Transboundary Resilience

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1 Introduction

The 21st Century is the century of transboundary crises. The 2006 European blackout, the 2013-16 Ebola outbreaks, the wildfires of 2017 and 2018, the COVID-19 pandemic, and the 2020 and 2021 floods in Europe are examples of transboundary crises, 'characterized by the potential to cross geographic and functional boundaries, jumping from one system to another' (p.4)[1]. Charles Perrow showed how accidents are an inescapable, 'normal' feature of the complex socio-technical systems that shape modern societies[2], and geopolitical conflicts, climate change, and poverty and inequality increase the frequency, intensity, and reach of their impact[3]. Transboundary crises are 'the ultimate nightmare' for crisis managers[4], because they are hard to predict in onset and evolution, cut across multiple domains, escalate rapidly, and involve multiple actors with conflicting responsibilities.

How to respond? Boin suggests two options: The first is to contain complexity. Brexit and other separatist movements, anti-immigration walls and fences, 'islanding' ICT systems for cybersecurity, or employing security guards and stewards to keep fans separate in a football stadium are ways of reducing complexity. Public Protection and Disaster Response (PPDR) practitioners routinely reduce the complexities of crises by evacuating the vulnerable and containing water, fires, or crowds. The COVID-19 pandemic response drastically reduced the complex social and economic interactions people normally engage in. However, reduction of complexity 'entails a decoupling from the benefits that complex systems generate.'[4] The second option is to 'ride' the inevitable risks of complex systems by investing in early detection, timely intervention, and enhanced resilience.

In this Whitepaper we observe the emergence of 'transboundary resilience' as a new practice of disaster risk governance and develop it as a concept that could mitigate the nightmare of transboundary crises. We begin by arguing the relevance of resilience to the management of transboundary crises (Section 2). We propose an inductive definition of transboundary resilience as a form of collaboration across national, geographical, organisational and functional boundaries, introducing five cases that highlight interesting aspects. These examples show how transboundary resilience is practiced through (sometimes improvised) collaboration, interoperability, translation in PPDR in cross-border regions between countries and in 'high reliability organisations' and networks. In section 3, we discuss motivations for a more concerted effort to develop transboundary resilience and European research and practitioner projects that constitute important groundwork. There are a range of challenges (Section 3.3) and we conclude by discussing how this emerging practice could be better supported (Section 4).

2 Transboundary crises and resilience

According to the United Nations Office for Disaster Risk Reduction (UNDRR)[5], a disaster is a severe disruption of the functioning of a community or society due to hazardous events, leading to human, material, economic, and/or environmental losses and impacts. Human ways of life intertwine natural and man-made causes of disaster. For instance, building houses in flood plains or failure to stop CO_2 emissions can increase the likelihood and aggravate the effects of natural phenomena, such as floods, wildfires or drought[6]. Modern societies are comprised of complex socio-technical systems where the social, technical, natural, cultural and political layers are so deeply interconnected that it is not fruitful to consider them in isolation.[7]

Disasters become transboundary crises when they cross national or geographical borders, and organisational and functional boundaries.[8] The 1986 Chernobyl nuclear disaster, and COVID-19 pandemic are extreme examples. Transboundary crises imply a broad range of negative changes in security, economic, political, societal, or environmental affairs[4], particularly when the disaster occurs abruptly, with little or no warning. According to Boin (2019), transboundary crises are particularly complex and uncertain because traditional or centralised forms of disaster risk governance are not adequate to respond. Transboundary crises hence imply a need to renew our thinking. For this reason, we explore emerging practices of transboundary resilience and argue that they represent an opportunity for the transformation of social systems that are increasingly facing transboundary crises. We will define transboundary resilience inductively by examples and then draw on research on cross-border cooperation and high reliability organisations and networks to develop the idea. Before we turn to examples, it is useful to briefly review the idea of resilience more generally.

