Critical Futures for Critical Infrastructures

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1. Introduction

The current era is characterized by poly-crises. i.e. overlapping and interconnected disruptions, posing unprecedented challenges for critical infrastructures. Climate change, geopolitical tensions, underinvestment, digital vulnerabilities, and evolving logistical demands have intensified the risk landscape. For fluvial ports, which serve as crucial nodes for the movement of goods and energy, as well as regional economic lifelines, these threats are compounded by their systemic role in both national and international supply chains. Fluvial ports are not only exposed to physical threats such as flooding, extreme weather, and aging infrastructure, but also to cyberattacks and hybrid threats that can disrupt operations, cause cascading failures, and undermine local, national and international security.

This paper aims to explore how anticipation and resilience-building strategies can better safeguard fluvial ports from the expanding spectrum of risks, with a particular focus on the usage of dystopian scenarios as analytical and communicative tools. Furthermore, the paper explores the specific case of two river ports located opposite each other on the Rhine within a cross-border context, providing a valuable opportunity to examine the complex interrelationships that influence the resilience of such infrastructures when confronted with disruptive events.

The structure of the paper is the following. Section 2 discusses the relevance of anticipation and resilience for critical infrastructures. In the next section, dystopian narratives are introduced as a method to enhance risk perception, participatory engagement, and systemic thinking. Section 4 examines the specific vulnerabilities and strategic importance of fluvial ports as critical infrastructure. The section after this one presents the IMMER project, a cross-border initiative applying new analytical tools to fluvial port resilience. Section 6 highlights the main results from scenario-based exercises and stakeholder inputs and extracts key lessons for policy, practice, and research. The final section concludes by assessing the potential benefits of dystopian narratives for critical infrastructures, while also acknowledging their limitations.

2. Anticipation as a Key Factor for the Resilience of infrastructures

Academics have not yet achieved a consensus on the definition and components of resilience, largely due to the diverse array of disciplines involved in its study. Even when excluding the natural sciences and focusing on social sciences such as psychology, economics, management, sociology and political sciences, the concept of resilience remains multifaceted and increasingly utilized across these fields (cf. Carpenter et al. 2012, Southwick et al., 2014, Raymond et al. 2020).

Within the scope of this paper, infrastructure resilience analysis centers on organizational dynamics rather than physical characteristics. Physical resilience constitutes only one dimension of a broader systemic resilience framework that integrates strategic decision-making, political considerations, and societal impacts (Cao, 2023). This multidimensional approach recognizes that infrastructure resilience operates at the intersection of technical systems and human/organizational factors. In addition, in the context of this paper, the discussion of resilience is confined to its relationship with extreme events impacting infrastructures, whether these events are seen as the result of foreseeable risks or the consequence of unexpected or unforeseeable causes. Resilience distinguishes itself from related concepts like flexibility and agility through its unique focus on crisis response and post-disruption recovery. While these adjacent qualities address adaptability to change, resilience specifically examines how systems withstand shocks and potentially emerge strengthened afterward through adaptive growth.

Hillmann and Guenther (2021) propose what they call an integrated definition of organizational resilience resulting from a systematic review of the literature: "*Organizational resilience is the ability of an organization to maintain functions and recover fast from adversity by mobilizing and accessing the resources needed*. (…) *The result of an organization's response to adversity is growth and learning*." (Hillmann and Guenther, 2021, p. 31). Furthermore, Duchek (2020) stresses the combinatorial nature of organizational resilience and considers it as a meta-capability: "(…) *we define organizational resilience as an organization's ability to anticipate potential threats, to cope effectively with adverse events, and to adapt to changing conditions*." (Duchek, 2020, p. 220).

Focusing on the sub-national level, the paper seeks to identify possible innovative solutions that strengthen the resilience of infrastructures at local level in terms of strategies and policy making. In this respect, Bristow and Healy (2014) argue that there is a lack of conceptual understanding of what role policy makers, particularly at local level, might play in building resilience. Consequently, and considering the possible role of policy interventions in complex adaptive systems they propose a conceptual framework within which policy action can be theorized and understood. They identify specifically three critical dimensions which frame the role and scope for policy intervention aiming at local economic resilience, i.e. the structure of governance, the types of policy interventions and the horizons for appropriate intervention.

