Advances in Reliability, Safety and Security, Part 9 – Kołowrocki, Dąbrowska (eds.)
 ISBN 978-83-68136-21-0 (printed), ISBN 978-83-68136-08-1 (electronic)

Advances in Reliability, Safety and Security

ESREL 2024
Monograph Book Series

Impact Of Sudden External Disruptions On Resilience Of Logistics Networks

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Abstract

The resilience of logistics networks and the responsiveness of actors to disruptions refers not only to the ability to restore systems to an undisturbed state but also to the dynamic response to disruptions and the adaptation of networks and actors to the best possible functioning of logistics networks in a state of disruption. Disruptions affecting logistics networks between 2019 and 2023 have resulted in logistics networks under constant pressure from human, or climatic factors, developing new reactive operating models rarely operating in a stabilised environment. SARIL's analysis of disruptions, conducted through surveys on participants in logistics chains, provides information on the real challenges that supply chain actors have to respond to due to sudden disruptions. This is because careful identification of the causes of disruptions and their consequences, and learning from incidents, allows countermeasures to be planned to reduce the risk of the consequences of disruptions. The disruptions identified in the first phase of the SARIL project illustrated the most important issues affecting goods flows in transport networks. Identified disruptions such as the COVID-19 pandemic, disruptions resulting from warfare in Europe, fires, floods, and cyber-attacks have occurred in high intensity in recent years and have caused several changes to both the transport infrastructure and the flow of goods. From the work carried out in the project to date and the interviews conducted, there is a strong need to develop countermeasures that respond dynamically to disruptions, and companies at every stage of global and local logistics networks are now seeing gaps in communication between the various links in logistics networks. Key to building the resilience of logistics networks is learning lessons before companies and looking back at the emergencies experienced as a result of disruptions, putting in place a standardized framework that gives guidance on how to respond to disruptions of a particular type. As the research carried out so far indicates, currently these actions are largely declarative. In contrast, actions are taken intuitively or based on the experience and operational knowledge of resources, which significantly affects the maintenance of the resilience of logistics networks to disruptions.

Keywords: logistics network, disruption, sustainability, resilience, freight transport, supply chain

1. Introduction

Sudden disruption affects transport networks at almost every level of logistics operations, whether concerning local, regional, or global goods movement chains. Over the past decades, designing an efficient yet resilient supply chain has emerged as a necessity and has been emphasized in both literature and practice. Nevertheless, the global disruption resulting from the COVID-19 pandemic has revealed the lack of resilience of many logistics networks, due to disruption at local transport hubs or lack of communication (Trump and Linkov, 2020)

The years 2019 - 2023 are a period in which a particular intensity of sudden disruptions can be observed in the area of freight transport, through which logistics processes, both in the areas of transport, storage, transhipment, but also production, encounter particular difficulties. However, the disruptions do not only affect the processes themselves but also affect the transport infrastructure, whose technical condition, capacity, and load are subject to changes, further significantly affecting the course of transport processes. The analysis of

sudden disruptions, their origin, and their impact on cargo transport processes in logistics networks should allow an assessment of the impact of disruptions on the course of processes and an attempt to identify countermeasures that can be applied by participants of logistics processes and infrastructure to anticipate the occurrence of disruptions. Ultimately, these measures should be used to prepare decision-support tools for companies to react dynamically to disruptions, while preserving the sustainability aspect of logistics networks as much as possible.

2. Disruptions and resilience logistics network

In a global market environment, logistics networks and transport chains are particularly vulnerable to several unpredictable events that can cause supply chain disruptions, operational disruptions, increased operating costs, and even loss of revenue and reputation for supply chain participants (Aldrighetti et al., 2021). As introduced by Tang (Tang, 2006), disruption risk is associated with a specific type of event that may occur due to a natural disaster (earthquakes, floods) or as a result of intentional or unintentional human actions (war, terrorist attack, epidemic/pandemic outbreak, strike). So far, this type of risk has typically been considered to be characterised by a low probability of occurrence and a high magnitude of consequences (Kinra et al., 2020; Ivanov 2021). Analysing the events of 2019-2023, however, it is possible to observe, an exceptionally high intensity of sudden disruptive events, both at the global level resulting from geopolitics, cases of global pandemics, as well as local disruptions caused by climatic factors or human activities. The work in the SARIL project therefore focuses on investigating the impact of these disruptions on the logistics networks of the three levels:

- global - wars, pandemics;
- National Park - fires, landslides;
- local - cyber-attacks, local flooding.