Resilience is an integrative concept that became prominent in 21st century scientific thinking as well as on the political agenda. In physical sciences and engineering resilience usually describes the capacity of a system to resist disturbance and the speed by which it can return to its original state[9] But the concept was further developed in ecology engineering, where it captured the capacity of complex, nonlinear and dynamic ecosystems to transform to absorb and prevent damage from future shocks.[10] It was subsequently applied to psychology, social sciences, and disaster management, with much debate[11]. Resilience encompasses two main ideas: the ability of systems to withstand stressful events and to recover from them.[12]

The field of disaster and risk management relies on resilience. Emergencies and disasters are characterised by their 'un-ness': they are 'unexpected, unscheduled, unplanned, unprecedented and definitely unpleasant' [13]. In addition, they generate extreme contexts, characterised by speed, the need for highly consequential and time-critical decisions, uncertainty and risks[14]. To address transboundary crises, a large spectrum of socio-technical systems, including private/public organisations, local communities, administration, national and international institutions, need to transform their practices, methods, norms, culture.[15] Resilience is a valuable capacity in this transformation. It manifests as an emergent process allowing different actors to overcome a disaster and associated consequences, leveraging absorptive, adaptive and transformative capacities.

This applies not only to organisations, but also to communities and territories. Also, it concerns each of the major steps of disaster management:

- In terms of **prevention**, being resilient means reducing exposure of people and assets to hazards.
- In terms of **preparedness**, it implies the building of collective capacities to react to weak signals and identify the multiple facets of a disaster. Resilience develops capacity to avoid incorrect and oversimplified representations and interpretations of situations. At the territorial level, models of crisis and disaster management are proposed as adaptive processes[16]
- In **response** to a disaster, resilience at prevention and preparation phases can support quicker and more efficient responses and recovery. In particular, it involves quick adaptation and learning from the uniqueness of the disaster.

- For **recovery** from a disaster, resilience allows adaptation and transformation, connecting the cycle back into risk assessment and prevention. It can help build buffer capacities to respond to the diversity of risks.[17]

Relying on resilience in disaster risk governance is a contested approach, because it can be a way of delegating responsibility from the state to individual actors who may be ill equipped to carry the burden[18]. However, resilience can also enable more effective, equitable and collective disaster risk governance, and calls for 'just resilience'[9] and 'societal resilience as it recognizes the potential for adaptation and transformation of systems, […] the self-organizing principles of emergent response networks, […] [and the] capabilities of local organizations and communities'. (p.261)[19]

In line with this view, several United Nations Resolutions promote resilience: the international decade for natural disaster reduction, the Yokohama strategy for a safer world, the Hyogo framework for action and the Sendai framework for disaster risk reduction.[20] A large spectrum of international organisations' guidelines such as the UNISDR Local Government Self-Assessment Tool the Rockefeller Foundation and ARUP resilient cities framework (CRF, 2014), The Infrastructure Security Partnership regional disaster resilience assessment and enhancement guideline (TISP 2011) or the HCFDC orange flag label[21] provide indicators and guidelines aiming to assess and improve territorial capacities. But the types of disasters considered in these frameworks are bounded.

2.1 Transboundary Resilience: definition and illustrative cases

In this Whitepaper, the term transboundary resilience describes the capacity of complex socio-technical systems to address and absorb transboundary risks, crises and disasters by cooperating across geographical, organisational, functional, and temporal boundaries when preventing, preparing for, responding to, and recovering from crises (Figure 1).
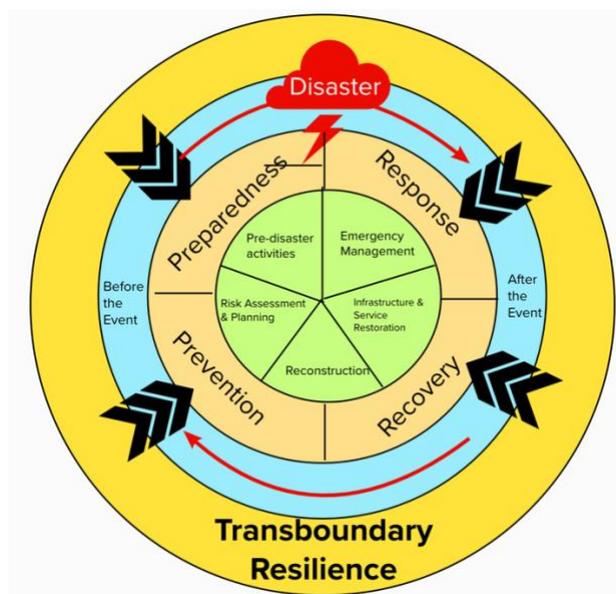

Figure 1: Transboundary Resilience lies the core of every step of disaster management.

