks to war.

Serdar et al., (2022) in their turn classify disruptive events, or disturbances as they call them based on (1) causes (natural hazards, intentional attacks, accidents and failure propagation, (2) *scale* (large, medium, small), (3) *affected parts* (random, predictable), and (4) impact (Low, medium, high).

Further, Jenelius & Mattsson, (2015) in their literature review of vulnerability of transport system classify distributive events based on so called 'triplet': (1) *duration, (2) the levels of capacity reductions, and (3) elements involved (the set of links and nodes).* Further, in their categorization of transport networks vulnerability to disruptive events, they include dimensions such as probability (what is probability that element is being disrupted) and the importance or criticality of the element. The main purpose behind the importance measure is to compare and rank different elements (nodes and links). This allows, for example, the identification of parts of the transport system where disruptions would be particularly severe (Jenelius and Mattson, 2015). In a bit similar vein, Burgholzer et al. (2013) categorize the

impact of disruptive events based on their (1) impact on *entire transport network*, and (2) impact on *individual transport units*.

Next, we investigated classification approaches used in supply chain risks. The discussion of disruptions also often covered the associated risks, to determine the likelihood and extent of impact. Hence, **classifications of risks** were studied to find relevance to disruptions.

While the importance of supply chain risk management is recognised in literature and reflected in a growing body of research, what constitutes risks is less well explored (Rao & Goldsby, 2009). However, Jüttner et al., (2003) identify four management aspects for supply chain risk management which could be seen as constituting key elements for what constitutes a supply chain risk. They are:

(1) assessing the risk sources for the supply chain.

(2) defining the supply chain adverse consequences.

(3) identifying the risk drivers; and

(4) mitigating risks for the supply chain.

Following this, a supply chain risk could be categorised by its cause, its consequences, as well as what drives it and what mitigates it.

The links between supply chain risk and resilience are well-explored in literature (Macdonald et al., 2018), but the same is not true for transport. However, some insights are transferrable due to the inter-connected nature of the topics. Nevertheless, supply chain risk literature has a different focus and typologies from this area are often structured according to different supply chain activities, such as sourcing risks, manufacturing risks, and delivery risks (Um & Han, 2020).

It is clear from the supply chain risk and resilience literature that a thorough understanding of the situations faced facilitates the employment of relevant mitigation strategies (Um & Han, 2021). Identifying antecedents and investigating their relative importance is regarded as essential to improving resilience to supply chain disruptions (Shekarian & Mellat Parast, 2021). This substantiates the importance of developing the typology of disruptive events in this report. Furthermore, the extant literature highlights that risk events have extensive ripple effects that result in further consequences and underscores the importance of sophisticated analytical tools in understanding the complexities of supply chain disruptions (Hosseini & Ivanov, 2020) and the factors linking disruptions to supply chain effects (Macdonald et al., 2018).

A supply chain risk classification review of articles from 2003-2015 provides useful insights into this topic (Hudnurkar et al., 2017). The authors identify nine sources of risks in supply chains including information systems, transportation, financial factors, and process related factors. Since ReMuNet deals with transport networks, the transportation related supply chain risks were reviewed in detail. Figure 2 shows a portion of the table on risk sources and descriptions reviewed by the authors. The first column is the source of risk, the second is titled “risk” and the third is the description of risk. The topics touched upon are relevant to the goals of ReMuNet, particularly multimodal transport. However, since the goal of the authors is to cover wider ground with generic supply chains, the discussions on multimodal

transport risks only finds a small mention. Throughout the review, the term disruption is referred to in various contexts, such as transport disruptions, supply disruption, and disruptions due to natural disasters.

Transportation	Transport Network	Disruption of Transport Network
	Network Complexity	Complexity, length of transport network
	Multimodal Transport	Product damage during product handling in multimodal transport
	Transshipment	Product damage during handling in transshipment
	Transport Delay	Risk to On-time /On-budget delivery due to delays in the transport network

Figure 2: Transportation risks in supply chains (Hudnurkar et al., 2017).

To create a reference point for ReMuNet, some of the relevant causes for disruptive events and risks of supply chains that are applicable for discussing disruptions in multimodal transport networks are selected from the more general list presented by the authors as follows:

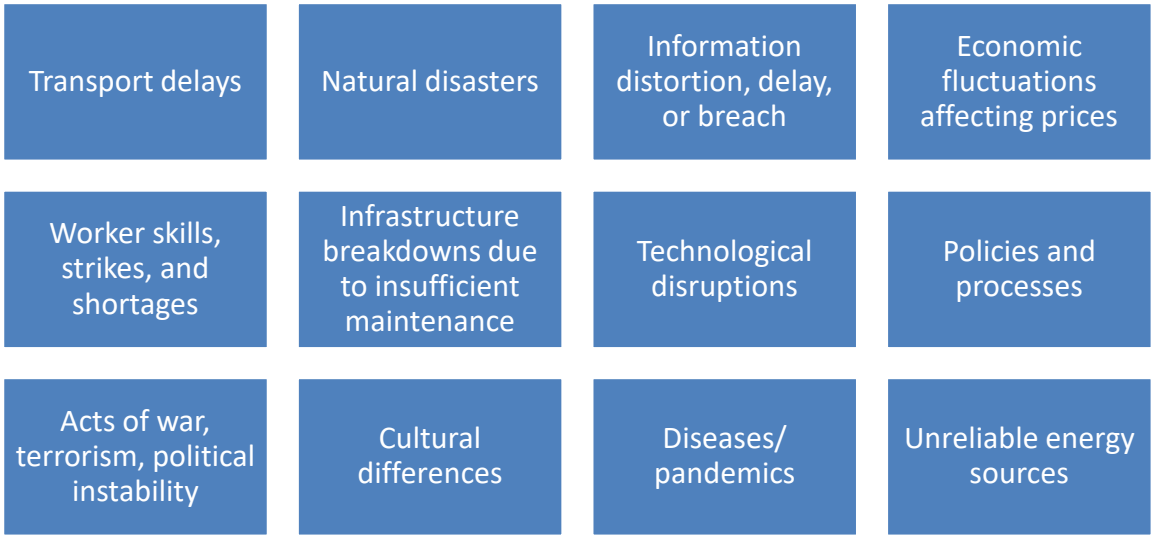


Figure 3: Possible categories of disruptions

This list of 12 categories will be used as a basis for comparing the results from the qualitative study that will be described in the remainder of this report.

3. Focus groups

The data collection for this work began with two focus groups. The first one (focus group-1) was conducted as a part of the 2-day physical kick-off meeting of the consortium in Aachen, Germany. The participants included not just members of the project consortium, but also industry board members. The second focus group (focus group 2) was conducted during a lecture at Hanken School of Economics for the course “Supply Chain Strategy for Sustainability”, involving master’s students. This section briefly describes the settings,

objectives, and initial observations from the focus groups. The Figure 4 shows a brief overview of the focus groups.

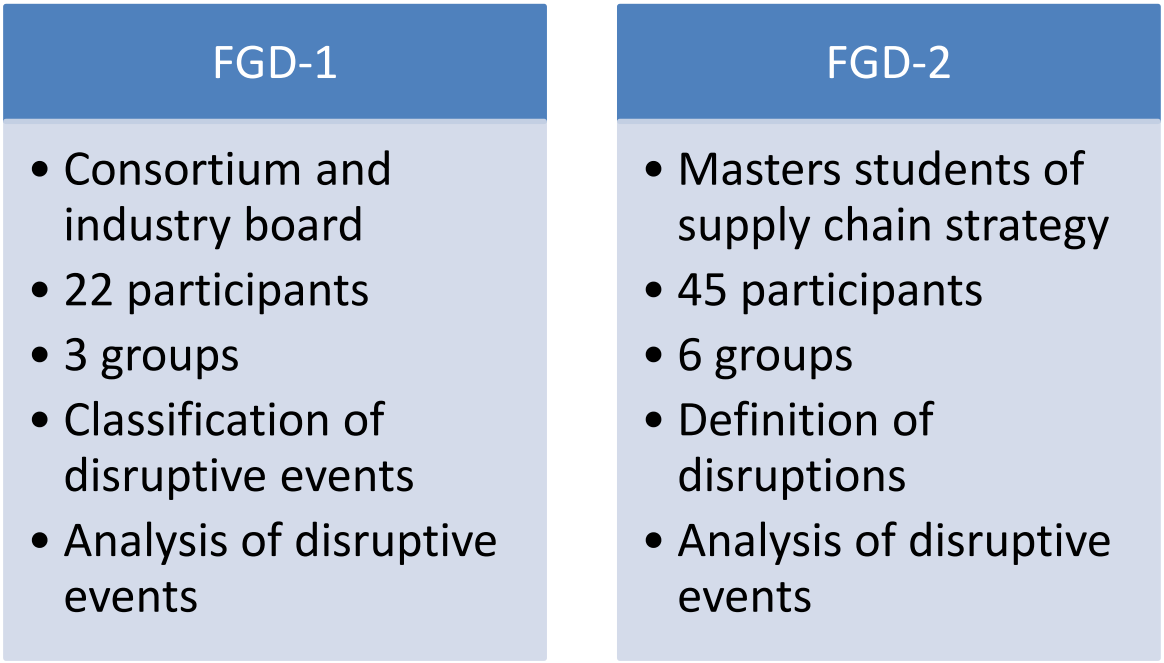


Figure 4: Overview of focus groups

3.1 Focus group on Classification (focus group-1)

For this discussion, the participants (total 22) were divided into 3 groups of 6-8 people each. They were then introduced to some existing classifications of disasters in the humanitarian logistics literature (Kovács & Spens, 2009). It was argued that the existing classifications are of insufficient granularity to be of value to the ReMuNet project. Therefore, a focussed discussion on classifications targeted at transport disruptions followed.

3.1.1 *Flow of the session*

The discussion had three parts. In the first part, the participants worked together to come up with categories for disruptive events based on their causes. These categories were jotted down on flipcharts. In the second part, participants were asked to think of examples of disruptions in each category that could affect the EU multimodal transport network. The groups were given post-it notes and encouraged to write each disruptive event on a separate note. The groups then placed the notes with examples on the flipcharts in the corresponding categories. Finally, in the third part, the participants discussed other bases for categorizing disruptive events, apart from their cause. The groups made additional flipcharts for this work.