The analysis of disruptions in the SARIL project carried out from the practical side through collaboration and interviews with logistics chain actors, provides information about the real challenges that supply chain actors have to respond to due to sudden disruptions. This is because careful identification of the causes of disruptions and their consequences, and learning from the incidents, allow countermeasures to be planned to reduce the risk of the consequences of disruptions (Sabouhi et al., 2018). Consequently, this provides the basis for creating disruption-resistant and sustainable logistics networks, which, operating in a constantly changing environment, rarely operate in a stable steady state (Haywood and Peck, 2004). The logistics network as well as its links must therefore be designed and planned in a way that should be resilient to disruptions.

The resilience of logistics networks understood as the ability of a system to return to its original state or even a more desirable state after a disruption (Shekarian and Parast, 2021), plays a significant role in managing and mitigating disruptions. Logistics networks can build resilience at individual links by setting themselves up for proactive mitigation - protecting themselves before disruptions occur, or by implementing reactive measures based on disruptions worked through. According to Ivanoy and Dolgui (Ivanov and Dolgui, 2019), one of the most popular methods of mitigating disruptions in logistics networks is to plan for proactive redundancies - e.g. buffer stocks, or backup suppliers, in the pre-disruption stage On the other hand, a reactive approach aims to adjust supply chain processes and structures when disruptive events occur (Aldrighetti et al., 2019). However, it is not said that the analytical and scientific methods developed apply to the real operational work of companies, making the resilience of logistics chains potentially insufficient.

3. SARIL Project - 3 levels of disruptions

The SARIL (Sustainability and Resilience for Infrastructure and Logistics networks) project is part of the European Union's Horizon Europe research and innovation programme, included in the call 'HORIZON-CL5-2022-D6-02-07 - New concepts and approaches for resilient and green freight transport and logistics networks against disruptive events (including pandemics)'. The project focuses on holistic approaches to managing the resilience of logistics networks, green resilience, and effective response to disruptive events in transport networks. The project aims to develop decision-support tools for supply chains, enabling process actors to react dynamically to sudden disruptions in the transport system and to recognise the triggers of these disruptions at an early stage. The starting point for the development of the project is the investigation of three scenarios in different geographical areas and dimensions of disruptions - natural hazards (floods, fires, pandemics) as well as man-made disruptions (war-related freight transport disruptions and cyber-attacks). The study will result in methodologies and tools that can be used by industry stakeholders and policymakers on how to prepare for and respond to disruptive events, maximizing the resilience, efficiency, and sustainability of freight transport

networks. The scenarios explored will define infrastructure interconnections and identify opportunities and threats from the perspective of sustainability and resilience of each event.

The SARIL project focuses on solutions, by employing developing and investigating natural hazards as well as man-made disruptions in different geographical areas and scenarios.

The geographical areas that are defined, are divided into three scales, with three different disruptive scenario cases:

- Scenario case 1: Regional scenario (Mantua, Italy);
- Scenario case 2: National scenario (Northwest Iberian Peninsula, Spain, and Portugal);
- Scenario case 3: EU-wide scenario (Europe).

The scenarios are used for analysing disruptions and their effects are identified and co-created with relevant stakeholders, ensuring realistic and relevant situations. This includes a mapping of all stakeholders in the value chain and assessing data availability, challenges, requirements, needs, main disruptive events, and their effects.

3.1. Global scenario

The 'EU-wide scenario deals with disruptions to the EU's maritime and land freight transport network caused by global events such as a pandemic, war in the EU's neighbourhood, and other events with long-term consequences. The EU-wide scenario focuses on identifying disruptions that have emerged in recent years in transport chains, mainly along freight flow lines from Asia to Europe, and further disruptions to intra-European traffic caused by events that disrupt or interrupt transport chains. The pan-European scenario analysis aims to answer the question of how transport chains have responded to global disruptions such as pandemics, wars, or energy crises, what changes have taken place in the organization of processes, what changes have taken place in the relationships between participants in global transport chains and logistics networks. The scenario will examine operational relationships in the context of containerized cargo flows from Asia to Europe towards imports, from the perspective of a logistics service provider.

The choice of such a scenario among several other global transport relationships affected by supply chain disruptions is because the share of European imports of containerized cargo from the Far East far exceeds Europe's share of trade with other regions of the world, and also exports from Europe to the Far East account for the relatively largest share of European trade (Dynamar, 2023).