Growing experiences of transboundary crises have given rise to new forms of this transboundary resilience, which promise some leverage on mitigating the nightmare of transboundary crises. The five examples below highlight important aspects across various phases of disaster management.

2.1.1 Euregio Meuse-Rhine Incident Control and Crisis Management

The Meuse Rhine Euregio (EMR) is one of the oldest cross-border regions in the European Union. It was established in 1976 and obtained legal status in 1991. It supports a cross-border collaboration across three countries and languages (French, Dutch and German) and five partner regions, covering an area of ca 11,000 km^2 including the cities Aachen (Germany), Maastricht and Hasselt (The Netherlands) and Liege (Belgium). The EMR has high population density, diverse industries, major arteries for traffic, and frequently hosts large-scale events. It has a complex risk profile including large scale accidents, floods, hazardous substances, and infectious diseases. The Euregio Meuse-Rhine Incident Control and Crisis Management (EMRIC) was set up in 2006, initially as a project to enable coordination of public protection and disaster response. One major obstacle was the fact that disaster management is a competence at national level in Belgium, while in Germany and The Netherlands it is a task of regional governments, another difficulty was the differences in language and terminology.[22] These difficulties inspired collaboration agreements and a tri-lingual dictionary, and EMRIC has since developed into a collaboration that allows PPDR services to easily cross borders in major disasters and accidents, but also for day-to-day emergency management. This creates new opportunities for efficiency. For example, sometimes rescue services from a neighbouring country can respond more quickly to an incident near the border than services from the country itself. Paquay et al (2020) also highlight that 'Operational agreements on emergency medical assistance, fire-fighting, technical assistance and assistance during CBRN incidents have been established'.[23] But they point out that language barriers and differences in emergency management protocols remain a source of difficulties. In addition, analyses of the ability to cooperate during the COVID-19 pandemic have provided a major lesson learnt: 'radio and telephone compatibility is crucial but currently largely lacking'[24]. In Sommer et al.'s study, one expert sharply criticised the lack of infrastructures for cross-border communications:

> *... they did not have a good connection to the dispatch center via the work cell phone and the colleague then had to call with the private cell phone afterward because [the call] always ended up in The Netherlands. That must no longer be the case today. This is a technical problem, I think, that can be solved. [...] That you can really reach [...] the dispatch center that guides you and sends you in with support. [...] that can of course also be optimized by properly setting the cell phones that we have on the vehicles and routing them correctly. [...]. (p. 14)[24]*

This example highlights rich existing practices of transboundary resilience, such as collaboration agreements, collaboration networks, and resources for cooperation. At the same time, it highlights limitations and opportunities for innovation, which we will explore in Section 3.1.

2.1.2 European Disaster Response Exercise (EDREX)

In addition to regional developments and cross-border activities, there are a number of institutionalised initiatives driven by EU level crisis management.

Noting that risk governance exceeds responsibilities of single institutions and governments, the EU civil protection effort comprises a set of initiatives meshing to gather support for disaster prevention and mitigation. These include the capacities of RescEU, which are standardised units of equipment as well as teams trained in an international context that operate (almost) autonomously and can be

mobilised through the EU Civil Protection Mechanism. Resources like medical teams or firefighting planes are ready to support disaster response at short notice within Europe and beyond. Furthermore, there is a novel form of collaboration, namely the European Disaster Response Exercise (EDREX). Hollis (2020) observed the first exercise in 2016-17 with more than 20 participating states and finds that "the form of transgovernmental networking (membership and structure) reveals a remarkably dynamic and flexible mode of coordination determined by the type of crisis that emerges". [25] The structure of the 18 months' exercise process was informal and respected the autonomy of states as well as their responsibilities and legal competencies. However, it provided space to explore collaboration between different types of actors, i.e. crossing boundaries between established domains such as public-private and civilian-military coordination. As a result, it emerged that a way of flexible adaptation and adjustments was necessary to react to the dynamic situation and that practical and creative ideas made response efficient. The only precondition was that collaboration remains voluntary. The European mechanisms and the EDREX exercise are guided by practical considerations and the principle of subsidiarity, meaning that crisis management should be driven from the local level, and assistance be granted on request. Hollis emphasises that it is 'the complexity of transboundary crises creates the main practical impetus of cooperation" (p. 248) and this can mean that traditional approaches through formalised processes and strategic interactions of horizontal coordination may not be sufficient.