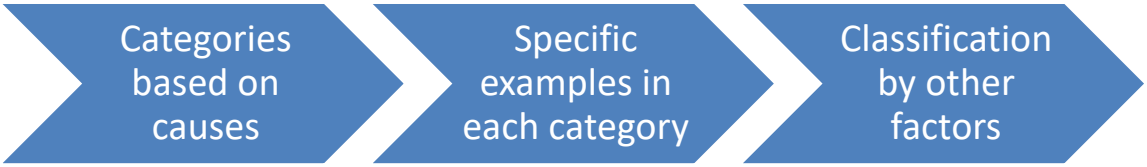
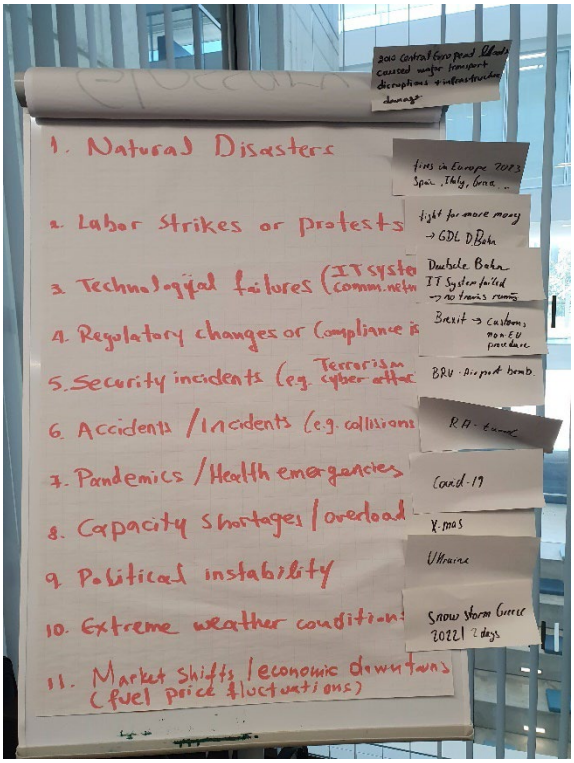


Figure 5: Parts of focus group-1

Figure 5 shows the outline of the session and its three parts. Next, a summary of ideas developed in the session is provided.

3.1.2 *Analysis*

The three groups came up with multiple recent examples of disruptive events globally and especially in the EU transport network. While one group preferred a simple, 2-category classification of natural and human-made disruptions, another group preferred to detail out 11 different categories. The last group had a middle of the road approach, with 6 categories. Figure 6 shows three of the flipcharts created during these sessions. The gathering as a whole discussed some of the findings after the group work. Some of the commonly identified disruptive events were Brexit (geo-political), the COVID-19 pandemic, the Russia-Ukraine war, and low water levels on the Rhine River. After a few rounds of discussion and based on inputs from all three groups, a common list of categories was collated. More details about these results are presented in the Section (6).



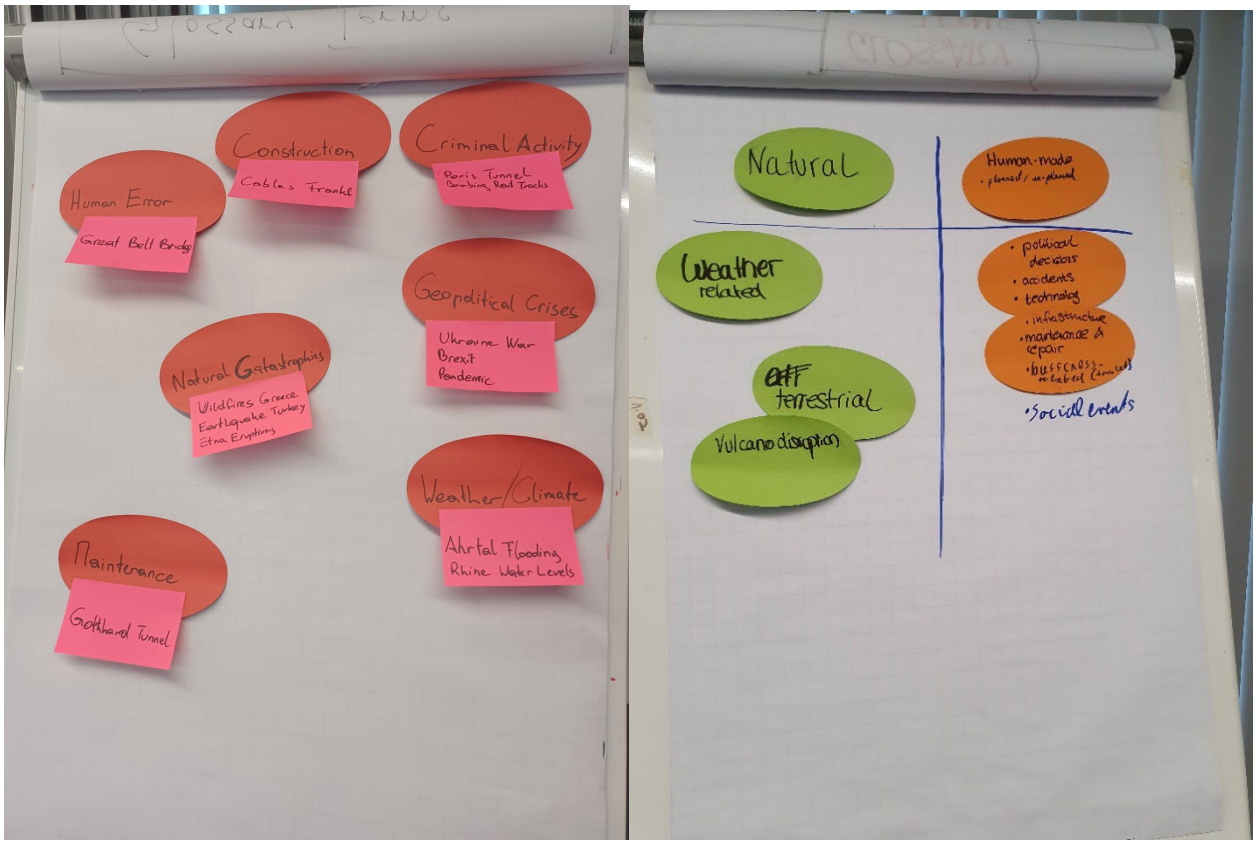


Figure 6: Classification of disruptive events

3.2 Focus group on Definition and Analysis (focus group-2)

The second focus group was conducted at Hanken School of Economics with the master's degree students, as mentioned earlier. The session saw a participation of 45 students, who were divided into 6 groups with 6-8 people in each group.

3.2.1 *Flow of the session*

Similar to the first focus group, this session also had three parts to it. First, the students were asked to define disruptions or disruptive events within their group. Next, the groups were asked to perform a survey of disruptive events in the last two years in Europe. After this, the groups chose any 3-4 examples from their list of disruptive events and identified the cause and impact for each. Finally, the participants came up with a list of categories for disruptive events based on their analysis. Figure 7 shows the outline of this session.

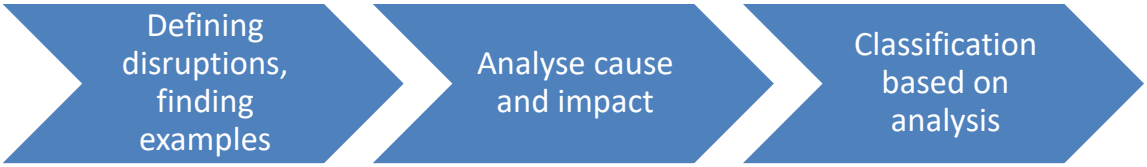


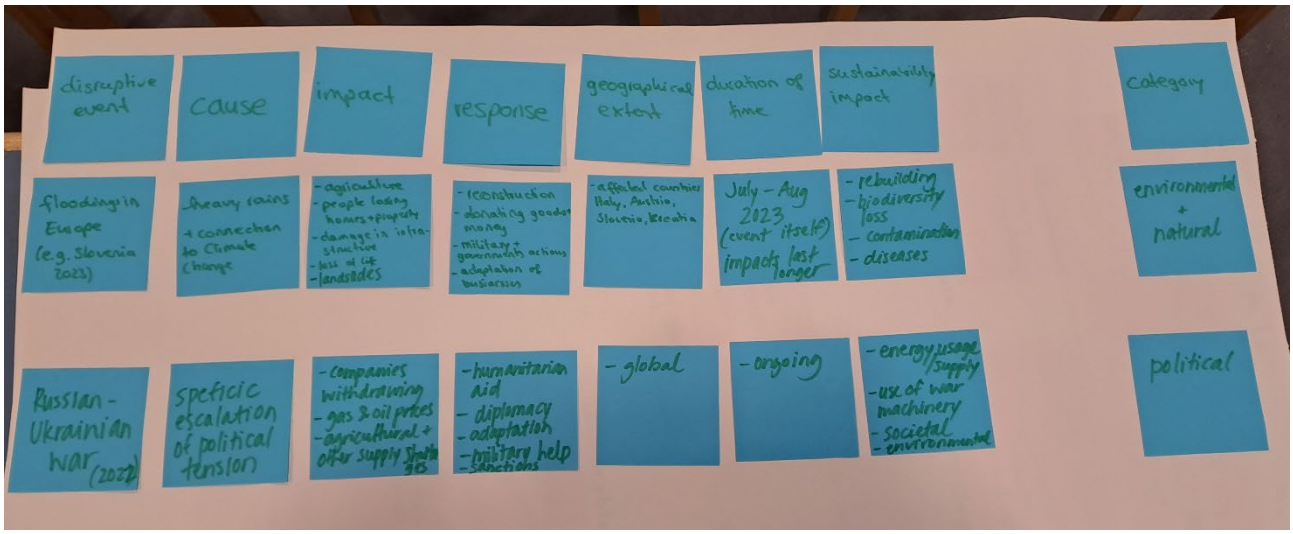
Figure 7: Overview of focus group-2

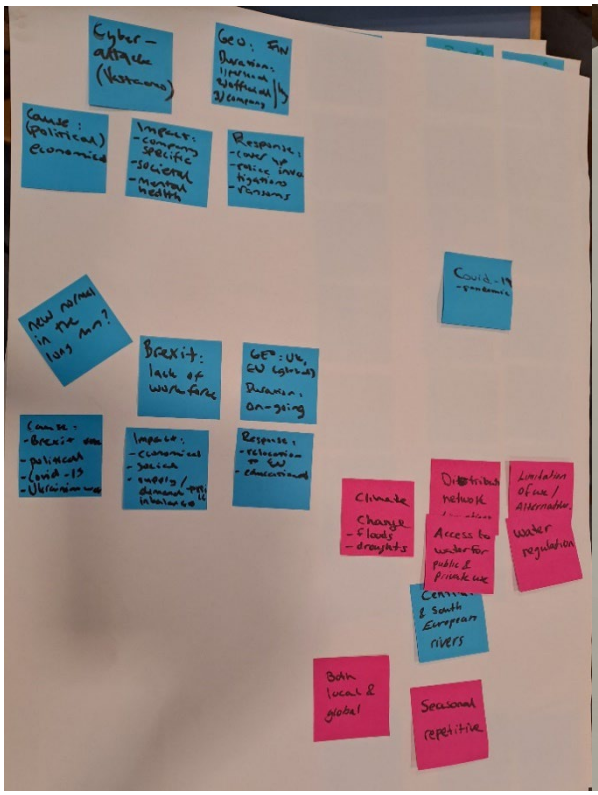
3.2.2 *Analysis*

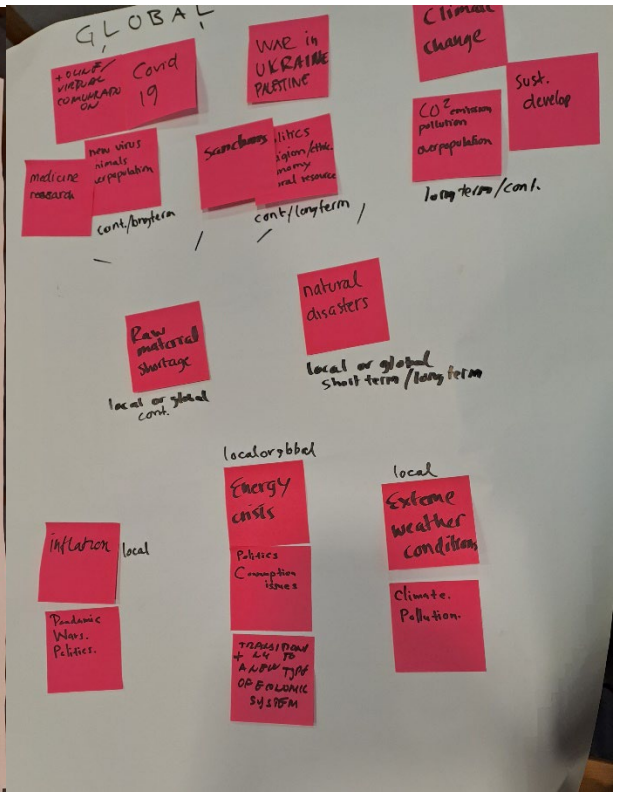
As part of the first step, each member of the group was asked to present their perspective to their teammates. Then the group was asked to discuss and arrive at a consensus for a common definition, that all members agreed with. The definitions from all 6 groups were displayed for the whole class and students had the opportunity to weigh in with their thoughts on other groups' definitions. In the second step, the students were given prompts to aid their analysis of the disruptive events they had shortlisted from step 1. These guiding questions were as follows:

- For each of the disruptions listed in the previous exercise
    - Identify the cause, the impact, and the response.
    - The geographical extent of the impact
    - The duration (time) of the impact
- Rate the disruptions based on their impact on sustainability.
    - Is the impact long-term or short-term?
- Come up with categories/classification of disruptions based on the characteristics identified.
    - Categorize disruptions you have identified.