Following the analysis of Duchek (2020) and as summarized by Gnamm (2024), resilience can be conceptualized as the combination of three main dimensions. This highlights its multifaceted nature, encompassing proactive preparation, robust recovery, and adaptive evolution:

- Anticipation : Resilience can be viewed as an expression of anticipation, involving the proactive identification and mitigation of potential future dangers. This dimension focuses on preparing for and preventing or minimizing the impact of adverse events through forward-looking strategies.
- Recovery : Resilience can also be understood as a form of recovery, where the emphasis is on withstanding shocks and aiming to return to a normal or stable state. This involves the capacity to absorb and cope with disruptions, with the ultimate goal of restoring functionality and equilibrium.
- Adaptation : resilience can be seen as a form of adaptation to a new environment. This perspective involves further developing and evolving in response to challenges, allowing systems or individuals to adjust and thrive in changing conditions. This adaptive resilience enables continuous growth and improvement, even in the face of adversity.

In the frame of the paper, priority is given to the first dimension, i.e. proactive preparation or anticipation. The specificity of this dimension is that it is of prime importance for the resilience of critical infrastructures.

According to De Felice et al. (2022, p. 1) "*Critical infrastructures are* (…) *those material resources, services, information technology systems, networks and infrastructure assets that, if damaged or destroyed, would cause serious repercussions on the crucial functions of society, including the supply chain, health, security and the economic or social well-being of the state and the population*."

Threats to critical infrastructure security have become a major concern for industrialized societies, given the increasing complexity and interdependence of these systems. Disruptions in one sector can rapidly cause cascading effects across others, amplifying vulnerabilities, particularly in the context of climate change and global instability. Consequently, effective management demands integrated strategies encompassing prevention, preparedness, and rapid recovery. As some threats are difficult or even impossible to predict, continuous risk assessment, adaptive planning, and cross-sectoral

collaboration are essential. Ultimately, safeguarding critical infrastructure requires a systemic, flexible approach that evolves alongside emerging risks and threats.

Woods and Alderson (2021) emphasize that, in the face of increasingly frequent and large-scale extreme events, current strategies aimed at achieving resilient infrastructure are progressing far too slowly. To date, efforts have largely relied on modeling tools that simulate the behavior of specific infrastructures within defined contexts. However, these approaches often fall short, as they struggle to address the complexity and interdependencies inherent in real-world systems. Consequently, what is needed is a deeper, broader, and forward-looking perspective, i.e. one that anticipates not just isolated failures, but systemic vulnerabilities. As they succinctly state: *"Resilience is a verb in the future tense"* (Woods and Alderson, 2021, p. 89).

In providing an overview of foresight methodologies Conway (2006) stresses that foresight refers to the particular human capacity that individuals have to think about the future and constitutes therefore a strategic thinking capability. Investigating the specific case of research infrastructures Keenan at al. (2007) points that foresight activities constitute a tool for the formulation of policies and strategies. In their views, foresight provides a process allowing key stakeholders to engage into a wide range of activities anticipating plausible trends and potentially implementing strategies for at least to some extent shaping the future. In their view, foresight activities should follow these key principles: future-orientation (though not in a predictive sense), participation (multiplicity of perspectives, interests, and knowledge) and multidisciplinarity (transcending traditional epistemic boundaries).

Nevertheless, and taking the example of the COVID-19 pandemic, Ansell et al. (2021) argue that extreme and unpredictable events disrupt the conventional repertoire of foresight, protection, and resilience strategies. Addressing such turbulent challenges requires cross-boundary collaboration, public sector innovation, and, perhaps most critically, the development of robust governance strategies. These strategies must be capable of navigating surprising, inconsistent, and highly uncertain events—conditions under which traditional foresight approaches often prove inadequate, if not outright ineffective.

3. How dystopian narratives can contribute to strengthen local resilience capacities

The purpose of this section is to demonstrate that incorporating dystopian narrative development into foresight analytics can enhance the resilience of local infrastructure by facilitating scenario-based preparedness and the formulation of stakeholder-aligned strategies.

Bourmistrov and Åmo (2022) consider that foresight is particularly useful for stimulating and leveraging creativity toward proactive action, but its effectiveness depends on how it is implemented and how it interacts with individual capabilities. According to them, foresight methods (especially based scenario-building workshops) can enhance creativity, proactivity and strategic management by reducing reactive behaviors.