This example highlights that collaboration can be coordinated across boundaries and complex transgovernmental networks and that there is not a single strategy but strength is provided by the interconnected set of activities that may be emerging from the bottom up, where situation awareness is the richest. But while the complexity of transboundary is a key driver for the creation of these complex cooperation networks and mechanisms, the complexity of the network and decision-making in this context is a challenge.

2.1.3 European Electricity Blackout 2006:

On 4th November 2006 an electricity tie-line in North-Western Germany tripped due to a combination of events. 20 seconds later, '*a cascade of power line trippings spread as far as Croatia and Portugal; synchronisation of the continental network was lost, and more lines and generating units failed as overloads and underloads proliferated throughout the subcontinent.*' (p.2056) [26] Van der Vleuten and Lagendijk (2010) show that this European blackout in 2006 embodied, on the one hand, the fragility of the European electricity network. The European Commission President Romano Prodi diagnosed a '*contradiction between having European [electric power] links and not having one European [electric power] authority*' (p.2054)[26]. On the other hand, this call for centralised control contrasts sharply with the energy sector operators' view: They argued that the blackout, which lasted in some cases just 30 minutes and saw the network completely restored within two hours, was evidence of the success of a high reliability policy and highlighted the resilience of the system. The transnational electricity operators' high reliability policy included principles that defined short-time disruptions as more acceptable than comprehensive network disturbance. This underpinned automatic protection mechanisms that would disconnect elements of the system when certain parameters were breached and trigger them to automatically reconnect when normal operation is restored, which is what happened on 4th November 2006. The final investigation report from the international association of Transmission System Operators (TSO) confirms the operators' view: "*due*

to the adequate performance of automatic counter-measures … a Europe-wide blackout could be avoided. The decentralized responsibilities of TSOs have demonstrated their efficiency" (p. 2054) [26].

This example puts a spotlight on deliberate 'high reliability' strategies for safety in high risk, complex critical infrastructure organisations, an approach that we will examine further in Section 2.2.2.

2.1.4 Entrepreneurial bottom-up transboundary resilience

Civil society and business can be a powerful engine of transboundary resilience. In many countries, including The Netherlands, the early phase of the COVID-19 pandemic very quickly brought a critical shortage of Personal Protective Equipment (PPE). As global supply chains collapsed and the bulk of the PPE in Europe had been sourced from China pre-March 2020, many countries scrambled to mobilise stocks elsewhere or start up in-country production. Government initiatives were slow, and sometimes incurred suspicion of, or actively enabled, disaster capitalism or profiteering from the shortage. Boersma and Larruina[27] describe a case where a non-profit civic organisation – Refugee Company – mobilised support from corporate donors and government to set up a non-profit PPE factory. The company has its roots in the earlier transboundary refugee crisis in 2015-17, when founder Fleur set up the company to support the socio-economic integration of refugees in the Netherlands. The company set up clothing design and production 'Makerspaces' and restaurants that employed refugees. The COVID-19 crisis affected some of these businesses, requiring them to suspend operation. The combination of a critical shortage of PPE in the Netherlands and their own disruption of operations led the group to develop the PPE factory. In the process, Boersma and Larruina describe how the organisation was able to improvise, bricolage, and practice a 'make-do' approach that focused on what could be achieved with the sources at hand. This involved sourcing the fabric needed for PPE production from China via a relative who worked as a KLM pilot with routes to Shanghai, as well as colleagues with friends and family in China.

This is an example of transboundary resilience that illustrates not only the functional dimension of interdependence (state, healthcare, private sector, civil society, corporations), but also the global interconnectedness (the Netherlands and China) of supply chains, as well as the power of social, informal networks.