At the end, the participants presented a list of disruptive events which were sorted by categories and discussed the basis for the categories they had identified. Figure 8 shows the flipcharts produced by the six student groups at the end of the lesson. It is interesting to observe that although the same information and guidelines were provided to each group, the final visualization of the disruption categories is quite different.


disruptive event
cause
impact
response
geographical extent
duration of time
sustainability impact
category
Floodings in Europe (e.g. Slovenia 2023)
heavy rains + connection to Climate change
- agriculture - people losing homes + property - damage in infra-structure - loss of life - landslides
- reconstruction - donating goods/money - military + government actions - adaptation of businesses
- affected countries Italy, Austria, Slovenia, Croatia
July – Aug 2023 (event itself) impacts last longer
- rebuilding - biodiversity loss - contamination - diseases
environmental + natural
Russian-Ukrainian war (2022)
speficic escalation of political tension
- companies withdrawing - gas & oil prices - agricultural + other supply
- humanitarian aid - diplomacy - adaptation - military help - sanctions
- global
- ongoing
- energy usage/supply - use of war machinery - societal - environmental
political


Cyber-attacks (Estonia)
Geo: Fin
Cause: (political) Economics
Impact: - societal
Response: - sanctions
Covid-19 - pandemic
Brexit: lack of workforce
Geo: UK, EU
Impact: - economical - social
Response: - education
Climate Change - floods - droughts
Distribution network
Limitation of use / Alternatives
Access to water for public & Private use
Water regulation
Central & South European rivers
Both local & global
Seasonal repetitive


GLOBAL
Covid 19
WAR in UKRAINE PALESTINE
Climate change
Sust. develop
medicine research
cont/longterm
cont/longterm
long term/cont.
natural disasters
Raw material shortage
local or global cont.
local or global short term/long term
local or global
Energy crisis
local
Extreme weather conditions
inflation
local
Pandemic Wars. Politics.
Politics Corruption issues
Climate. Pollution.

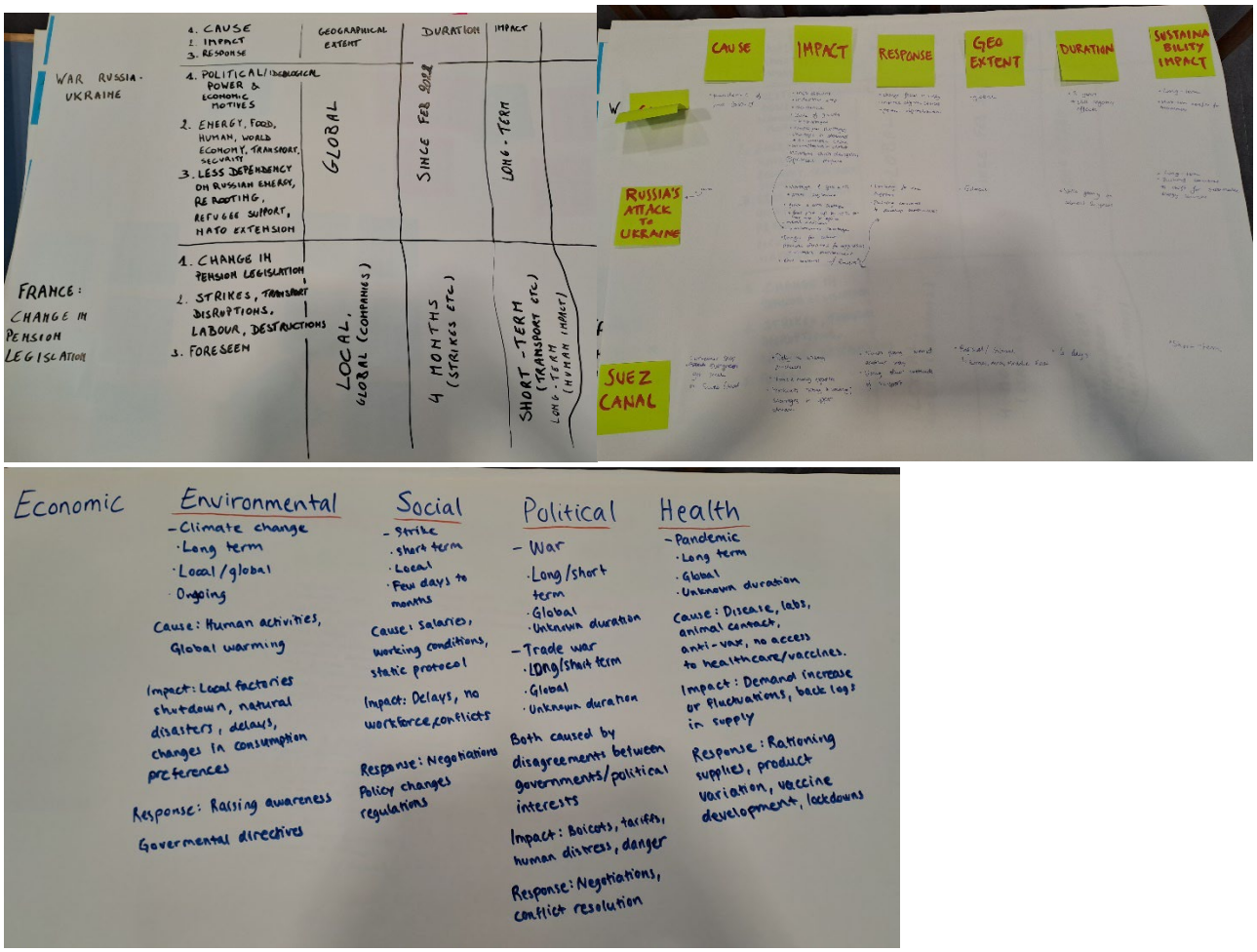


Figure 8: Flipcharts from focus group-2

More detailed results and the reasonings of each group from this focus group are presented in Sections 5 and 6.

4. Interviews with transport network stakeholders

Literature mentions 3 types of interviews: Informal conversational interview, general interview guide approach and standardized open-ended interview. The general interview guide approach is selected, which is a semi-structured approach (Iii & Hagstrom-Schmidt, 2022). The interviews followed the data management guidelines mentioned in the project proposal. Additionally, Hanken research services were consulted to draft a “Research’s privacy notice” and consent slides for the interviews. Appendix 10.1 of this report shows the forms shared with the participants and for which consent was sought and recorded. The deliverable for task 3.1 in month 36 of the project will officially present the data management plan for the entire project.

An interview guide is a list of questions which directs conversation towards the topic at hand during the process of the interview. The term is used interchangeably with “probe table”,

"interview protocol" and "interview questions" in literature. The interview guide used during this research is appended in the annexure of this report (Appendix 10.2). A total of 17 interviews have been conducted to gain insight into stakeholders' perceptions of disruptions in the EU multimodal transport network. Before analysing the inputs shared by the participants, a preliminary analysis was conducted, which processed all the information obtained from the participants before the interview. This will be referred to as metadata in the remainder of this section and is discussed next.

4.1 Analysis of metadata

The analysis of the metadata is now presented. First, the demographics of the interviews are analysed, including the countries they represent, gender of the interviewees and their relationship with the project, if any. Next, the role of the interviewee's organization in the EU multimodal network is analysed. Table 2 shows the coded information of the interviewees, indicating their role in their organization and the sector in which they are employed, along with the country.

Table 2: Interviewee details at a glance

S.No	Code	Role	Sector	Country
1	01-131023	Technical director	Combined transport	Belgium
2	02-161023	Member of management board	Terminal operator	Estonia
3	03-171023	Founder	Road freight relay	Germany
4	04-181023	Manager	Network planning	Germany
5	05-201023	Head, digitalization	Air freight	Switzerland
6	06-231023	Managing director	Terminal operator	Austria
7	07-231023	Transport consultant	Combined transport	Lithuania
8	08-251023	Head of sales	Network planning	Germany
9	09-271023	Senior project manager	Combined transport	Germany
10	010-271023	Managing director	Combined transport	Germany
11	011-011123	Logistics development manager	Government transport agency	Finland
12	012-021123	Sales manager, specialist	Terminal operator	Finland
13	013-021123	Consultant	Humanitarian logistics	Denmark
14	014-031123	Founder	Combined transport	Germany
15	015-101123	Consultant	Maritime shipping	Estonia
16	016-201123	Data manager	Terminal operator	Finland
17	017-211123	Project manager	Combined transport	Germany

4.1.1 *Demographics and background*

Figure 9 shows the countries of affiliation of the interviewees. Since the project eventually aims to focus on two pilot corridors: the Rhine-Danube corridor and the North-Sea Baltic corridor, stakeholders in countries along these corridors were targeted. A total of 8 countries were represented in these interviews: Germany, Finland, Lithuania, Estonia, Switzerland, Austria, Denmark, and Belgium.

Figure 9: Geographical spread of interviewees

When the stakeholders were approached for the interviews, they were given a brief about the project goals and were asked to recommend a person from their organisation to participate. Figure 10 shows the gender distribution of the interviewees. Of the 17 interviews, 2 interviews had 2 interviewees each (both from the same organization), resulting in a set of 19 interviewees, that have been used for the following analysis. The women represented just over a quarter of the participants. Although this distribution is hardly balanced, it is not an indicator of preferring one gender more over the other in the interviews.