Narrative foresight emphasizes the exploration of worldviews, myths, and stories that shape possible, probable, and preferred futures, moving beyond traditional, technology-focused approaches (Milojević and Inayatullah, 2015). Narratives provide a user-friendly and accessible method for engaging diverse stakeholders, as they are easier to understand and communicate compared to statistic-heavy methods (Keenan et al., 2007). They enable organizations to explore distant futures, including disruptive and uncertain events, while addressing unique industry dynamics and challenges. By involving economic actors in workshops and interviews, narratives foster co-creation of future scenarios, enhancing ownership, commitment, and proactive responses to potential threats (Foresight Manual Empowered Futures for the 2030 Agenda, 2018). Additionally, narratives align foresight

activities with cultural and organizational values, facilitating integration into decision-making processes.

Imagination and creativity are critical for foresight, allowing organizations to envision unconventional possibilities and anticipate emerging challenges (Vanatta and Johnson, 2019). Imagination extends beyond current knowledge, enabling exploration of unforeseen possibilities and overcoming "presentism" (Hauptman and Steinmüller, 2018). Creativity builds on imagination to develop innovative strategies and solutions. While imagination must be used judiciously to avoid biases, it thrives in collaborative brainstorming and personal reflection. Together, imagination and creativity empower foresight practices, enabling organizations to adapt to uncertainties and align strategies with future visions.

Durante et al. (2024) establish a distinction between predictive future-making and imaginative future-making. Their research indicates that predictive future-making supports organizations to prepare for plausible futures by analyzing current trends and signals. In contrast, imaginative future-making encourages creativity and critical reflection, empowering organizations to envision futures that are not only plausible but also desirable. The positive scenarios emerging from imaginative approaches emphasize community-driven initiatives, stakeholder collaboration, and education as essential strategies for addressing future challenges. These scenarios depict a future where collective action and cultural renewal are at the forefront of societal progress.

However, in an era characterized by uncertainty and volatility, traditional planning tools often prove inadequate when organizations confront “unknown unknowns” (in the meaning of Ramsesh and Browning, 2014). Science fiction (SciFi), particularly in its dystopian form, offers a valuable perspective for organizational foresight and strategic planning. Dystopian narratives enable stakeholders to envision worlds profoundly shaped by disruption, thereby facilitating the anticipation of emerging threats and the rehearsal of responses to potential crises. Once regarded primarily as entertainment, SciFi has increasingly been recognized as a catalyst for organizational creativity and innovation (Bucher and Husig, 2024; Michaud and Appio, 2022; Sætra, 2024). Specifically, dystopian SciFi serves as a means to anticipate unforeseen threats (Roussie et al., 2024), presenting a promising avenue for enhancing the resilience of both private enterprises and public organizations. Gendron et al. (2017) highlight the value of SciFi as a form of thought experiment within the social sciences, while Calvez (2018) emphasizes its capacity to foster "what if?" thinking. By constructing immersive worlds in which established systems collapse or undergo radical transformation, dystopian narratives stimulate novel perspectives and empower stakeholders to imagine alternative futures and develop innovative strategic responses. In essence, dystopian SciFi disrupts conventional modes of thinking and challenges cognitive biases by immersing audiences in unfamiliar—and frequently unsettling—future scenarios (Candy and Dunagan, 2017).

The following section presents an example of how dystopian narrative development can be integrated into foresight analytics to enhance the resilience of fluvial ports. Specifically, it demonstrates the application of scenario-based methodologies to strengthen preparedness and adaptive capacity within these critical infrastructures.

4. Fluvial ports as critical infrastructures

Critical infrastructures are defined as assets, systems, and networks that are essential for the functioning of society and the economy. They provide vital services such as transportation, energy, and water supply, and their disruption can have catastrophic consequences for public safety, the environment, and economic stability (Davey et al., 2021). Fluvial ports, as part of this category, are

pivotal in ensuring the continuous flow of goods and resources, thereby supporting both local and global economic systems.

Fluvial ports (also known as river ports or inland ports), are specialized facilities located along rivers that facilitate the transport of goods and passengers via inland waterways. These ports play a crucial role in connecting inland regions to broader trade networks, providing an essential link for economic activities and regional development. As critical infrastructures, fluvial ports are integral to the seamless operation of supply chains, contributing significantly to the economic vitality and resilience of the regions they serve.

Despite their importance, fluvial ports have often been overshadowed in research and policy discussions by their maritime counterparts. Studies and risk management frameworks frequently focus on seaports and harbors, which are perceived as more significant due to their role in international trade and exposure to high-impact threats such as extreme weather events and geopolitical conflicts (Mathuthu et al., 2017). This bias towards seaports leaves a significant gap in understanding and addressing the unique challenges and vulnerabilities faced by fluvial ports.