2.1.5 Roya Valley resilience: across times and societal layers

On the first of October 2020, storm Alex hit the Britanny coast in France. 24 hours afterwards, it generated heavy rains and flash floods on the Mediterranean Coast, in particular on the Roya Valley on the French Italian border. The Roya valley takes its name from its river, and it is rich in French-Italian interactions. Not only does its population frequently move from one country to another (because of family and professional ties on each side of the border); throughout history, some municipalities (such as Breil-sur-Roya) alternatively belonged to France or Italy. Hence the Roya Valley has a unique transborder identity, built on French and Italian political, linguistic and administrative footprints.

When storm Alex hit, the valley was already prepared and quickly activated resources and evacuation protocols. In 2016, (one year after the 2015 flash flood in the South of France), the Alcotra Interreg project[28] was launched to support cross-border cooperation in the monitoring of the

impact of climate change on the Roya River. Hence, the population close to the river is taking careful measures for early detection and timely intervention.

However, storm Alex was particularly brutal, pulling off roofs, damaging houses, a gas station and cemeteries. Approximately 2000 persons were evacuated at mid-day on the 2nd of October (some hours after official forecast alerts), but houses, electrical and telecommunication infrastructures were destroyed by the storm and the floods.

When the recovery phase started, the Alcotra Interreg project supported the collection of testimonies of the event, fostering cross-border memory and reflecting on the future resilience of the population.[29]

In this example, transboundary resilience manifested across the frontiers, especially when an Italian mayor braved the floods to provide supplies to the French population. In addition, the Foreign affairs ministries helped French and Italian firefighters to connect to support each other. The Roya valley case embodies the long-term of transboundary resilience before, during and after the storm, across societal layers (citizens, mayors, officials), and across time, connecting past, present, and future.

2.2 From Cross-border and High Reliability to Transboundary Resilience

The examples above highlight that transboundary resilience is a feature that cuts across all parts of the disaster risk cycle and its geographical, organisational, and functional dimensions. In the first example, 'transboundary' characterises phenomena that do not stop at national borders. However, examples 2-5 reveal the importance of boundary spanning on other dimensions. In this section, we explore the functional, transnational, organisational, social, cultural, and temporal dimensions of transboundary resilience in more depth. We first examine how cross-border collaborations actually involve multiple forms of boundary spanning and to what extent the concept of 'transboundary' goes beyond national borders. Cross-border resilience is currently the most studied field and there is much to learn from cross-border areas, such as regions that have grown together (or apart) over long periods of time and have developed their own culture, like the Euregio Meuse-Rhine or the Roya Valley. Secondly, we examine how 'High Reliability Organisations' (HRO), like electricity critical infrastructure TSO, nuclear power stations, hospitals, and High Reliability Networks – such as PPDR networks – practice boundary spanning. These examples show that as transboundary crises increasingly "cross geographic and functional boundaries, jumping from one system to another" (p.4)[1], so does resilience.

2.2.1 European Cross-border resilience

The Oxford English Dictionary defines a frontier as 'the line that separates two countries', and in the history of nation state political, legislative, and economic systems, borders divide these systems and distinguish one from another. However, borders and border regions can be much more complex.[30]

Historically, many borders between countries have shifted many times, such that border areas are not always peaceful. As a result, some regions have developed enmities with neighbouring countries, while other regions, due to their changes of different national affiliations, became so deeply rooted in their regional identities that they even speak their own language or share a regional dialect. Hence, borderlands can be regions where individual communities grow who are strongly connected

across the borders.[31] Over time, borderlands generally may develop as contact points between 'previously distinct peoples'[32] and become 'meeting place of peoples in which geographic and cultural borders were not clearly defined' (p. 815).[33] Such connections can not only result in common traditions and habits across the border, but also linguistic terms and harmonised semantics in the spoken language.

2.2.1.1 Harmonisation: Cultural, political and institutional connectivity

Harmonised meanings and a shared understanding are particularly important in the context of resilience and collaborative crisis management operations. Problems can occur when actors from different organisations, domains or disciplines share the same language but terms are defined differently. For example, in the UK civil emergency services use the terms strategic, tactical and operational to capture different hierarchical levels, while the military uses the different order 'strategic, operational and tactical'. McAleavy and Rhisiart (2019) show that in the context of interorganisational crisis management, the fundamental principles are the same, but the terminology differs. [34] Problems are avoided through translation, liaison officers and cross-training and formal guidance from the Ministry of Defense. This problem increases when organisations are collaborating across nations, hierarchical levels and PPDR functions may not match each other and cover different responsibilities and powers, as we saw in the case of the Euregio Meuse-Rhine.