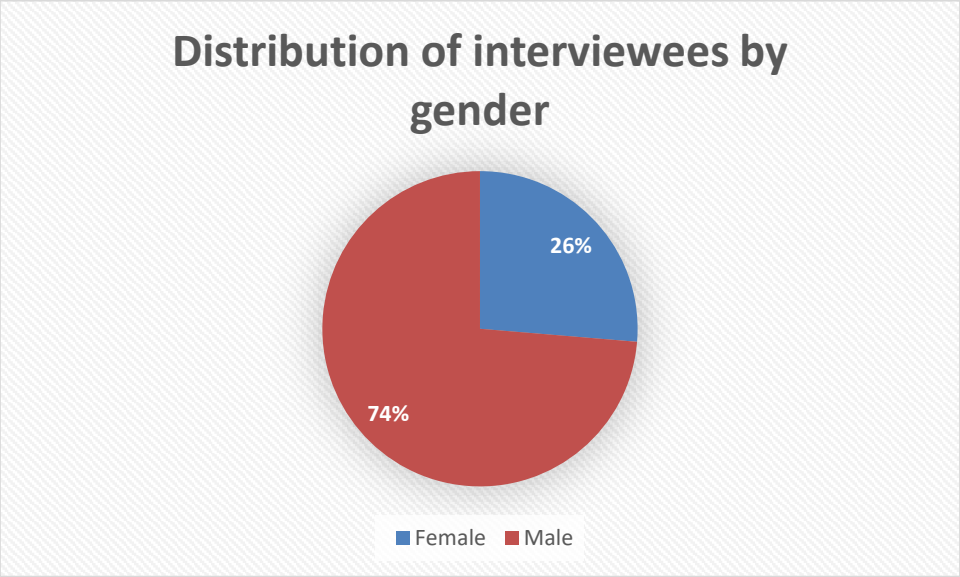


Figure 10: Gender of interviewees

In fact, it is quite reflective of the highly skewed gender ratio in transportation and logistics, as confirmed by many participants. According to the EU Platform for Change Women in Logistics, only 22% of transport workers are women, a similar percentage as that of the interviewees (*Women in Transport - European Commission*, n.d.). The next part of the analysis examines the nature of the organizations represented by the participants and their relationship with the project, if any.

4.1.2 *Role of the organizations*

The organizations represented by the interviewees are quite diverse yet sharing a common interest in the EU multimodal freight transport network. Figure 11 shows the relationship of the organizations with the ReMuNet project. As indicated by the pie chart, there is a good mix of participants from both within the project (members) and external. The project members and the industry board were expected to already have an idea of the project goals and the aims of this work package. Furthermore, most members had also participated in a focus group conducted during the project kick-off (Section 3.1).

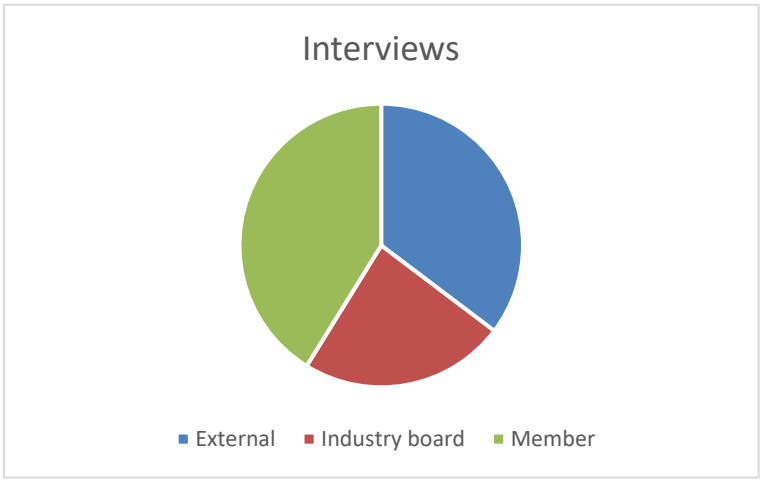


Figure 11: Affiliation of interviewees with the project

The external participants represented different roles in the logistics network and needed to be introduced to the project prior to the interviews. A project poster and brief information was shared during the outreach. A careful effort was made to reach out to organizations that either represented, operated, managed, or dealt with in some capacity, different models of transportation and different intermodal operations commonly practiced in the EU.

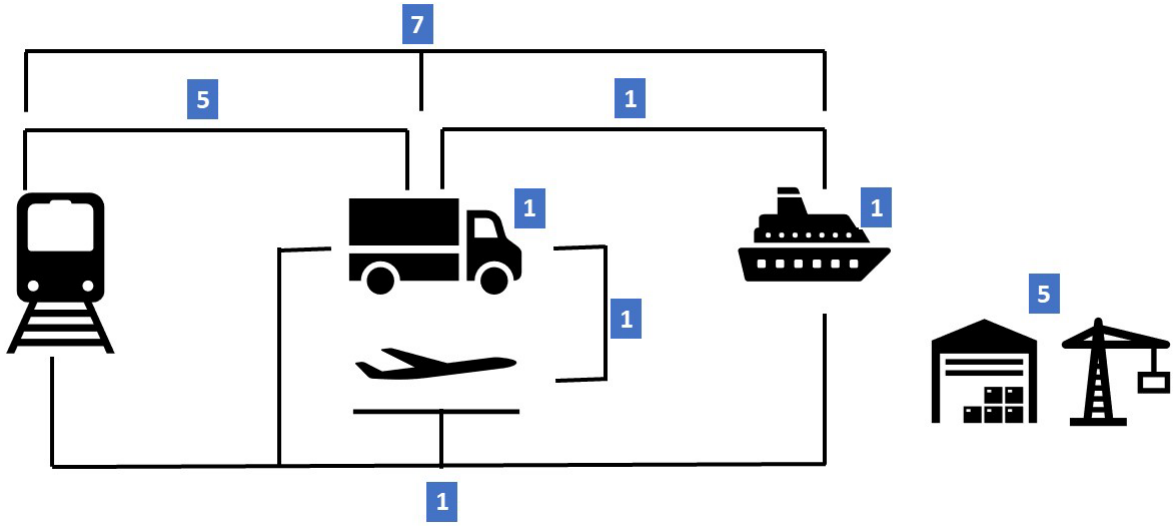


Figure 12: Transport modes and nodes and number of interviewees representing each.

Figure 12 shows the different modes of transports that the interviewees represented. 7 of the interviewees were involved in intermodal transport including rail, road, inland waterways, and short sea shipping. 5 others represented combined transport operations involving rail and road. One organization managed the combined transport of road and air. There were 5 organizations who also managed terminals and/or warehouses. One organization regularly dealt with 4 modes of transport: air, rail, road, and short-sea shipping. Two organizations were focussed on single modes of transport, one on road and one on maritime shipping, and did not consider multimodal operations.

In the remainder of this report, the inputs from the focus groups and the interviews are analysed to synthesize 1) definition(s) of disruptions 2) classification of disruptive events and 3) known and future challenges in the EU multimodal network.

5. Definition of disruptive events

Before building any tool or model, it is of paramount importance that the underlying information is clearly defined. One of the bigger aims of the ReMuNet project is to build a collaborative platform that helps stakeholders find alternate routes in case of disruptions and prioritizing sustainability. Therefore, it is crucial to understand what disruptive events mean to the different players in the network. In this section, several descriptions of the terms disruption and disruptive events are compiled from focus groups and interviews. The similarities and differences are analyzed, and some common elements are identified. A total of 23 definitions of disruptions have been obtained, 17 from interviews and six from focus group-2. These have been grouped into five themes based on their core emphasis. These

themes are not to be confused with categories of disruptions (which will be discussed in the following section), but represent ideas used by experts to define disruptions as they see them.

5.1 Themes for defining disruptions.

The participants of the study stated that disruptions can be defined as one of the following: a blockage of flows, a technological paradigm shift, delays in schedule, unplanned events, or any deviations from business-as-usual. Figure 13 shows these 5 themes.

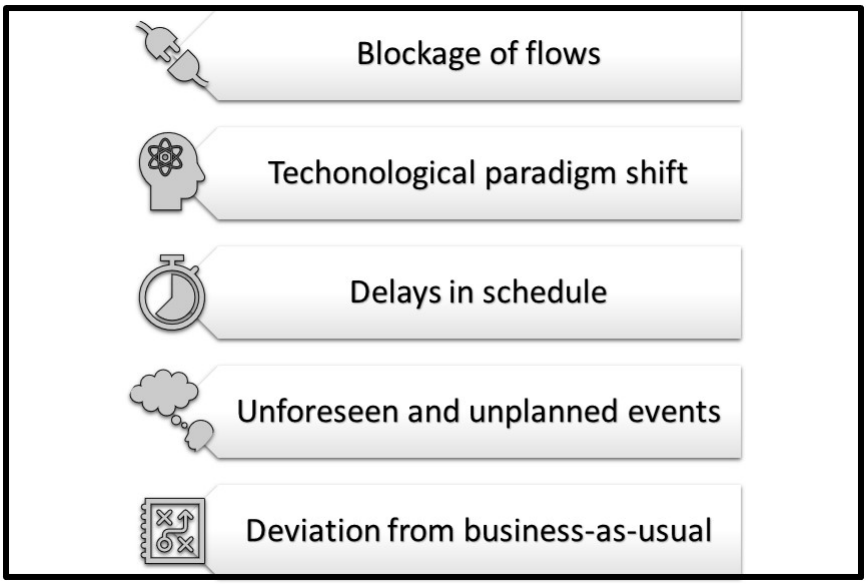


Figure 13: 5 themes of disruption definitions

5.1.1 *Disruptive events as blockages in flows*

Some participants viewed the multimodal ***transport network as a flow of material and information***. Disruptions, then, were viewed as any blockage to either flow (material or data). 6 of the participants came up with definitions around this concept. These are reproduced below:

- “Any logistical issue that prevents the product or service from going to where it's supposed to go.”(Group 1 from focus group-2)
- “Things need to go from A to B, and it doesn't go from A to B, then that's a disruption.” (Interviewee 4)
- “Well, for us it meant that the initial traffic that was supposed to come to the terminal was stopped.” (Interviewee 12)
- “To me, disruption is mainly a time event or whether something is blocked.” (Interviewee 9)
- “It is about server reliability and something that makes the data lag.” (Interviewee 8)
- “When operations are disrupted at one of the points or by one of the stakeholders due to natural or artificial causes, the entire value chain of combined transport is

affected. So, for us, if a particular element of this combined transport chain is affected, that is a disruptive event." (Interviewee 17)

5.1.2 *Disruptions as technological paradigm shifts*

There was a small subset of participants (3) that assigned a positive connotation to the term disruption, associating it with rapid technological advances. All these people had advanced software skills and were involved in digitalization in some capacity. A common emphasis here was on the magnitude of the impact. These participants strongly opined that disruptions are high-impact events, causing not just minor changes, but entire transformations to the businesses. Some of their views are presented next:

- "Usually when I say the word disruption, I talk about technological disruptions." (Interviewee 15)
- "It is a massive change to the way that we manage logistics and transport that makes it almost unrecognizable compared to if you look back. And so, for me, disruption in this area is huge, huge." (Interviewee 5)
- "Disruption can be a disruption from nature, it can be a disruption from politics, and disruption from technology." (Interviewee 3)

5.1.3 *Disruptive events as delays in schedules*

A third group of participants viewed the ***transport network as a series of coordinated activities governed by a schedule***. To them, disruptions were any delays in the planned schedules. The stakeholders who subscribed to this viewpoint were found to be either engaged in intermodal or terminal operations or network planning. Some of their opinions are as follows:

- "Delays." (Interviewee 2)
- "...as irregularity or delay. (Interviewee 1)"
- "So, a disruption is if a train or a vessel does not arrive according to schedule." (Interviewee 6)
- "When you'll have a delay, I mean, usually you work based on plans, and when you'll have a delay bigger than 60 minutes, you have a disruption." (Interviewee 10)

5.1.4 *Unforeseen and unplanned events*

Some participants of both the focus groups and the interviews strongly believed that disruptions, by definition, are unplanned, unforeseen, and unexpected events. When asked about events such as labor strikes, which are known in advance, causing disruptions, they offered alternate definitions for such events, preferring to call them *known issues* or *challenges* instead. Some of these definitions are reproduced below.