The resilience of fluvial ports is a critical area of concern that warrants greater attention. Resilience, in this context, refers to the ability of these ports and their associated systems to withstand and adapt to changing conditions and recover from shocks and stresses (Davey et al., 2021).

Enhancing the resilience of fluvial ports is essential for several reasons. First, fluvial ports are vital nodes in the transportation network, handling a substantial portion of inland trade. Disruptions in these ports can lead to significant economic losses and affect the livelihoods of communities dependent on riverine trade (Davey et al., 2021). In short, the good functioning of fluvial ports guarantees economic stability. Second, fluvial ports are part of a complex system of interconnected infrastructures. Enhancing their resilience requires a comprehensive understanding of these interdependencies and the potential cascading effects of disruptions (Haimes, 2009). Third, fluvial ports offer an environmentally friendly alternative to road and rail transport. Investing in the resilience of these ports supports broader environmental goals and helps mitigate the impacts of climate change (Wamsler et al., 2020).

Additionally, it is important to emphasize that certain fluvial ports are located along international rivers, as is the case with the two ports analyzed in this paper. The operation of these ports necessitates cross-border cooperation, and the integration of comprehensive risk management strategies serves to strengthen their resilience. Such measures, in turn, have the potential to enhance regional stability and promote international collaboration (Kröger, 2008).

The fluvial ports of Strasbourg (France) and Kehl (Germany) are located exactly opposite each other on either side of the Rhine. They are at the core of the so-called Upper Rhine, where two distinct political and administrative systems coexist. They constitute crucial hubs in the European inland waterway transport network, each with distinct characteristics and significant contributions to regional and international trade.

The fluvial port of Strasbourg is the second-largest French fluvial port, handling approximately 7 million tons of fluvial traffic and 1.2 million tons of rail traffic annually. It serves as the largest logistics zone in Alsace, featuring three multimodal container terminals and spanning 1,050 hectares. The port of Strasbourg hosts 500 companies and provides 10,000 direct jobs, extending its operations to nearby areas. Well-connected to major European seaports like Rotterdam, Antwerp, Le Havre, and Marseille via the Rhine and an extensive railway network, it is a crucial multimodal transport hub. The port owns 100 kilometers of railway tracks, 100 kilometers of waterfront, and 34 kilometers of roads.

The fluvial port of Kehl, is strongly oriented towards cargo handling and storage, covering 320 hectares and employing approximately 4,500 people across 120 enterprises. Situated directly opposite Strasbourg on the Rhine River, Kehl is a key Rhine River cruise port and a hub for large-scale goods traffic. The port hosts prominent German firms, including Badische Stahlwerke, Koehler, Bürstner, RMA Kehl, and Herrenknecht.

Kehl and Strasbourg share a history of transboundary cooperation, with each port having a representative from the other within its direction committee, fostering strong bilateral ties and collaborative efforts. Together, these ports exemplify the importance of fluvial transport in supporting regional economic stability, environmental sustainability, and cross-border cooperation.

5. The IMMER project

The IMMER (Increasing Municipal Mobility and Energy Resilience) project was part of the European Union funded Futuresilience project that groups 10 labs across Europe.[1] The overall project aims at reinforcing exchanges and information sharing about crisis situations specific to each region. More specifically, the IMMER lab aims at reinforcing resilience within the Strasbourg-Kehl area in terms of mobility and energy by 2050. This lab is working with 14 partner organizations among others energy and mobility producers, private companies, public organizations and fluvial ports.

In the frame of the IMMER project, 3 workshops have been realised using methods that combine long-term foresight and science fiction to think about potential consequences of future crises and to highlight future challenges the organization of the Strasbourg-Kehl area will have to face in the future.

On July 4, 2024, a workshop was organized, bringing together the project's partner actors, all of whom were active in the Upper Rhine area, the audience was both French and German. For the workshop whose aim was to develop the narratives, the World Café method has been chosen because it allows all participants to share their experiences and points of view in a simple and interactive way. It is a method that represents a creative process designed to facilitate constructive dialogue and the sharing of knowledge and ideas (Slocum, 2006). First introduced in 1995 by Brown and Isaacs (2005), it is inherently designed to be a participatory tool that facilitates community change by hearing the ideas and opinions of as many community members as possible. Furthermore, as a participatory method, it not only produces data for the researchers but also has the potential to benefit the participants, as it facilitates dialogue and mutual learning, thus motivating their participation and responses. The World Café method is a tool widely used as a participatory method for citizen participation and organizational change processes (Slocum, 2006). For these reasons, the World Café method was the most appropriate choice for the first workshop of the IMMER project.