Table 1. European container volumes in import relations in the 1st half of 2023 (Dynamar, 2023).

Trade	Imports		Export	
	Share 2023	Volume [TEU]	Share 2023	Volume [TEU]
Far East	64%	8 178 900	33%	3 166 400
North America	10%	1 326 300	25%	2 425 400
Australasia	1%	89 900	3%	296 800
Middle East	13%	1 622 800	19%	1 841 300
Sub-Saharan Africa	4%	492 500	11%	1 012 200
Latin America	8%	1 023 100	9%	812 800
Total	100%	12 742500	100%	9 554 900

As a result, the transport relationship from the Far East to Europe has been the most exposed in recent years to the disruption of the global supply chain, both by sea and by rail from China to Europe.

This scenario will analyse the two main transport routes connecting the Far East with Europe:

- maritime route - from Far Eastern ports via the Suez Canal to Northern European ports;
- railway route - from the Far East to Europe via the Trans-Siberian Corridor / Central Eurasian Corridor, via Malaszewicze to Poland / Germany.

A maritime route and a rail route can be complementary or alternative to each other in the event of a disruption in the transport process. Depending on the type of disruption and its location, the rail route can replace the sea route or the sea route can replace the rail route blocked due to the disruption.

The European scenario aims to verify the types of disruptions that have occurred in recent years on this transport route, infecting the transport infrastructure, and affecting the shape of transport networks and the relationships between users. By analysing these factors, it will be possible to identify the critical points of disruption and the main problems faced by supply chain participants when they encounter disruptions. Ultimately, this knowledge is intended to feed into the SARIL project and explore how actors respond, whether they have the tools to anticipate disruptions and, if not, identify from previous experience what tools are missing to deal effectively with disruptions.

3.2. National scenario

A national scenario case study analyses the extreme meteorological phenomena of forest fires between Spain and Portugal, within the perimeter of the infrastructures of the Atlantic corridor in the north-western area of the Iberian Peninsula.

Climate change brings new and extreme weather phenomena to regions previously unaccustomed to dealing with them. A clear example is the existence of large wildfires that cannot be easily controlled. These wildfires, which previously occurred very sporadically in very specific latitudes, are beginning to appear due to this climate change in a very important way in areas of southern Europe such as Spain and Portugal. Portugal and Spain are suffering in 2022 the hottest summer since the existence of meteorological data, dry vegetation, and poor forest management. A definitive contributing factor to poor forest management is also the socio-economic changes in the territory, such as the depopulation occurring in many areas of Europe (abandonment of rural activities such as agriculture and livestock). This results in the loss of pastureland for livestock and croplands, which could act as firebreaks in case of wildfire. Both are countries with temperate climates and are not used to this type of weather, although in recent years, again due to the increased incidence of climate change and the presence of extreme weather phenomena, this type of event appears with ease, and impacts distribution and logistics networks (e.g. the Atlantic corridor). Spain is among the top five European countries with the highest number of wildfires. In the NW region of Galicia (within the perimeter of the infrastructures of the Atlantic corridor), forest fires are one of the natural hazards. In 2019, 1676 forest fires were registered in the Galician region, covering 13,691 ha.(Gobierno de España Ministerio de Agricultura, 2020)

The impact of climate change and related disruptions can be seen in the national logistics networks. In terms of both the impact on infrastructure and logistics processes, the region is burdened with several disruptions that impede the free movement of goods, and the detailed impact of these on logistics processes is being investigated in the SARIL project.

3.3. Regional scenario

The 'regional scenario' examines local disruptions such as flooding affecting the transport network, as well as cascading effects caused by a simultaneous cyber-attack affecting the quality and flow of information required to support emergency decision-making. The region analysed is the province of Mantua in the Lombardy region, crossed by several major rivers, including three tributaries of the Po: the Mincio, Oglio and Secchia. The region could be significantly affected by flooding involving the Mincio River, which flows through the city of Mantua. Mantua is an important destination and interchange point for interregional transport and trade outside the region, involving several modes of freight transport such as water, road and rail. The Mantua region influences the functioning of the TEN-T transport corridors - Mediterranean, Scandinavian-Mediterranean and Baltic-Adriatic - also exerting an influence on key global transport routes.