- "Unexpected, overwhelming event in the SC causing cascading effects within the SC network and preventing the flow of goods within the network and ultimately to the

customer, having negative effect on business, environment, and the society." (Group 3 from focus group-2)

- "Disruption can be an unexpected or a new event that affects some link in the supply chain that impacts all of the supply chain." (Group 4 from focus group-2)
- "Disruptions can be categorized as unforeseen or unlikely events causing trouble in the upstream or downstream supply chains, or in both." (Group 5 from focus group-2)

5.1.5 *Deviation from business-as-usual*

The largest group of participants belonged in this category, with all of them agreeing that any event which requires changing the standard operation or normal ways of operations is a disruption. These definitions include the following:

- "Any change in the working system or the normal way of working is a disruption." (Interviewee 15)
- "Well, a disruptive event is something that changes, to me, is something that changes the normal day-to-day life that you are used to." (Interviewee 13)
- "Internal or external unexpected events disturbing the established situation/order and interrupting the normal supply chain." (Group 2 from focus group-2)
- "It means that we have to react at some level." (Interviewee 11)
- "So, anything that makes them choose an alternative route against their normal practices that might be inconvenient or prevents them from carrying out operation, I would consider a disruption." (Interviewee 7)
- "External damaging and severe interruptions to daily activities in the supply chain." (Group 6 from focus group-2)
- "I call disruption whenever the original optimized plan, because of these changes in reality, significantly deviates from optimal." (Interviewee 14)
- "It's anything that prevents you from running your day-to-day operations or anything that requires extra effort to keep the things running." (Interviewee 16)

5.2 Criteria for disruptive events

Some of the participants had very specific criteria on what constitutes or does not constitute a disruption or a disruptive event. These are as follows:

1. Disruption is always unplanned. As quoted by Interviewee 3, "If it's planned and you have the opportunity to find solutions, then it's not really disruption. So if you take the technological development in the last 300 years, it's in total a very big difference of how we worked 300 years ago and today, but it was so slow and it was, we were able to be prepared for that."

2. Disruption needs an external driver of change. As quoted by Interviewee 15, “Let's say it comes from outside and it's not the way. You have to react for that. Something big changes and then you have to react. Yes, yes, it's external, yeah. Of course, you can try, but it kind of changes the world when you're working.”
3. If it lasts too long, it is the new normal and not a disruption. Interviewee 7 said, “Yeah, so it stops being disruption at some point. So, I guess when it happens for the first maybe half a year or a year, everyone kind of hopes that things go back to normal like something never happened, but after some period of time, you have to adapt and understand that it's like new normal and no longer disruption.”
4. Disruption is too strong a word and needs to be used when the system is forced to change completely. Interviewee 1 said: “So, disruption is already a hard work, I think, to say, oh, that's something, I think, important that happens on the infrastructure…. But it's more than just a delay, it's just more than an irregularity. So, it can be an irregularity that suddenly transforms into a disruption. Disruption means that there will be a quite important impact on the traffic, and then you have to reorganize somehow the traffic, and then it's coming back to relationship to the customers, because for customers disruption meaning also for them immediately that there is a break in the logistic chain, and also, they have to adapt to that. The same interviewee also added: “Yeah, but again, we're not going to call a disruption, and we're not going to use this word when there's a minor incident. We're going to speak about incident and accident. And then, of course, accident immediately, you know there's a disruption. That's for sure. For minor event, we are not going to use the wording disruption.”
5. All the participants agreed that the impact and response of the disruption is more important than the cause. For example, Interviewee 10 said: “But the most important thing is how we react to incidents that have an impact on our plan.”

5.3 Summarizing the definitions

During the 17 interviews, 2 FGDs and 53 student assignments conducted as part of the qualitative research for this study, one aspect that was evident is that researchers and stakeholders lack consensus on what constitutes disruptive events. While certain major events such as the COVID-19 pandemic or flash floods are all easily identified and agreed to be disruptive event, the transport network users find it hard to agree on some other events. For example, change of legislation affecting transport operations, workforce shortages (or strikes), and lack of standardized communication were identified by 2 groups out of 6 (from the supply chain course) as disruptive events. This viewpoint was also supported by nearly 60% of the interviewees. However, there were many others who did not view such planned or foreseen events as disruptions. One main point of contention was the perceived magnitude of impact associated with the term “disruption”. At least 40% of the interviewees and 4 out of the 6 groups participating in FGD in the supply chain course associated the term disruption to an event that results in a complete transformation of the business, place, or person.

Of the 5 themes of disruption definitions, themes 1 (blockage of flows), 3 (delays in schedule), and 5 (deviation from business-as-usual) have a similar basis. All three views believe that there is a baseline scenario of operations which may be called a plan, a schedule, or business-as-usual. Any interruption to the baseline, be it in the form of delays, blockages, or entire closure of the system, is a disruption. Although theme 2 (technological disruption) has a positive connotation, it also brings about a change to the normal operating procedures and patterns (possibly quite radically). Hence, it could be argued that this theme, in spirit, agrees with the more general ideas of themes 1, 3, and 5. Theme 4 stands out from the other themes and presents an idea that is disputed and hotly debated. The participants were strongly divided on whether disruptions need to be unexpected by definition. This line of thought is explored in detail in a subsequent report for this project on analysis of root causes of disruptions (T1.4). Leaving aside theme 4, all other definitions and views on disruptions expressed in the data collected for this report can be reflected by the following definition of disruptions:

> A disruptive event can be defined as any interruption or change, planned or unplanned, in the operations of a transport network, creating effects, such as delays, blockages or closures.

Next, the classification of disruptions into categories is discussed based on the insights from the focus groups and interviews.

6. Classification of disruptive events

During the study, the participants engaged in discussions that described different disruptive events in the recent past, with particular focus on the disruptions in the EU. Using these examples, participants (both in the interviews and in the focus groups) attempted to categorize the disruptions. This section compiles the insights from the qualitative study and presents the synthesized results. The different categories suggested by the participants can be grouped into three themes, based on the underlying classification factors. As shown in Figure 14 these are 1) the layer of operation in which the disruption has occurred, 2) the cause of the disruption and 3) the impact of the disruption.

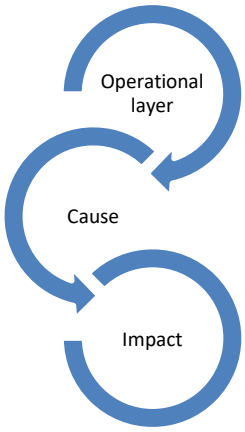


Figure 14: Themes of classification of disruptions

The three themes of classification are now discussed, along with the categories and examples in each.

6.1 Layers of operations

When discussing disruptions with intermodal operators, some of the stakeholders chose to describe their experiences in two layers of operations of the transport network. They called these the information and the physical layers, which have been covered in the literature review of this report. The different flows have been extensively discussed in the supply chain management literature in particular (Kaipia, 2009). This study highlights their importance also when discussing transport networks that support the operations of supply chains and are also increasingly going beyond the merely physical.

Some of the activities in the information layer include network planning, order scheduling, workforce documentation, communication, and invoicing, to name a few. As (Cheung et al., 2021) highlight, while the increased use of information technology has improved transport operations significantly, it has also increased the attack surface in the logistics environment from a cybersecurity perspective. While the logistics industry is implementing the Internet-of-Things (IoT) to reduce human errors and enhance efficiency when collecting data, processing orders and delivering materials and/or products, these improvements also make the information layer more prone to disruptions due to outside actors (Cheung & Bell, 2021).

The physical layer includes the actual vehicles of transportation and the nodes of the network such as terminals and warehouses. The origins of what is now termed supply chain management lie in physical distribution, which is focused on this layer (Hou et al., 2017). The information layer corresponds to the flow of data, while the physical layer corresponds to the flow of materials. This differentiation, which is common in academic studies in the logistics and supply chain management area was reflected in how respondents in this study viewed their work at nodes and links of the European transport network. Figure 15 shows a sketch of these layers based on the description by the participants. The operations in both layers always interact closely and hence a disruption in one layer affects the other layer as well.

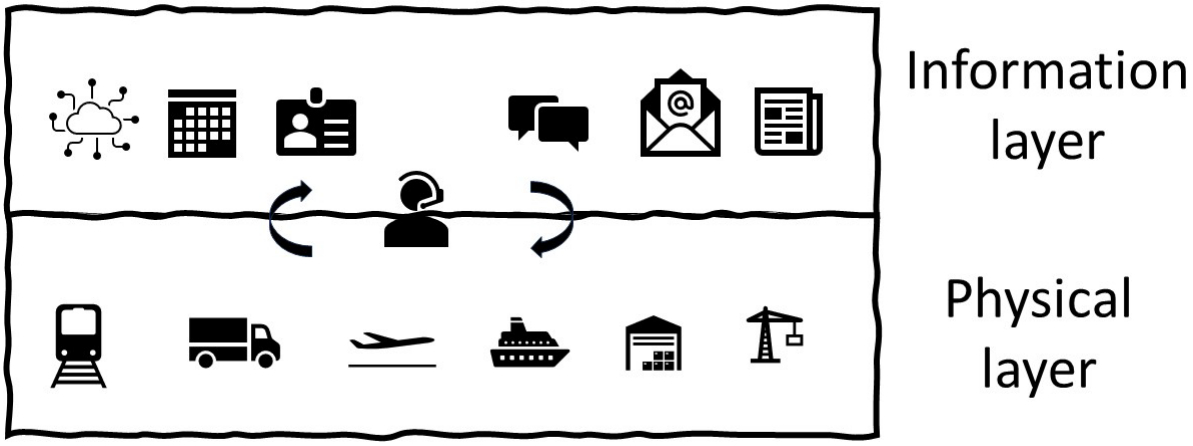


Figure 15: Layers of operations

The first classification of disruption was based on the operation layers. Disruptions can be differentiated based on which layer they originated in, although they all have the potential to affect both layers, especially any disruption in the information layer affecting operations on the physical layer as data processing is interrupted, which is essential for modern transport operations. The following table shows some examples of disruptions in each layer.

Table 3: Examples of disruptive events in each operational layer

Information layer	Physical layer
Server disruptions, cyber-security attacks, internet fluctuations, electricity outages, lack of standard frameworks, paperwork (lack of digitalization), language barriers, insufficient digital literacy, untrained workforce	Fuel shortage, fuel pricing, accidents with vehicles, infrastructural damage, workforce shortage, workforce strikes, road/ rail/ waterway unavailability, theft, regulations

Next, the classification based on causes of disruption is presented.