During the workshop, three scenarios have been presented to the participants: ‘Fluvial tsunami’, ‘Societal collapse’ and ‘Blackout’ (cf. box 1).

[1] This project has received funding from the European Union’s Horizon Europe research and innovation programme under grant agreement No 101094455.

Box 1: The starting points of three dystopian scenarios

Blackout 2050

Spring 2050 marks a turning point, as the vulnerability of energy and transportation infrastructures becomes starkly evident. The accelerating climate crisis is placing unprecedented strain on energy generation and distribution systems, while also disrupting road, rail, and river transport networks. Concurrently, the economic, political, and social landscape is deteriorating, and global tensions are running high. On Friday, May 13, 2050, a shadowy, unidentified organization launches a coordinated attack on critical nodes of the electricity grid in France and Germany. Sabotage teams infiltrate several power plants, planting high-impact explosive devices that detonate with devastating precision. Major distribution hubs are also targeted, while sophisticated cyberattacks are unleashed simultaneously to amplify the chaos. By nightfall, the entire energy system grinds to a halt. In the aftermath, a state of emergency is declared. The reliability of electricity supply is thrown into question, communication networks collapse, and the flow of information comes to an abrupt stop. Public authorities, deprived of essential coordination tools, are effectively paralyzed.

Tsunami 2050

Weeks before the river tsunami hits, scientific monitoring stations begin detecting significant permafrost melt and deep fractures in the glaciers. When the first ice caps break off—two to three days before the wave reaches the Strasbourg-Kehl region—research institutes and civil protection authorities alert senior officials in Switzerland, Germany, and France of the impending disaster. As signs of a major mountain collapse emerge, images, videos, and eyewitness reports flood social media, quickly picked up by news channels and broadcast to a wider audience. On Friday, May 13, 2050, in the final hours before impact, widespread alarm turned into panic. Thousands attempt to flee to higher ground considered safe, but the sudden exodus creates chaos, blocking roads and crippling the region's mobility. Flooded areas make many routes impassable, trapping some evacuees. Energy infrastructure is hit, halting rail services. Traffic lights fail, worsening congestion—even in areas not directly affected. A partial radio network outage disrupts communications, including mobile phones, isolating residents and hampering the authorities' ability to issue safety instructions.

Collapse 2050

By 2050, global vulnerability is acute. The prolonged economic crisis has deepened inequality and strained governments, while geopolitical tension and sporadic conflicts fuel a wave of migration that overwhelms already fragile systems. Against this backdrop, a new, unidentified virus quietly emerges in South America. The threat goes largely unnoticed until disturbing videos on social media show sufferers in Amazonian towns becoming violently aggressive. Initially dismissed as fake news or conspiracy, the evidence mounts. Experts speculate about the source—mutant rabies, poisoning—but the World Health Organization hesitates to declare an emergency. Meanwhile, the virus spreads rapidly and mutates, becoming transmissible via saliva. Desperate governments try to hide the scale, but outbreaks erupt globally. Medical responses fail: treatments are ineffective, rushed vaccines catastrophic. Unchecked, the infection sparks unpredictable violence in communities. On Friday, May 13, 2050, reality breaks through denial as mainstream news airs footage of chaos at major airports: infected people attacking indiscriminately, gripped by hallucinations and rage. The world faces a pandemic of mass hyperviolence, with institutions and public order collapsing under the weight of the crisis.

Each scenario took place in three stages: 2050, 2051 and 2025. This workshop lasted approximately 3 hours. Three groups were predefined to maximize the diversity of profiles and experiences within the groups. The three themes chosen for the narratives from the interviews formed the basis of this workshop. Each theme was explored in three 35-minute rounds. Participants were asked to envision and describe the world after such crises. Groups were rotated so that each participant could contribute to one stage of each scenario. Each stage corresponded to a specific time period: 2050, 2051, then 2025. The idea here was to share the knowledge and ideas of all participants for each of the narratives. Risk management is about striving for better outcomes. To achieve this, it is essential to identify various potential risks and understand their causes and consequences. By proactively addressing potential future threats, organizations can better navigate uncertainties and achieve more favorable outcomes (Anderson, 2014). By imagining a catastrophe scenario, one can backcast to find solutions to implement and improve the preparedness capacity of local organizations. Envisioning a worst-case scenario can help to identify critical vulnerabilities and potential points of failure within the system in case of crisis.