The territory of Mantua is characterized by the significant presence of rivers, tributaries, and artificial tributaries, which undoubtedly affect the transport system. The exchange of goods in the province of Mantua takes place mainly on road routes, the operational condition of whose bridges play a key role in the provincial transport system. The interconnectedness between the transport system and the water system in the area results in vulnerability to exceptional hydraulic events such as flooding and river flooding. Flooding can cause significant damage to bridges, such as the scouring of pillars, which can reduce functionality and compromise safety (Qin, 2022). The vulnerability of bridges strongly depends on the state of maintenance. Sometimes, as in the case of the city of Mantua, protection systems based on river level monitoring are installed to mitigate flood risk. Both the structural and hydraulic monitoring systems and the water level control system rely on the use of real-time information that allows adaptive emergency interventions (reduction of bridge functionality, regulation of water levels in the city centre) to reduce the impact of flooding. A disruption in the flow of information, caused, for example, by a cyber-attack during a flood, can affect both the emergency management of bridges and the functionality of the water control system. Missing or altered bridge condition information can lead to delays in emergency interventions (e.g. inspections by emergency teams or the implementation of emergency actions such as restriction/suspension of traffic) due to inadequate prioritization of interventions and mismanagement of emergency teams.

Disruptions in this region are local but extremely important for the movement of goods in logistics networks. The impact of disruptions due to both human factors (cyber-attacks) and climatic factors - floods - can exceptionally affect freight flows and disrupt local transport networks. The subject of SARIL's analysis in this area is to examine the impact of disruptions on local transport stakeholders, taking into account managers of transport infrastructure directly attacked by cyber-attacks and exposed to flood risk.

4. Methodology and first outcomes

The methodology of the project followed a social science approach using a qualitative semi-structured interview. Interviewing is a method to discern the perspectives of actors and stakeholders that are the bearers of the challenge or solutions in question and to learn from them. As such, the method is not about learning facts or truth per se but locating important issues for these persons or actors. Further, what one can learn from a semi-structured approach can be seen as a knowledge-producing approach more than a knowledge-gathering approach, as the questions might lead the interviewee to think outside the box or about events that did not occur to them before. For this particular purpose, semi-structured interviews are particularly good for understanding disruptions, both their consequences but also ways to mitigate them. While there are many approaches to doing interviews (e.g., Fontana and Frey 2005), in this project the interviews were done either face-to-face or online, and usually in the language of the stakeholder.

The stakeholders in question for this project are any actors (organization level) or groups of people being affected by or responding to disruptions in logistics chains. This means the target group of relevant stakeholders is quite wide, meaning anyone from suppliers, goods owners, and customers if one thinks from a supply chain perspective, and terminals and logistic service providers from a transport network and logistics chain perspective. and not least infrastructure operators and owners, which can be both public authorities or private companies. An example of the supplier, in this case, is anyone from a primary industry such as agriculture, to industrial suppliers, depending on where one is in the chain.

The number of interviews across the scenarios varies according to their focus. The total number for each scenario is EU-wide scenario: 7 interviews, National scenario: 13 interviews, Regional scenario: 10 interviews. The types of stakeholders interviewed for each of the scenarios can be seen in the table below. Finding the right stakeholders was part of a process further described in an internal deliverable of the project part of task 1.1.:

Table 2. Types of stakeholders interviewed across the scenarios

Type of stakeholder	EU-wide -	National	Regional	Total
Regional and local authorities		2	2	4
National authority			1	1
Workers association -representing truck drivers			1	1
Logistic operator for port, terminal, rail (public or private)	3	4	1	8
Logistic service provider or forwarder	3	1		4
Infrastructure maintenance for road, rail or waterway (private or public)		1	4	5
Company dependent on deliveries or producer	1	5	1	7
Total interviewed per scenario	7	13	10	30

The interview guide contained 19 open-ended questions related to the disruption theme of the SARIL project. The questions were divided into the following main topics:

- status, including about organisation and work with logistics/importance of logistics;
- disruptions and consequences of them;
- data available and solutions or strategies to mitigate disruptions;
- other stakeholders and collaboration possibilities.

The analysis of the interviews followed an approach of comparing findings across scenarios and across stakeholder types for the main topics. The following analysis focuses on discerning similarities and differences in experiences with disruptions and how to deal with them.

4.1. Main disturbances identified by stakeholders

In recent years, the European freight transport network has faced and continues to face major disruptions due to global crises. The logistics network participants surveyed in the first phase of the SARIL project highlighted several problems, due to both human and climatic factors, that they have had to face in recent years.