6.2 Causes of disruption

In general, categorizing disruptions based on their causes was the most intuitive approach for most of the participants. Many of them did not consciously realize that they had been classifying based on causes, until they were specifically questioned on what the basis was. Technological failure, natural disasters, and geo-political crisis were the three common categories that most individuals and groups identified. Combining the inputs from all participants, the exhaustive list of categories contained ten entries, as shown in Table 4: Classification based on causes. Some of the examples in each of the categories are also shown.

Table 4: Classification based on causes.

Natural disasters	Rockslides closing routes in the alps summer 2023
Technological failures	Signalling failure, internet outage

Regulatory changes	Customs changes due to Brexit
Security incidents	Cyberattack, border closures
Accidents	Rastatt tunnel collapse, Gotthard base tunnel derailment
Health emergencies	COVID-19
Capacity shortage	Driver shortages due to Brexit
Geopolitical crisis	Russia-Ukraine crisis, Brexit
Extreme weather	Drought-induced low water on the Rhine 2022
Economic slowdown	US-2008, EU-2022

Natural disasters, such as floods, earthquakes, or landslides, can severely disrupt transport networks. They often cause physical damage to infrastructure at both nodes and links, such as bridges or ports, leading to delays and rerouting of freight. The recovery and repair period following a disaster can further prolong these disruptions. Logistics performance of countries is linked to the impact natural disasters have in them (Vaillancourt & Haavisto, 2016).

Technological failures, including malfunctioning transport management systems or breakdowns in communication technologies, can lead to significant inefficiencies (Klumpp & Loske, 2021). As previously discussed, the information layer is now crucial to transport operations, which results in vulnerability to technological failures. These failures can result in delays, misrouted cargo, and a lack of real-time information, hindering the smooth operation of the freight transport network.

Regulatory changes, such as new customs procedures or environmental restrictions, can impact the European freight transport network, as has recently been demonstrated with the consequences of Brexit. Such changes often require adjustments in operational processes, leading to temporary slowdowns, increased compliance costs, and potential bottlenecks at borders. Changes in environmental regulations relevant to transport are another example of a potential cause for disruptions (Xu & Xu, 2022).

Security incidents, including cyber-attacks or terrorism, pose significant risks on both the physical and the information layer. They can lead to the closure of key transport nodes, heightened security measures causing delays, and a general sense of instability affecting the movement of goods. Security incidents can have serious adverse effects on global supply chain and therefore garner significant attention from both practitioners and academics (Lu & Koufteros, 2013), especially in global maritime and air transport (Yang & Hsu, 2018). The importance of this cause of disruptions to the respondents in this study demonstrates its relevance also in inner-European transport.

Arguably, the most immediately evident cause of disruption are accidents. Accidents such as collisions or derailments can cause immediate and localized disruptions. These events often lead to temporary closure of transport routes, diversion of freight traffic, and can sometimes have cascading effects on the broader network. While interviewees stressed that

accidents such as road transport collisions are frequent and somewhat routine disruptions, they also highlighted that some such disruptions can have a very wide-spread effect if they affect particularly crucial transport links. A frequently cited example was the tunnel collapse at Rastatt, Germany, in 2017 at a crucial North-South rail link impacting the rail network in a significant area of central Europe (Büchel et al., 2020).

Health emergencies, like pandemics, impact freight transport by causing labour shortages, altering supply and demand patterns, and necessitating new health and safety protocols. These factors collectively lead to operational challenges and potential delays in the freight network. While the most prominent example that respondents referred to was evidently the COVID-19 pandemic, with its wide-spread impact on logistics and supply chains (Singh et al., 2021), there is evidence in literature of the impact of for example avian influence (Kumar & Chandra, 2010) or mad cow disease (Broadway, 2006).

A shortage in capacity, whether in terms of transportation vehicles, infrastructure, or human resources, can lead to bottlenecks and increased transit times. This issue is particularly critical during peak demand periods or when other disruptions put additional pressure on the network. Respondents were well aware of disruptions associated with capacity shortages, particularly the wide-spread shortage of truck drivers in the aftermath of the COVID-19 pandemic in combination with the outbreak of the war in Ukraine (Ji-Hyland & Allen, 2022).

Geopolitical crises, such as conflicts or trade disputes, can lead to border closures, restricted access to certain routes, and increased scrutiny of goods. These factors often result in longer transit times, rerouting of freight, and increased operational costs. Foremost in the minds of respondents in this study was the impact of Russia's war in Ukraine both within Europe (Caramuta et al., 2023) and globally (Ngoc et al., 2022).

Extreme weather conditions, like heavy snowfall, storms, or heatwaves, can disrupt all modes of freight transport. They can cause physical damage to infrastructure, reduce operational safety, and lead to closures or reduced capacity on certain routes. This is well-documented for both road transport (Doll et al., 2014) and rail transport (Ludvigsen & Klæboe, 2014) but was most prominent in interviews in relation to inland waterways, especially recent droughts affecting key European transport arteries like the Rhine (Gobert & Rudolf, 2023).

As transport is a derived demand, an economic slowdown can lead to a decrease in demand for freight transport services. While this might reduce congestion, it can also lead to overcapacity issues, financial strain on transport providers, and a reduction in investment in the transport infrastructure, potentially impacting the long-term efficiency of the network. For example, COVID-19, amidst its manifold societal impacts, had a significant impact on transport volume and freight capacity dynamics in Europe (Loske, 2020).

These ten different categories based on causes of disruptions were identified based on the rich data gathered through focus groups and interviews, which highlighted a multitude of disruptive events. Respondents often subconsciously structured their initial responses based on categories of causes.

Finally, the classification based on impact of disruptions is presented.

6.3 Impact of disruptive events

When discussing impact of disruptive events to the individual actor, participants considered different aspects such as delays, the cost, extent of damage, loss of revenue, and whether the disruption can cause a domino effect and lead to more disruptions. Based on these, they classified disruptions as minor, medium, or major (or on similar lines).

When discussing about impact of distributive event on the transportation network, participants highlighted the duration of the disruption and geographical extent of the distribution. Table 5 shows one such analysis using impact as a basis. The time duration of the disruption can be short, medium, or long, while the geographical extent of the impact can be narrow (small area affected) or wide (many regions affected at once). Based on an interplay of these factors, the overall impact of the disruption can be considered minor, medium, or major. Some examples of each of the six possible combinations are also included in the table below.

Table 5: Impact of disruptive events on transportation networks

		Geographical extent	
		Narrow	Wide
Time duration	Short	Minor (traffic jam)	Medium/Major (earthquake)
	Medium	Medium (outage)	Major (flood)
	Long	Major (war)	Major (pandemic)

Further ways in which respondents discussed the impact of disruptions, was number of options available, e.g. the ability to find alternative routes around a particular incident. For example, the tunnel collapse in Rastatt, Germany, in 2017 (Büchel et al., 2020) was highlighted as particularly impactful because there were limited opportunities to reroute rail freight and rerouting to parallel railway lines in France came with additional challenges of cross-border rail operations.

7. Other insights from interviews

While the qualitative study was targeted to achieve the goals of defining disruptions and their classification, the interviews and discussions were rich sources of information on the operations, practices, and challenges in the EU multimodal transport network. This section presents other interesting insights derived from the analysis of the interviews, apart from disruption definitions and classifications. While a more detailed discussion of these topics is out of scope for this report, they will be published separately as open-source scientific articles.

7.1 Vulnerabilities in transport networks

The participants experienced with intermodal or combined transport networks were asked for their insights on what they considered to be the vulnerable parts of the network, most susceptible to disruptions. Some of the commonly mentioned vulnerabilities are as shown next:

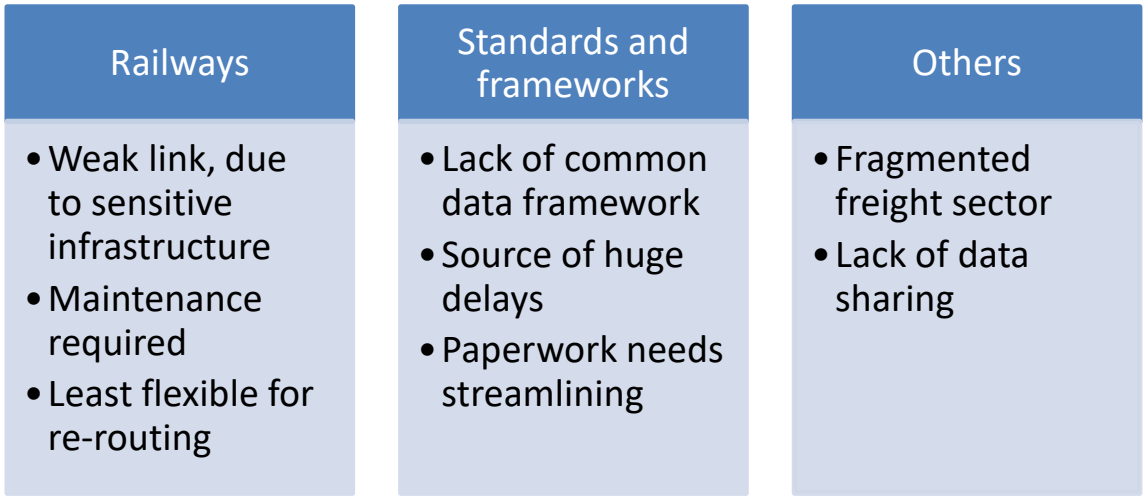


Figure 16: Vulnerabilities in transport networks

Figure 16 shows the three sets of vulnerabilities identified from the studies. Many of the interviewees from the combined transport sector (including Interviewees 1, 3, 4, 6, 7, and 8) identified railways as the weak link the EU multimodal transport network. The reason for this was the sensitivity of the rail operations to specific infrastructural needs. It is hard to reroute and build rail tracks in short time. In an example given by Interviewee 7, due to the war with Russia and the resulting EU sanctions on Belarus, the Lithuanian railways suffered drastic losses, since a large section of their tracks was through Belarus. This resulted in a loss of employment for nearly 30% of the workforce. Interviewees 1 and 6 highlighted that the railways in central Europe, particularly Germany, are behind on their maintenance schedules, resulting in frequent outages. Interviewee 14 provided a rationale for this, by describing the huge volumes supported by the German railways and the practical challenges in providing a complete overhaul of systems. A downtime on German railways, even for maintenance or upgrade reasons can be massively disruptive for the EU. The challenging problem for policymakers here, is to find ways to continue operations and yet upgrade the railways to meet the rising demands.

The second set of vulnerabilities mentioned by Interviewees 1, 3, 4, 5, 6, 9, 10, 11, 12, 15, and 17 is the lack of standards, common data framework and digitalization of paperwork in EU logistics. Some of the issues caused by this are delays due to translations and lack of timely arrival of the right papers. Since the EU is a zone of multiple languages, the drivers are often required to be multilingual across the regions of operations. Interviewee 1 mentioned at least one instance where the lack of knowledge of local language has led to an accident in the railways. A common framework for communication is thus highly desirable to reduce delays and improve safety and resilience of the transport network.