After the workshop, each narrative resulted in a document of a few pages written by the IMMER team. After the development of three narratives, it has been possible to spot common points between each of them in terms of immediate consequences of the crises, of consequences of the crises one year later and of measures to take in the next coming years to be better prepared to face future crises. This highlights the need for effective crisis management strategies, including preparedness and response plans.

On November 21, 2024, the second IMMER project workshop was held in Strasbourg, gathering the same representatives that were at the first workshop plus some others from private and public organizations of the Strasbourg-Kehl area. The workshop aimed to build upon the outcomes of the first workshop held on July 4th The goal was to immerse participants in these dystopian scenarios, examining key factors, discussing concrete resilience measures, and exploring identified threats and opportunities. Participants were divided into three groups, each addressing specific disaster scenarios for the year 2050 that had been developed during the first workshop: "Tsunami 2050," "Blackout 2050," and "Collapse 2050."

The workshop began with an immersion phase, where participants were shown three videos created by the IMMER team using AI to reactivate memories and emotional connections to the scenarios. Following this, each group analyzed a "TOSA" (Threats, Opportunities, Stakes, Actions) framework adapted by the IMMER team. This framework guided participants in systematically analyzing critical aspects of societal resilience across various disaster scenarios, encouraging creative thinking and deep immersion.

In the final phase, to synthesize the TOSA analysis of the different scenarios, three participants took on the roles of fictional personas: the Minister-President of Baden-Württemberg, the head of the disaster management unit, and a young, successful entrepreneur. These personas collected information from each group and synthesized the scenarios from their perspectives. The exercise aimed to identify measures each persona could implement in their respective roles, which were then presented to the plenary session.

6. Main results and key lessons for critical infrastructures

The Threats, Opportunities, Stakes, and Actions (TOSA) framework was central to the workshop, guiding participants in systematically analyzing critical aspects of societal resilience across various

disaster scenarios. The results of the TOSA analysis provided insights into how different sectors—such as energy, mobility, water, and social cohesion—might respond to and be impacted in each scenario. By addressing potential threats, uncovering opportunities, identifying key stakes, and formulating actionable measures, participants developed a nuanced understanding of the interdependencies and vulnerabilities within their system (cf. box 2).

Box 2 : the results of the TOSA analysis

Threats:

- Each scenario highlighted the failure of critical infrastructures such as energy grids, water systems, and communication networks, leading to severe shortages and chaos.
- Rapid spread of disease or lack of medical supplies overwhelms healthcare systems, causing widespread health crises.
- Each scenario pointed to potential increases in violence, anarchy, and social instability due to fear, isolation, or resource scarcity.
- Limitations in transportation and mobility are common, affecting the distribution of essential goods and services.

Opportunities

- Adoption of simpler, more sustainable solutions such as manual water pumps, renewable energy sources, and non-motorized transport options.
- Enhanced local community bonds and self-organization, fostering closer relationships and localized interactions.
- Potential for developing decentralized systems, including energy and food production, which can increase resilience and autonomy.
- Development of new technologies and adaptive strategies in response to crises, such as alternative energy sources and localized production methods.

Stakes

- Ensuring access to essential resources like water, food, and energy is a critical stake across all scenarios.
- The need for effective governance that balances control with flexibility to adapt to evolving situations.
- Maintaining social cohesion and trust within communities is crucial for collective resilience and recovery.
- The importance of resilient infrastructure that can withstand and quickly recover from disruptions.

Actions

- Establishing decentralized and autonomous systems for energy, water, and food supply to enhance local resilience.
- Training and educating communities on resilience practices, including survival skills, first aid, and local resource management.
- Strengthening local networks and cooperation, including cross-border collaborations, to improve crisis response and resource sharing.
- Utilizing traditional and low-tech communication methods to ensure information dissemination during infrastructure failures.

- Implementing proactive measures such as stockpiling essential supplies, developing evacuation plans, and preparing survival kits.
- Investing in infrastructure that supports alternative energy sources, mobility solutions, and robust local supply chains.