Of particular note during the interviews is the impact of the COVID-19 pandemic factor, which affected both global and local logistics chains. Respondents also noted that in 2020, transport chains were disrupted by the COVID-19 pandemic, then in 2021 by the blockade of the Suez Canal, and in 2022 by the impact of the war in Ukraine on global transport networks. According to interviews, which is also in line with the observations of other researchers, the COVID-19 pandemic significantly affected supply chains (Rejeb et al., 2020), including Asia-Europe supply chains (Motowidlak, 2022). The lockdown in China first brought production and transport to a standstill, only to trigger a wave of freight difficult for supply chains to handle a few weeks later. The

congestion at Asian ports, and the increased volume of products that had to be exported from Asia, caused both a shortage of cargo units that could handle the transport and a lack of ship capacity. The main ports in Europe, which were initially idle, faced an oversupply of cargo a few weeks after production resumed. Overcrowding at storage yards significantly reduced cargo handling at terminals, causing delays in loading intermodal trains, handling ships or loading trucks. In this situation, cargoes were diverted to less busy ports with spare handling capacity. On the other hand, the infrastructure of previously less-used ports was taken by surprise by the sudden increase in transhipment and capacity problems arose for ports, terminals and the rail network.

Capacity problems in maritime transport and port congestion have led to increased interest in rail links between Asia and Europe. European logistics operators faced congestion at port terminals, transhipment problems, no or limited access to rail intermodal platforms and, finally, a lack of professional truck drivers in the market.

Another factor affecting supply chains was the outbreak of war in Ukraine, which caused further disruption to transport chains. The sudden need to divert cargo from Black Sea ports to European ports resulted in an increase in transshipments at Polish ports and the need to organise efficient transport chains between European ports and Ukraine. Sanctions imposed on Russia due to the war caused Polish ports to suspend transshipments to Russia and cargo was stored at terminals, resulting in reduced terminal capacity. The war also caused a sudden outflow of labour from the transport market - the shortage of professional drivers increased. In particular, Polish transport companies were affected by the exodus of Ukrainian drivers, who had to return to Ukraine. The New Silk Road has also been disrupted by hostilities. While rail connections via Belarus have not been disrupted, major customers have withdrawn from transport via the northern route for ethical reasons. Another issue for customers is the insurance of cargo that passes through the war zone along the New Silk Road route. As a result, cargoes that were transferred to the rail line during the pandemic had to return to the sea route or find an alternative connection via the trans-Caspian New Silk Road corridor. The New Silk Road route through Ukraine to Poland to Slavkov was suspended. The war situation on the New Silk Road has forced operators to reorganise their supply chains and look for alternatives.

In identifying the main disruptions due to the human factor, respondents pointed to the COVID-19 pandemic, the war in Ukraine, and the blockade of the Suez Canal in 2021. From these main causes, however, there are specific disruptions that have a significant impact on the functioning of individual links in the logistics network, such as:

- sudden reduction in access to raw materials;
- increase in transport rates;
- sudden drop in transport rates;
- introduction of lockdowns;
- problems of access to transshipment infrastructure;
- lack of available transport facilities;
- congestion at ports and transshipment terminals;
- workers' strike;
- sudden increase in volume;
- sudden drop in volumes;
- decrease in availability of staff including drivers shortage;
- increase in energy costs including an increase in fuel costs;
- reduced capacity of transport routes - especially railways.

The above disruptions were predominantly identified by those working operationally in the goods supply chain, such as manufacturers, logistics operators, terminal operators and freight forwarders. These actors noted the widespread impact of geopolitics on their day-to-day operations. Also for those operating locally, infrastructure managers noted a problem arising from the disruption associated with the COVID pandemic19. In addition, actors interviewed under the national and regional scenario run pointed to disruptions resulting from climate disruption, such as:

- forest fires;
- storms;
- snowbirds;
- downpours;
- flood;
- icing on the roads;
- landslides;
- droughts;
- earthquakes.

Disruptions related to climate impacts have instead not been the focus of attention for operators involved in the global supply chain, paying more attention to operational factors in a broad perspective, even though the local perspective and impacts of climate factors may also affect their parts of the transport chains (Table 3).

Table 3. Disturbances identified by research respondents in regional (R), national (N), and global/European (EU) scenarios.