As a result, *political and institutional connectivity* is an important element of cross-border resilience. There are many different forms and motivations to establish cooperation between border regions. In the example of the United States and Canadian border, the interchange of economic goods was the main motivator to establish formal collaboration, such as regulatory alignments and legal agreements. However, trade and economic development can lay the ground for further steps of institutional and political connectivity which are prerequisites for an effective cross-border crisis management.

In this context, the European Union's efforts on regional development include the creation of cross-border regions, which are supported via long-term funding by the Interreg initiative to strengthen cross-boundary cohesion and economies. Starting in 1990 from incentivizing the regional cross-border collaboration, Interreg has been extended to transnational and interregional cooperation. In particular, as the EDREX Example shows, the European Commission fosters increased cross-border cooperation between member countries with the aim of eliminating the imbalances, inequalities and problems of the periphery caused by the barrier effect of national borders. Perkmann (2003) highlights that in the European Union more than 70 municipalities and regional authorities cooperate across national borders.[35]

However, the European Union goes a step beyond formal cooperation with the objective of bringing Europeans closer together and to establish a security community[36] and even *European identity*.[37] Also these actions are not only dedicated to disaster response, but foster a general understanding of the other traditions and cultures which can be both a starting point and basis for increased transboundary resilience. The regions in their function as an "engine of cross-border cooperation" should enable citizens living in a border region to develop a common sense of history and to find or revitalise a common mindset that is more oriented towards a European future.[38]

2.2.1.2 Shared identity, social capital and spontaneous willingness to help

This common identity can strengthen social capital, which is usually measured by general trust in fellow citizens. As outlined in the example of entrepreneurial networking to produce PPE in The Netherlands, in a disaster situation, informal communication channels can effectively support collaboration in the complex and uncertain environment of a disaster, when tailor-made place-based responses are required. It is important to know the correct contact persons and to have established trustful relationships. From a socio-economic perspective, cross-national attachment and cosmopolitan social capital can be seen as important drivers of open and amicable attitudes as well as cooperativeness and social cohesion on a transnational level.[39]

An underestimated additional resource for disaster resilience is the *self-help capacity* of communities and their willingness to help. The impact of spontaneous interventions has recently been observed in the aftermath of the summer 2021 flooding in Germany, where in particular the Ahrtal was hit. There was a huge willingness to support the affected areas within the population. In addition to the large amount of donations, reams of persons spontaneously equipped with shovels set out to help on-site. This help was not only seen within the German population but, despite the fact that Belgium was hit by the disaster itself, Belgians also travelled to the Ahrtal in Germany to support cleaning and rebuilding processes. However, this well-intentioned solidarity and spontaneous readiness to help also caused problems for the local civil protection agencies. Thus, such scenarios need to be included into training exercises, so that PPDR practitioners are able to guide the flow of helpers by dedicated media campaigns and use the high potential of the work force that the volunteers offer.

2.2.1.3 Organisational and technical interoperability

Formally, the main responsibility for crisis management clearly lies with the civil protection agencies so that it is important to strengthen their ability in collaboration. In this regard, preparation dedicated to disaster response should not be neglected. This is why the European Union maintains the "European Civil Protection Pool". Its specialised support units can be, for example, mountain rescue teams, mobile laboratories, medical air evacuation, or water purification equipment. Besides relief assistance for EUs member states such as during the Greek Forest Fires and Floods in Belgium in summer 2021, they can also be requested by non-EU states as seen in the search and rescue support after the Lebanon explosions in 2020. Furthermore, there is the setup of the "EU Civil Protection Knowledge Network" in progress, which is dedicated to become a learning and knowledge management system for increased decision-making capabilities based on collaborative sharing of experiences and lessons learnt.