By identifying these common elements, it becomes clear that enhancing resilience in the face of dystopian scenarios involves a combination of decentralized systems, community engagement, infrastructure adaptation, and proactive planning. These strategies can help mitigate threats, leverage opportunities, address critical stakes, and implement effective actions to ensure societal resilience.

In summary, the workshop highlighted the importance of training, education, decentralization, and relocation in enhancing crisis preparedness for governments, children, and society. It also emphasized the need to evaluate the strength of community solidarity during crises and to identify points where influence factors could turn positive, comparing optimistic and pessimistic views to understand potential differences.

In terms of implications for the two fluvial ports the analysis reveals that the cross-border dimension generates a number of additional difficulties, as experience shows that it is more difficult to create perfectly homogenous maps in terms of content extending to both sides of a state border. Statistical systems, for example, cooperate only partially, and the same concepts do not always correspond to the same realities.

Putting into perspective the results of the TOSA analysis with the contents of interviews performed with representatives of the two ports, three core elements of interest can be identified. Those elements tend to prove the relevance of the use of dystopian scenarios as a strategic tool.

First, both the Port Autonome de Strasbourg (PAS) and the Rheinhafen Kehl (RHK) acknowledged in interviews the growing threat posed by climate change, and are actively investing in infrastructure and technologies to adapt to fluctuating water levels and extreme weather events. They underscored the importance of developing more resilient and adaptable infrastructure, particularly through the deployment of new technologies and the upgrading of existing facilities to better withstand future challenges. PAS is currently focused on justifying investments in long-lasting infrastructure and on the development of flat-bottom boats designed for improved navigation during low-water conditions. Meanwhile, RHK is in negotiations to acquire additional port facilities in order to enhance operational flexibility and resilience. In this context, the use of scenario-based approaches to anticipate and prepare for extreme events may serve as a valuable tool in guiding such strategic investments.

Second, increased collaboration between ports enables the development of effective communication plans and stakeholder engagement strategies to ensure coordinated responses in times of crisis. For instance, RHK underscores the value of its enterprise network for crisis management and points to the benefits gained from enhanced storage capacity during previous logistics disruptions. PAS, on the other hand, highlights the creation of experimental zones aimed at improving cross-border freight traffic flow, while RHK emphasizes regular stakeholder meetings and strong networking as key components of its crisis response strategy. Dystopian scenarios, in this context, can powerfully illustrate the critical importance of cross-border cooperation and inter-port collaboration in mitigating the effects of extreme and unpredictable events. By working together, ports can pool resources, share knowledge, and align strategies to strengthen their collective resilience.

Third, both ports emphasized during the initial interviews the need to align their strategic priorities and business models with emerging challenges, ensuring greater sustainability and adaptability. PAS is developing a long-term vision focused on improving soil quality and enhancing water retention capacity, while RHK is planning a shift toward increased bulk cargo transport via waterways to reduce reliance on vulnerable rail infrastructure. Amid growing energy constraints, ports are also exploring alternative energy sources and storage solutions to maintain operational continuity during crises. For example, PAS is investing in energy storage systems to manage fluctuations in hydroelectric power generation, while RHK is exploring the production and storage of green hydrogen as a resilient energy alternative. In this context, dystopian scenarios—with their multidimensional nature—can serve as valuable tools for fostering the consideration and integration of innovative, forward-looking solutions. Such approaches may further encourage collaboration with local private and public stakeholders, supporting more robust and adaptive infrastructure planning.

The key lessons that can be drawn from the IMMER project and may lead to a generalization for critical infrastructures in terms of advantages and shortcomings are summarized as follows (cf. box 3).

Box 3: Advantages and shortcomings of dystopian narratives

Dystopian narratives present following advantages :

- Easy to understand due to the immersive effect.
- Cheap to produce.
- Easy to communicate.
- Motivating and mobilizing ("serious fun" and "us against the world effect" vs. boring presentations and reports).
- Allows participants with different backgrounds to contribute with less limitations as usually (no or little impact of hierarchical differences, institutions or countries) even in an bilingual context.
- Systemic character of the results.
- Backcasting makes it possible to learn lessons from the future.

Dystopian narratives present following shortcomings:

- Possible instinctive reactions of denial when confronted to dystopic futures.
- Reluctance since it may appear as not scientific, serious, etc. enough to some participants (rare but happened for some participants, at least at the beginning of the experiment).
- Conversion into operational tasks/strategic planning requires additional resources.