	Authorities			Workers association - representing truck drivers			Logistic operator for port, terminal, rail (public or private)			Logistic service provider or forwarder			Infrastructure maintenance for road, rail or waterway (private or public)			Company dependent on deliveries or producer		
	R	N	EU	R	N	EU	R	N	EU	R	N	EU	R	N	EU	R	N	EU
Pandemic		2			1			4	2		1	4		1		2	4	1
War												2						1
Suez Canal blockage												2						
Lack of access to raw materials																		1
Increase of transport rates												3						1
Decrease of transport rates												2						
Lockdowns									1									1
Lack of infrastructure capacity												1						1
Lack of transport equipment												4						1
Congestion in ports									1			3						1
Strikes				1							1						2	
Decrease from cargo volume									2			3						
Increase of cargo volume									2			3						
Drivers shortage				1								2						1
Increase of energy costs (energy, fuel)									2			2						1
Reduced capacity of railways									1			1						1
Fires in port								2										
Forest fires	1	2		1	1		1	2					1	1		1	2	
Sea storms																	1	
Snowfall					1									1			2	
Heavy rains											1					1		
Flooding	3	2					1	2		1			1			2		
Ice roads		2												1			1	
Landslides	2			1			1			1			1					
Droughts													1					
Earthquake	3	1								1						2		

4.2. Similarities and differences across the scenarios

After analysing the information provided by stakeholders in each scenario (regional, national and European), it was possible to identify preliminary similarities and differences between the different scenarios. The similarities and differences between the scenarios relate to the disruptions, their consequences and solutions, based on the different types of stakeholder perspectives. Despite the differences due to the specific activities of the companies, once the disruptions attacking the different links in the logistics networks have been identified, it is noticeable that the individual disruptions are repetitive in the different elements of the supply chains, both between the different types of actors and between the scenarios.

A factor similar to many stakeholders in the different scenarios, although most noticeable in the global scenario, was the pandemic outbreak-related reduction in cargo in transit at the start of the pandemic, followed by an increase in cargo volumes. A recurring problem was congestion at ports and terminals and lack of capacity on vessels. The extraordinary workload in ports due to the pandemic led to strikes in some European ports (Le Harve, Hamburg, Gdansk), which were mainly strikes by terminal or port workers. Due to the war in Ukraine and the special privileges granted to Ukrainian carriers, Europe also faced carrier strikes at the Polish-Ukrainian border. In the domestic scenario, logistics stakeholders (such as logistics service providers, and terminal loading

port) also experienced problems due to the pandemic, related to drivers' working hours. Another issue, not directly related to the pandemic, was the carriers' strike. This was a significant disruption in the national and European scenarios.

In terms of regional and national scenarios, only two interviewees referred to the impact of the pandemic on logistics networks, and all other interviews referred to flooding. Nevertheless, the farmers' representative mentioned paradoxically that they experienced increased profits during the pandemic due to having one of the largest storage infrastructures in the area. In the case of truck drivers, their comment was more social, highlighting that during such events communities become more isolated and reaching them to deliver goods becomes essential, regardless of the conditions of the transport network. However, in the regional interviews, the main disruptions centred around flooding and transport disruption.

Data dispersion is an issue in all regional, national and European scenarios. As the EU scenario stakeholders explained, there is a need to aggregate market data in one place. This need stems from discussions with several scenario users who point to a lack of data transparency - goods train timetables, rail line occupancy, vessel arrival times at particular ports or cancellation of particular services, and terminal yard occupancy. Users point out that the data is dispersed and has to be searched for in different sources or on individual shipowners' websites. The dispersion of the data, and access to it, especially in the case of meteorological data, is pointed out by stakeholders in the local and national scenarios.

The lack of cooperation between actors at the local, regional and national level is another issue that is similar for all three scenarios. In the regional scenario, part of the solution is to involve more local authorities as local communities are affected. There is a lack of communication and coordination between the different stakeholders. In the regional scenario, between authorities and other stakeholders involved in disruption. In the national scenario, a similar issue was coordination in emergencies - where there was a lack of involvement of the wider sector in responding to disruption. A step-by-step plan is needed to determine who should be involved to prevent the consequences of disruption. In addition, both regional and national scenarios identified the need for more uniform systems to warn and inform the public in the event of disruption. The lack of accurate information on meteorological phenomena, in both the regional and national scenarios, points to the need for improved and centralised weather forecasts.