In terms of organisations involved, disaster response requires a *multi-skilled approach*, for which common exercises and training build the basis. Recent technology developments such as virtual reality can support these exercises. However, despite the strong support of the EU for border regions, some challenges remain. The above-mentioned approaches lead to a very heterogeneous picture concerning cross-border cooperation in the field of emergency response on different levels:

- On the **political level**, cross-border cooperation depends on the political ties of the countries, ranging from a history of armed conflicts (e.g. in the Balkans) to friendly relations with intensive socio-economic relationships (some with borders that are not physically recognisable), but also significantly depend on the relationship between the professional

actors on the ground in the border regions. To achieve effective cooperation between countries and regions, the (mutual) dependencies through infrastructural framework conditions, such as the availability of resources close to the border, coupled with the individual goals and incentives of the diverse actors, continue to play a major role. Both the ability and willingness to cooperate thus form the basis. However, the practical design of the cooperation can also lead to a variety of challenges.

- On the **operational / tactical level**, the lack of technical interoperability in the area of equipment and material (for example, incompatible radios, and a lack of pan-European communications infrastructures for PPDR) is mentioned, but there are many more problems with data exchange. There is a need for secure, legal and ethical communications infrastructures and data interoperability that reflect European values.[1] These are vital, because in any crisis that needs to be managed across borders, the rapid establishment of shared situation awareness and a common operational picture essentially determines the success of all subsequent measures. In cross-border scenarios, the origin and cause of a crisis may initially be unclear and therefore responsibility for crisis management may be unknown. Jurisdictional issues may arise that cannot be quickly resolved, and responders may not be able to physically cross national borders. Different interests or goals in crisis management may also lead to problematic situations. A possible cultural difference in risk perception must be taken into account, which can be reflected in the interpretation of the incident, the management strategy applied, but also in advance in crisis preparedness in the countries.

- On the **administrative level**, factors such as the different organisational systems of emergency response influence cooperation. This particularly applies to structural and organisational conditions, such as training and operating methods of the emergency responders. For example, Germany's distinctive system of volunteer fire departments meets professional fire departments in neighbouring countries, which may have some reservations about the perceived inferior training of volunteer units. However, this also includes, for example, the different staffing of emergency vehicles with or without an emergency physician or the different competencies of the emergency workers. The Euregio Meuse-Rhine example also highlights how different languages can lead to problems in cooperation, especially the use of specialised terminology commonly used in emergency response.

Further administrative problems may arise with the coverage of costs for operations, as well as with questions of data protection when passing on security-relevant information to the neighbouring country. Another challenge can be the different responsibilities for preparedness and crisis management, which are located on different administrative levels in a federal state structure than, for example, in states that are organised in a centralised manner. Contacts on the other side of the border must first be identified in the differently organised system of emergency response. When it comes to cooperation, there may be major differences due to the different areas of responsibility and a possible power imbalance.

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[1] There are many projects that develop innovative solutions for transboundary resilience, including the BroadWay, DISASTER, EPISECC, DRIVER+ and other projects. We provide a selective review in Section 3.1.

Concluding this discussion of cross-border collaboration as a specific case of transboundary resilience, we outline that border regions are diverse and resulting in "zones of variously overlapping (but not congruent) political, economic, and cultural boundaries".[40] These boundaries do not only divide, but also connect. However, each area is unique, which complicates the production of a general framework. When a disaster spreads across several countries, additional influencing factors for strengthening resilience must be taken into account. Due to the fact that border regions in particular were often fought over and assigned to different political systems, different political views, cultures and languages often clash within the population in border areas to this day. In order to achieve a holistic improvement approach for increasing resilience in these regions, such differences must be acknowledged and a place-based way to deal with them must be found. This not only comprises organisations of the civil protection but also coordination with institutions from several fields as politics and companies as well as among the population itself. Instead of putting the burden to single actors, collaboration among all of them is required.

2.2.2 High Reliability Organisations and Networks

Our second case of emerging practices of transboundary resilience turns to organisations and networks, deliberately designed to produce high reliability for services under highly complex and dangerous conditions.

The analysis of High Reliability Organisations (HRO) was a reaction to a ground-breaking analysis of the Three Mile Island nuclear accident in 1979. Charles Perrow's book *Normal Accidents* (1984)[2] states that errors and accidents cannot be prevented due to the complexity of modern socio-technical systems. While Perrow's Normal Accidents Theory (NAT) suggests a reactive approach to minimise the impact of accidents, high reliability theory (HRT) takes a different view. While the assumption that errors and accidents are unavoidable is shared, however, here the finding is that error frequency and magnitude can be reduced by technological, structural and organisational measures. This view enables a proactive approach, i.e., the development of strategies to reduce the frequency of errors. Following this idea, observations were made by a range of scholars. Le Coze (2022) provides a very useful review of the debates between NAT and HRT. By juxtaposing core conclusions and strategies, he prepares the ground for revision and extension of these theories.