These advantages and limitations must be considered in relation to the broader insights discussed in earlier sections. As Bristow and Healy (2014) argue, building resilience within complex systems—such as critical infrastructures—is inherently challenging and cannot be managed solely by centralized authorities. Instead, it requires collaborative efforts among a diverse range of actors, many of whom operate under significant capacity constraints. Similarly, Duchek (2020) emphasizes the combinatorial nature of organizational resilience, describing it as a meta-capability that emerges from the integration of various competencies, such as adaptability, learning, and transformation. This complexity is particularly evident in the case of critical infrastructures, which are essential to maintaining public

safety, environmental security, and economic stability. The disruption of services such as energy, water supply, or transportation can lead to severe cascading consequences. In this context, fluvial ports play a strategic role, offering a lower-emission alternative to road and rail transport. Investing in the resilience of these ports not only safeguards vital supply chains but also supports long-term environmental objectives and climate change mitigation (Wamsler et al., 2020). Moreover, traditional foresight methods often reach their limits when confronted with extreme events and compounding uncertainties. This underscores the need for more adaptive and inclusive approaches to preparedness and planning. Narrative-based methods, as discussed by Keenan et al. (2007), offer a promising avenue in this regard. By providing relatable and accessible means of communication, narratives can help engage a wide range of stakeholders and translate complex risk scenarios into actionable insights. This is particularly valuable in resilience-building for critical infrastructures.

As Woods and Alderson (2021, pp. 96-97) stress it : "*Increasing the tempo of progress requires a strategic course adjustment synchronizing efforts across stakeholders, disciplines, and agencies in new ways. Ironically, the guide for a shift in course—as researchers, managers, operators, funders—is to apply the results on adaptive capacity and resilient performance to ourselves to keep pace with changes, growth, interdependencies.*" Dystopian narratives may serve as an effective tool in this regard.

7. Conclusion

As discussed in the previous sections, the integration of dystopian scenarios with other analytical tools has the potential to greatly improve an organization's ability to anticipate, prepare for, and mitigate future risks and extreme events. This approach is particularly relevant for groups or networks that protect and manage critical infrastructures—such as energy grids, communication networks, and transportation systems—where the consequences of failure can be far-reaching and severe. The experience of the IMMER project offers valuable insights into why and how dystopian narratives can be beneficial to critical infrastructures, as well as where their limitations lie.

First, dystopian scenarios are easy to understand due to their immersive nature. Second, dystopian scenarios are cost-effective. Motivation and mobilization of local stakeholders constitute additional strengths. Another key benefit is that these exercises enable a heterogenous group of participants to contribute ideas and perspectives, often with fewer constraints than in more formal or hierarchical settings. The outcomes of dystopian scenario exercises also tend to be systemic in nature. By imagining how a crisis unfolds, participants naturally consider interdependencies and cascading effects, elements essential to understanding complex infrastructures but often overlooked in traditional risk assessments. Finally, the technique of backcasting starting from a projected dystopian future and working backwards enables organizations to draw lessons from hypothetical failures, identifying vulnerabilities and decision points that might otherwise remain hidden.

However, it is important to recognize certain shortcomings when employing dystopian narratives. One challenge is that confronting participants with dire scenarios can provoke instinctive denial or resistance. A second issue is credibility. For some participants the narrative approach might initially seem insufficiently rigorous or serious, possibly leading to skepticism or reluctance to participate. Lastly, while dystopian scenario exercises can generate insights and broaden perspectives, their conversion into operational tasks or strategic plans typically requires added resources. Turning imaginative, qualitative scenarios into actionable steps demands dedicated time, further expertise, and organizational commitment.

Finally, the authors wish to emphasize that, over the past several years (and across various exercises extending beyond the scope of the IMMER project) they have repeatedly reflected on why they

consistently chose to adopt dystopian rather than utopian scenarios. The rationale is, in many ways, philosophical. In an era characterized by polycrises, dystopian approaches are assumed to be more effective in provoking critical reflection and stimulating preparedness. Paradoxically, this choice reflects a form of cautious optimism in the face of dire prospects. Drawing an analogy with Saetra (2024, p. 2), who asserts that *"By creating and shaping imaginaries of **more sustainable futures**, such futures become **more likely**"* (emphasis added), we are inclined to propose a alternative view: *"By creating and shaping imaginaries of **more overwhelming futures**, such futures become **less likely**."* In this sense, dystopian narratives serve as a catalytic tool—not to predict disaster, but to prevent it.

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