On a similar note, Interviewee 14 mentioned how the freight sector in EU is highly fragmented, with several small players. This has resulted in a large number of aggregators, who sometimes have insufficient knowledge of the underlying fleet and its problems. A similar problem was also mentioned by Interviewee 13 in the context of humanitarian logistics. Due this nature of the sector, data sharing is often not as open as desired. For example, to estimate carbon emissions in planning sustainable routes, certain vehicle specific parameters are required. However, due to trust issues, fleet owners are hesitant to share actual numbers. This results in inaccurate estimates for carbon emissions, based on which routes are planned. As mentioned by Interviewee 14:

> "It is a choice between being blinded and being fooled."
>
> On data availability to calculate emissions

In a similar context, Interviewee 16 mentioned that data should be used for forecasting and prediction, and not real time updates. Hence, a true sharing of performance parameters is required.

> "If we use real-time data, we are already too late."
>
> On the importance of data and forecasts

7.2 Climate change, sustainability, and challenges

Since the EU has set high targets for sustainability for the transport sector, the participants were asked their views on whether the development was on track to meet the goals. Interviewee 13 mentioned that the severity of climate change is already being felt, and hence it is already a climate crisis:

> "It is no longer climate change that we are dealing with, it is climate crisis."
>
> On the impact of climate change

While most participants agreed that significant efforts are being made across the network, they also highlighted some areas that need to be

considered in the near future, to avoid new challenges once the sustainability goals have been met. Some of these are shown in Figure 17. According to some of the participants, once the EU transitions to replace a certain percentage of the current fleet of trucks with electric vehicles (EVs), they will require infrastructure to maintain these trucks, and not just charging stations. Along with EVs for freight, it is expected that passenger vehicles will also become hybrid vehicles, increasing the load on existing services. This scale-up of requirements must be carefully anticipated. A group of participants (including Interviewees 7, 16, and 17) highlighted that while electric transportation is being heavily promoted, electricity pricing has been highly variable in recent months due to multiple geo-political crises. The EU must work out ways to ensure supply of electricity at stable prices. One participant (Interviewee 7) highlighted a different perspective. While the EU is making advances in engine technology and efficient fuels, there are other parts of the world that will not be able to support these advanced machines and vehicles.

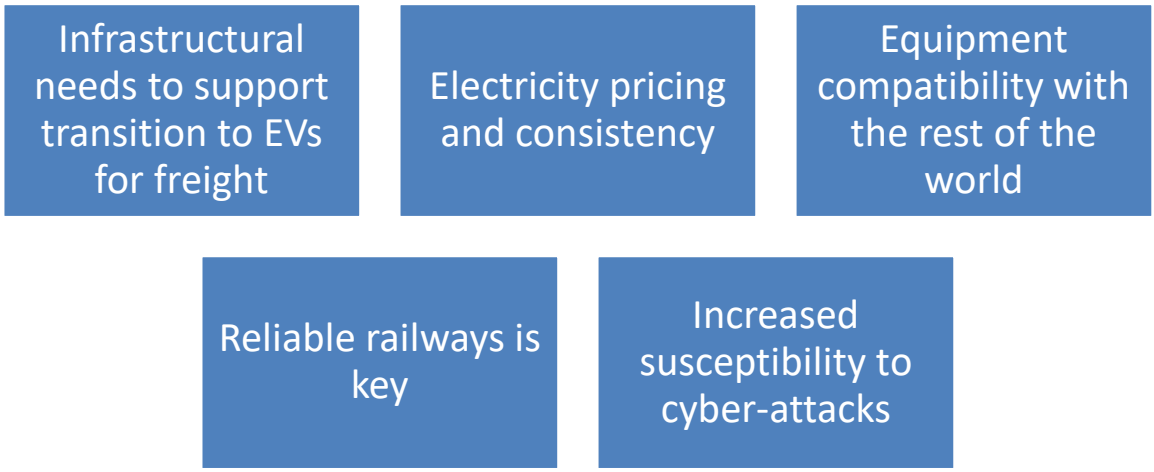


Figure 17: Future challenges for sustainable goals

For example, an electric car manufactured in the EU might not be able to find the required charging infrastructure in some lesser developed countries. These could affect, for example, humanitarian work, that requires intercontinental mobility. The majority of the participants (as discussed in the previous section) concurred that the railways held key for successfully meeting the sustainability goals. Hence upgrading and maintenance of railways across the EU should be prioritised. Finally, moving to EVs and greener alternatives will also lead to increased digitalization and use of smart grids, which will bring in new vulnerabilities in the form of cyber-attacks. These must be anticipated and planned for. Interviewee 14 highlighted the need for transport networks to be adaptable and flexible. They mentioned that while striving for resilience, the EU must not

> "Do not make repeated efforts to get back to plan A, in the name of resilience. Be adaptable instead and redirect your sails as per the wind."
>
> On the importance of being flexible and adaptable

target to achieve the normality of the past. Instead, the new challenges must be embraced, and new strategies must be adopted.

Interviewee 15 had a practical perspective on this matter. They said that although the eventual goal of the EU is to bring down carbon emissions, to incentivise stakeholders to take active measures towards it, there must be some monetary benefits attached to it. The recommendation was for policymakers to offer greater financial incentives for business to adopt green initiatives and for consumers to make sustainable choices. As quoted by the interviewee:

> "If you want people to take something seriously, attach a price tag to it."
>
> On how to ensure sustainability

8. Discussions and Conclusions

This report presents the work done towards defining disruptions and classifying disruptive events, which are identified as some of the primary tasks in the ReMuNet project, addressing the core goal of standardized methodology development for EU multimodal transport networks. The work began with a review of the state-of-the-art. Firstly, the definitions of disruptions and disruptive events from literature were gathered and summarized. While risk and resilience are extensively studied in the supply chain management literature (Macdonald et al., 2018; Hossein & Ivanov, 2020; Um & Han, 2021; Shekarian & Mellat Parast, 2021), the same is not true for transport networks, although some insights are transferrable.

The relevant aspects of the definitions were noted and the missing contexts with respect to the project goals were identified. Next, some fundamental literature regarding transport flows, networks and layers was presented, to provide a quick reference for readers of different backgrounds. The review concluded with a summary of existing classifications used. Based on the knowledge gaps identified in the literature review, a qualitative study constituting two focus groups and 17 interviews was designed. The qualitative study brought about interesting perspectives from a set of diverse stakeholders and researchers associated with the EU multimodal transport network.

An important goal of this work package is to accurately define terminology. As was evident from the analysis presented in this report, the terminology used by the stakeholders depended on their role in the transport network and the extent of impact faced by their organizations/businesses from the disruptions. Despite the apparent lack of consensus on terminology, there are common grounds on which stakeholders agree. Based on the research conducted for this report, a transport disruption is defined as any interruption or change, positive or negative, such as delays, blockages, or closures in the planned operations of a transport network. Business transformation, discussed also in the interviews,

is a strategically intended change to react or prepare for changing market requirements, and therefore constitutes an active measure to deal with disruptive events and build resilience.

Another key observation that came from the participants from the combined transport sector is that the railways are key to achieving the EU sustainability goals, since they have the least emissions. However, the railways are thought to be ill-maintained and unreliable, making it hard for logistics providers to get customers to shift to rail from road. Also, given the current geo-political dynamics and unpredictable pricing of electricity, the railways are at a risk of facing major operational challenges (such as stopping routes in certain countries or sudden increase prices due to high electricity rates). These are matters of great concern and require strong policies and risk mitigation efforts.

Participants generally prioritised response and impact over cause of disruption. While this makes intuitive sense from a business perspective, where the pressing need is to ensure minimal downtime, understanding causes and antecedents facilitates the employment of relevant mitigation strategies (Um & Han, 2021) and the resilience to disruptions (Shekarian & Mellat Parast, 2021). This makes the development of the typology of disruptive events in this report so crucial for enhancing the resilience of the European transport network as ReMuNet aims to do.

Figure 18 presents the typology of disruptive events developed in Task 1.3 of WP 1 of the ReMuNet project. First, the typology acknowledges the importance of both the physical and the information layer. It then includes the ten categories of disruptive events by causes that were identified in this research. These result in disruptive events that can impact on transport nodes, transport links, or both. Based on both literature and findings from the primary research conducted as part of this study, the typology also includes multiple dimensions of events that will ultimately determine the disruptive event's impact. These include time duration and geographical extent of the disruptive event, the criticality of the disrupted node(s) and/or link(s) and the existence and number of alternative options for example to reroute freight on the same transport mode or to switch it to an alternative mode, as well as the probability of the disruptive event and its predictability. Importantly, the typology acknowledges that the impact of disruptive events can be manifold. While it includes direct impacts on individual actors, nodes, and links, it also includes cascading effects that impact the entire transport network, supply chains, and society. before a disruptive event results in an impact on the transport network. The causes for disruptive events identified in this report all have underlying root causes. Root causes will be discussed further in the final report for Task 1.4.

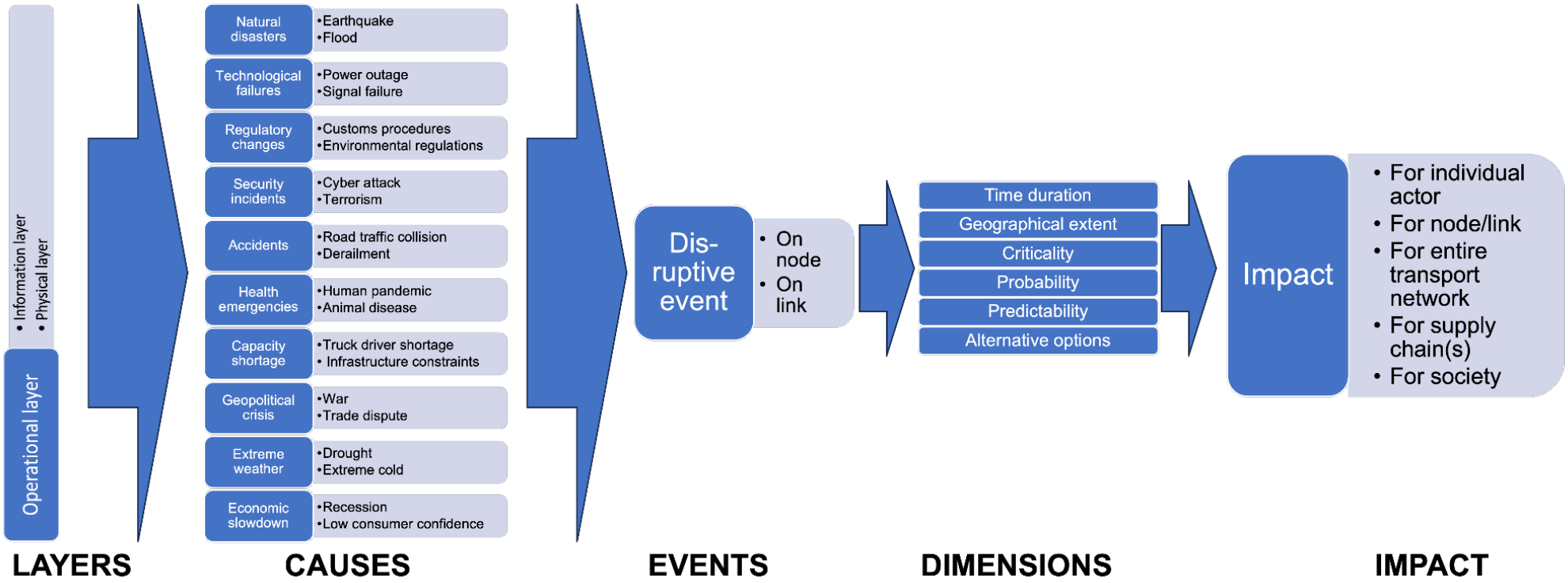


Figure 18: Typology of disruptive events

To conclude this report, we revisit the RQs that guided this study and present some answers based on the analyses.