Almost all stakeholders interviewed observed an increased frequency of extreme natural hazards, such as floods and heavy rain. Some highlighted the crucial role of the accuracy and timeliness of weather forecasts during these events, according to the national scenario interviews, and pointed to the need for more reliable weather information. Others highlighted that predictive mathematical models are based on outdated data that inaccurately represent the evolution of traffic demand. Regarding the risks of natural disturbances, most stakeholders agreed that cooperation between local and regional authorities is effective during extreme natural events. However, some respondents emphasised the need for an internal communication channel between these actors to coordinate and ensure reliable communication during such crises, given that traditional communication channels such as telephones can be compromised. The need for internal and more resilient communication channels was also noted in the national scenario. Some stakeholders suggested improved training and simulations with these actors in peacetime, as also suggested in the national scenario.

The Global/EU scenario and the consequences mentioned here differ slightly from the regional and country scenarios. Fuel supply and fuel prices are listed as disruptive issues, which is not indicated in the other case scenarios. These disruptions do not directly affect the transport infrastructure or network but lead to a 'chain of disruptions' in supply chains and transport networks that have serious consequences.

There are also similarities between the scenarios in terms of priorities for ensuring the resilience of supply chains. In the regional scenarios, stakeholders interviewed emphasised that during extreme natural events, the main objective is to ensure safety and the rapid restoration of transport services. For truck drivers, the top priority is to complete the delivery of goods quickly by seeking alternative routes in the shortest possible time. Truck drivers emphasised that they rely on traditional methods to find alternative routes during such extreme events. It was pointed out that often navigation systems provide impractical alternatives for heavy trucks, suggesting routes and alternatives with obvious geometric barriers, according to a national case study. They are looking for a dedicated support system tailored to heavy vehicles, providing viable alternatives. In addition, as in the national case study, truck drivers do not have a common system of information consultation and communication on traffic status, routes and possible road closures. They currently use a network of WhatsApp groups to access and share such information.

An important finding of the research is the declaration of the majority of stakeholders who state that there are no structured and formalised lessons learned from previous disruptions. Companies mostly do not apply any preventive measures and rely on the experience of their employees who reacted in real time to disruptions from previous years. They collect data but mostly do not draw lessons for the future. Stakeholders say they cannot predict what the next disruption will be, so they do not know how to future-proof themselves and do not take

such operational measures. In the European scenario, stakeholders say that the most important thing for them is to meet customer expectations according to the contracted time and cost of the order. Environmental and sustainable transport issues are not at the centre of attention.

In the national arena, interviews with infrastructure managers showed that contracts lack chapters on budget, resilience and sustainability measures. If this aspect is not defined and written into the contract, it is difficult for the company to implement different and sustainable solutions.

5. Conclusion

The disruptions identified from the first phase of the SARIL project - during interviews with logistics network stakeholders in each scenario - illustrated the key issues affecting freight flows in transport networks. Identified disruptions such as the COVID-19 pandemic, disruptions resulting from warfare in Europe, fires, floods and cyber-attacks have occurred in high intensity in recent years and have caused many changes to both the transport infrastructure and the flow of goods. The resilience of supply chains understood as the ability to restore logistics networks to their pre-disruption state, has been put to the test, with many companies failing to respond nimbly to disruptions. From the work carried out in the project so far and the interviews conducted, it is evident that the majority of companies so far have not had countermeasures, or disruption response plans in place. There is a strong need to develop countermeasures that respond dynamically to disruptions, and companies at every stage of global and local logistics networks currently see gaps in communication between the different links in logistics networks.

The resilience of logistics networks to disruptions appears nowadays no longer simply as the ability to respond to sudden external factors and restore logistics networks, processes and infrastructure to their pre-disruption state (Carpener et al., 2001), but as the modification and adaptation of wider logistics processes to new situations, their modification and improvement (Timothy et al., 2019). As noted during the research conducted on respondents to the SARIL project, it is crucial to learn lessons before companies look back at situations that have arisen, to put in place a standardised framework that gives guidance on how to respond to disruptions of a particular type. As the research conducted so far indicates, these actions are currently largely declarative, while for companies, employees act intuitively or based on their own experiences and operational knowledge.

The disruptions attacking logistics systems in recent years have drawn the attention of individual logistics companies to the need to keep an eye on the global market by discovering the close interdependencies between the various links in global logistics networks, and the need to react nimbly to signals anticipating the emergence of disruptions. The need to diversify, to disperse both suppliers and customers and to identify weak links in transport networks has been recognised.

Disruptions in logistics networks affect every link from the infrastructure manager, the manufacturer, the consignee, to logistics operators, forwarders and carriers in each transport mode. Due to the wide range of participants, a questionnaire has been drawn up based on initial interviews with each of these market players in the SARIL project, which will be used to survey market stakeholders in detail using the Delphi method. This two-stage survey is intended to broaden the answer to the question of disruptions attacking individual market participants, once their needs for preventing these disruptions have been identified. The results of the survey are also expected to contribute to the creation of decision-support tools for logistics processes that respond to real market needs, supporting the building of resilience in transport networks.

Acknowledgements

The presented work was performed in the context of the Horizon Europe project SARIL which is funded by the European Union under grant agreement ID 101103978. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency. Neither the European Union nor the granting authority can be held responsible for them. More information on the project can be found at https://saril-project.eu.

References

Aldrighetti, R., Battini, D., Ivanov, D., Zennaro, I. 2021. Costs of resilience and disruptions in supply chain network design models: A review and future research directions. International Journal of Production Economics 235, 108103.

Aldrighetti, R., Zennaro, I., Finco, S., Battini, D. 2019. Healthcare Supply Chain Simulation with Disruption Considerations: a Case Study from Northern Italy. Global Journal of Flexible Systems Management 20, 81-102.
Carpenter, S., Walker, B., Anderies, J., Abel, N. 2001. From Metaphor to Measurement: Resilience of What to What? Ecosystems 4(8), 765-781.
Dynamar. 2023. Newsletter 36/23, 4.
Fontana, A., Frey, J. H. 2005. The interview. The Sage Handbook of Qualitative Research 3, 695-727.
Gobierno de España Ministerio de Agricultura, Pesca y Educacion, 2020. Available online: https://www.mapa.gob.es/es/desarrollo-rural/estadisticas/Incendios_default.aspx (accessed on 22 July 2020).
Haywood, M., Peck, H. 2004. Supply Chain Vulnerability Within Uk Aerospace Manufacturing: Development Of A Vulnerability Management Toolkit. Supply Chain Practice 6, 72-83.
Ivanov, D., 2021, Introduction to Supply Chain Resilience. Springer Nature, Cham.
Ivanov, D., Dolgui, A. 2019. Low-Certainty-Need (LCN) supply chains: a new perspective in managing disruption risks and resilience. International Journal of Production Research 57, 5119-5136.
Kinra, A., Ivanov, D., Das, A., Dolgui, A. 2020. Ripple effect quantification by supplier risk exposure assessment. International Journal of Production Research 58, 5559-5578.
Motowidlak, U. 2022. Multi-dimensional analysis of synchromodal logistics on the development of sustainable transport corridors from the perspective of reconfiguring European-Asian supply chains. LogForum 18 (3), 335-343.
Nagy, J., Foltin, P., Ondryhal, V. 2022. Use of Big Data Analysis to Identify Possible Sources of Supply Chain Disruption through the DOTMLPFI Method. LogForum 18 (3), 309-319.
Qin, S. 2022, 'Recent hydraulic bridge failures in China: review and discussion. Revista de La Construcción, 21(2), 193-203.
Rejeb, A., Rejeb, K., Keogh, J.G. 2020. COVID-19 and the Food Chain? Impacts and future research trends. LogForum 16 (4), 475-485.
Sabouhi, F., Pishvaee, M.S., Jabalameli, M.S. 2018. resilient supply chain design under operational and disruption risks considering quantity discount: A case study of pharmaceutical supply chain. Computers & Industrial Engineering 126, 657-672.
Shekarian, M., Parast, M.M. 2021. An integrative approach to supply chain disruption risk and resilience management: a literature review. International Journal of Logistics Research and Applications 24(5), 427-455.
Tang, C.S. 2006. perspectives in supply chain risk management. International Journal of Production Economics 103, 451-488.
Pettit, T. J., Croxton, K. L., Fiksel, J. 2019. The evolution of resilience in supply chain management: a retrospective on ensuring supply chain resilience. Journal of Business Logistics, 40(1), 56-65
Trump, D., Linkov, I. 2020. Risk and resilience in the time of the COVID-19 crisis. Environment Systems and Decisions 40, 171-173.