What are the categories of disruptive events based on their causes? As described in Section 6.2, ten categories of disruptive events were identified based on their causes. These are natural disasters, technological failures, regulatory changes, security incidents, accidents, health emergencies, capacity shortage, geopolitical crisis, extreme weather, and economic slowdown.

What disruptive events are specific to which transport mode? A detailed discussion on disruptions in various transport modes is presented in 7.1. Since many of the participants identified the railways to be the most vulnerable transport mode, this has received more attention.

What are examples of each category of disruptive events? Apart from cause, what are other ways of classifying disruptive events? Section 6 presents different categories of disruptions and examples of each kind. Apart from cause, the disruptions are also classified based on their impact and layer of operation (physical transport or information) where the disruption occurred.

What is most relevant for the disruptive event: cause, effect, reaction, or something else? As highlighted in this report, for the majority of the participants, the impact and response to disruptions takes precedence over cause. While causes are analyzed retrospectively, economics dictate prioritizing response measures.

What type of disruptions have been most impactful in recent times? Section 7 presents a discussion on some of the recent disruptions as experienced by the respondents. The Russia-Ukraine crisis, the subsequent energy shortages, and the COVID-19 pandemic are commonly mentioned. A more detailed discussion on this topic is presented in the following report in this work package on analysis and impact of disruptions (Task 1.4).

What types of disruptions will gain / lose importance in the next 5 years? One of the key goals of the EU until 2030 is sustainability and the transport network has several objectives planned to meet these goals. Section 7.2 presents an insightful discussion with the participants on what disruptions they expect in the coming years, given the current geo-political and climate situation and the upcoming goals of sustainability.

Further on the topic of sustainability goals, some participants highlighted the drastic measures taken by various sectors to meet the targets for 2030. A concern has been raised that in a rush to achieve drastic reductions in emissions in a short span, organizations might miss out on developing support systems for sustaining the new transport systems that emerge. For example, the replacement of traditional fleet of trucks with electric trucks will necessitate several additional charging points, maintenance units and personnel and disposal systems for obsolete trucks. These issues should also be carefully planned to avoid the possibilities of chaotic disruptions resulting from ineffective planning.

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10. Appendices

10.1 Data management plans and research ethics

The ReMuNet project has an extensive data management plan, which will be delivered as part of Task 3.1, in month 36. The guiding principles for all research are the data management processes mentioned in the project proposal. In preparation for the qualitative study in this work package, the Hanken research services was consulted, and an interim data management plan, along with a research privacy notice and consent slides were created. A short brief of the research privacy notice (4 pages) is presented here. The complete documentation is available on request.

The Research's Privacy Notice

This privacy notice describes what personal data will be collected from you as a participating individual, and why and how the personal data will be processed in the research, as well as the details of the research and related participation. It also provides the information on what rights you as the data subject have pertaining to your personal data and how you can exercise these rights in relation to the processing.

Date: 13.10.2023

Title of the research: Resilient Multimodal Freight Transport Network (ReMuNet)

The research is conducted for the research project ReMuNet

1. Data Controller

Research is conducted under an employment contract with Hanken. Hanken is the data controller.

Hanken School of Economics
Arkadiankatu 22, 00100 Helsinki, Finland
Postal Address: P.O.Box 479, 00101 Helsinki
Phone: +358 (0)29 431 331
Business ID: FI02459077

Hanken's Data protection officer (DPO): dpo@hanken.fi

Questions regarding the research and personal data processing are addressed to the contact person(s): Ketki Kulkarni ketki.kulkarni@hanken.fi

2. Information about the research

Participation in the research is not expected to cause any risk, harm or inconvenience to the research participants. No rewards will be paid for the participation in the research study.

Research data will be processed during the data analysis phase in a manner that the research participants are not directly identifiable. Direct identifiers such as names and addresses will be replaced with random pseudonyms, aliases or codes.

The identity of an individual research participant will not be disclosed in a scientific publication and any other research results to be published.

The research is a single study, but the research participants may be contacted later for a further study if they give their consent to such contact.

Research members who will carry out the research activities and be authorised to process the personal data during the research are Ketki Kulkarni, Anna Aminoff, Sarah Schiffling, Gyöngyi Kovács.

The principal investigator (PI) or person in charge of the research is: Anna Aminoff.

3. Purposes of processing personal data

The purpose of personal data processing is scientific research. The research will only process the personal data that are necessary and proportionate to the accomplishment of the research tasks and execution of the research.

The research aims to understand disruptions to the EU freight transport network to make efforts to minimize their impacts, increase resilience in the network and make transport more sustainable and eco-efficient.

4 Legal bases for processing personal data

The legal basis for the processing of personal data is:

Processing is necessary for scientific or historical research purposes or statistical purposes, the performance of a task carried out in the public interest or in the exercise of official authority vested in the controller.

5. Categories of data subjects

The research's population of interest is: European union freight transport network, logistics operators and supply chain experts.

Estimated number of the research participants in the research: Less than 50 research participants.

6. Categories of personal data

The following types of personal data will be collected and processed:

- Direct identifiers such as name, email address.
- Indirect identifiers such as occupational status, nationality, place of work.
- Interview responses.
- Audio or video recordings and the transcribed version in a text form.
- Findings, observations or notes made by the researcher about the research participants.

7. Sources of personal data

Personal data will be collected from the research participants through interviews, surveys or questionnaires.

8. Recipients of personal data

Others to whom the personal data will be disclosed:

- The research members and partners will have access to the personal data for the purpose of conducting the research.

- The recorded interviews be shared with a third-party transcription service provider based in Finland for the purpose of obtaining a transcript of the interview. A Data processing agreement (DPA) will be signed with the service provider.

  The service provider who will have access to the personal data is: Spoken Oy.

9. Storage and security of personal data

The data controller will be responsible for taking appropriate technical and organisational measures including pseudonymisation and encryption to protect the personal data against unauthorized access or illegal use and against damage to or loss of the personal data.

Contact information and other direct identifiers will be stored separately from all other data and not used for purposes non-related to this research.

Personal data in digital form will be stored and backed up securely in:

- IT systems provided by Hanken (e.g., Hanken's H: drive, OneDrive for Business, Webropol, SPSS).

For secure data transfers, the research project will use:

- OneDrive storage space in Hanken-provided account to share files with the research partners or supervisor. "Specific people"-option will be used to ensure access control.

10. International data transfers

- Personal data will not be transferred outside the EU/EEA or to international organizations. Personal data processing and transfers will reside inside the EU/EEA and be limited to the research.

11. Retention and erasure of personal data

Data retention and erasure plans:

- The personal data will be retained for further processing for other scientific research purposes than for completing this research project and will be erased after five years since the last publication where the research data have been used.

Data archival plans:

- Metadata of the research data will be published through Fairdata Qvain metadata tool offered by the Finnish Ministry of Education and Culture and produced by CSC.
- The anonymised research data will be archived in a data repository such as IDA, Aila or Zenodo for later and shared reuse.

12. Data subjects' rights

According to the General Data Protection Regulation of the European Union (GDPR, EU 679/2016), you as the data subject have the right to:

- receive transparent information on the processing of your personal data and how you can exercise your rights (Art.12),
- access the personal data collected and processed (Art.15),
- have the inaccurate or incomplete personal data corrected (Art. 16),
- have your personal data erased (the right to be forgotten) in certain situations (Art. 17),
- restrict the processing of your personal data in certain situations (Art. 18),
- have your personal data transferred between systems in certain situations (Art. 20),
- object to the processing of personal data in certain situations (Art. 21),
- not be subject to automated decision-making, with certain exceptions (Art. 22), and
- be informed of a personal data breach involving a high risk (Art. 34).

When personal data processing is for archiving, scientific or historical research or statistical purposes, the rights may be restricted under the GDPR and Finnish Data Protection Act (1050/2018). Restrictions of rights always require special protective measures.

Personal data will always be processed lawfully, fairly, and in a transparent manner to protect the fundamental rights and freedoms of the data subjects. The data controller(s) follow a GDPR-compliant procedure to respond to subject access requests.

If you have questions or requests related to data protection or the processing of personal data, you can contact the contact person(s) or Data protection officer (DPO) mentioned above.

You have the right to lodge a complaint with the supervisory authority if you feel that the processing of your personal data is an infringement of data protection laws.

Contact information of the supervisory authority/Data protection authority (DPA) in Finland:

Office of the Data Protection Ombudsman
Visiting address: Lintulahdenkuja 4, 00530 Helsinki, Finland
Postal address: PO Box 800, 00531 Helsinki, Finland
Switchboard: tel. +358 29 566 6700
Registry: +358 29 566 6768
Email: tietosuoja@om.fi
https://tietosuoja.fi

10.2Interview guide (probe table)

Firstly, groups /categories of questions are formulated as shown in next table:

Table 6: Organization of interview questions

Group	Group name	Corresponding questions in guide
A	About you and your domain (relation to EU transport)	1-7
B	Your thoughts on disruption	8–11
C	Classification of disruptions	12-18
D	Managing disruptions	19-23
E	Root cause analysis	24-27

Table 7: Interview guide

	Question group	Questions
1	A	What is your role in the EU transport network (service provider, customer, passenger)?
2	A	What modes of transport do you have access to or are involved in managing?
3	A	How frequently do you access/manage the transport modes?
4	A	Do you encounter transport disruptions as part of your work, commute, or regular activities?
5	A	Are you in a role that is expected to manage these disruptions?
6	A	What is the severity of the disruptions you encounter most often? Are there easy alternatives available?
7	A	Do you have access to transport related data?
8	B	What does disruption/disruptive event mean to you (in context of your domain)?
9	B	Can you recall any disruptions in your specific transport sector in recent times?
10	B	How often do you encounter or hear about disruptions?
11	B	How do disruptions impact you?
12	C	What do you think are the main categories of disruptions?
13	C	What is the basis for the categories mentioned in #12?
14	C	Can you give examples of disruptions for the categories mentioned?
15	C	Can you think of any other basis for classifying disruptions?
16	C	For each category of disruptions, what is the most prominent aspect: the cause, the effect, or the reaction? Or something else?
17	C	Which disruptions (or category of disruptions) affects more than one mode of transport?
18	C	Can you rate/prioritize the disruptions (or categories) based on their perceived impact?

19	D	In your experience, which events are the most disruptive?
20	D	How likely are these disruptions to occur again?
21	D	Do you think there are enough alternatives in place to minimize the impact of these disruptions?
22	D	According to you, which transport mode is most susceptible to disruptions?
23	D	Is there a transport mode/segment for which there is no known alternative yet?
24	E	What do you think are main causes of disruptions in your transport domain?
25	E	What future disruptions do you see due to the current climate trend?
26	E	What current trend/behaviour/situation can cause disruptions in future?
27	E	What were the major happenings in the past that led to some disruptions we have seen lately?

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
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	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

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FMI	ILMATIETEEN LAITOS	FMI
alice Alliance for Logistics Innovation through Collaboration in Europe	ALLIANCE FOR LOGISTICS INNOVATION THROUGH COLLABORATION IN EUROPE	ETP-ALICE
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