Table 1 Key conclusions, and strategies of NAT and HRT

High Reliability Theory (HRT)	Normal Accident Theory (NAT)
Accidents are inevitable, but preventable to a high degree	Accidents are inevitable in tightly coupled and complex systems
The following strategies can promote safety:	These strategies cannot prevent accidents, because:
1. Make safety the number one priority	Safety is one priority among competing ones
2. Redundancy enhances safety	Redundancy increases complexity and risky behaviour

3. A culture of reliability can be created, it consists of
   a. centralised discipline as in military contexts
   b. decentralisation of decision making
   c. deference to expertise at all levels
	Power, interests, and contradictions prevent a culture of reliability from counteract accidents and there are inherent contradictions between centralisation decentralisation
	A culture of reliability is incompatible with civil and commercial organisations

4. Continuous training to cope with problems	Training cannot cover all situations
5. Learning based on trial and error	Learning is inherently flawed, impaired by political processes, uncertainty and ignorance

Elaborating the five strategies of HROs, Weick and Sutcliffe (2010) describe HROs as organisations that "operate constantly under very difficult conditions and yet experience far fewer accidents and incidents than would be statistically expected" (p. 19).[41] One of the distinguishing features of these organisations is that the top priority organisational goal is safety, while operating with a background where the consequences of errors could be severe. In their observations, Weick and Sutcliff derive additional principles, which they summarise as a "culture of mindfulness" (p. 10)[42], including a reluctance to simplify, sensitivity to operations, and a commitment to resilience. They also elaborate that deference to expertise means that anyone, regardless of status within the organisational hierarchy, can trigger a suspension of operations if safety is at risk in their expert interpretation of a situation.

These strategies and commitments require HRO to recognise the interdependencies between different systems and parts of organisations, and their economic and political context. Failure to consider risk across intra-organisational boundaries and the wider context can be catastrophic. Analysing the 1986 *Challenger* disaster, for example, Vaughan observes how an engineering culture of evidence-based decision making, conformity to rules, and budget cuts had produced an environment where the signals of a potential failure of technical components were ignored, leading to the explosion of the spaceship.[43]

Perrow's critique suggests that high reliability is impossible. However, principles of HRO were originally observed in individual organisations, e.g. in the field of aviation safety, medicine or nuclear power plants, and they have since been extended to high reliability networks, as we will see below, including PPDR. Contemporary analysts like Le Coze argue that, "most accidents or disasters result from lack of enough resources and attention to [Perrow's] DEPOSE system": design, equipment, procedures, operators, supplies and materials, and environment (p. 15)[3]. High reliability across all these factors may be impossible, but, observing the irrefutable reality of proliferating complex high risk systems at the heart of modern societies, high reliability *seeking* is a valuable goal, and the strategies and commitments of HRT can provide valuable input.

In this Whitepaper, we argue that transboundary resilience is, among other things, a product of a network of actors who are dealing with the prevention, preparation and management of crisis events, such as extreme weather events. Bierbichler et al. (2017) observe that European efforts recognise a "web of dependency relationships, which makes the consideration of 'self-sufficient' organisations [...] difficult." (p. 15)[42]. The emergence of high reliability networks (HRN), has been studied by Berthod et al. (2017), Roth et al. (2016) and others.[44] Berthod et al. (2017) understand HRN as "interorganisational networks [which] need to function with dual, uninterrupted attention to both the anticipation and the containment of incidents and peaks in activities. This characteristic implies ever-changing goals and relational contexts, depending on the nature of the event to be contained" Berthod et al. (p. 354).[44] Their example is a collaboration between the Düsseldorf fire service, police, emergency medicine and a wide network of diverse collaborators including the city-wide marketing company, businesses, civil society organisations, major industries and many others. The network operates in different modes covering acute 'routine' emergencies, extraordinary events and major incidents, as well as disaster prevention and preparedness. Berthod et al. highlight the

capacity to 'layer' and 'switch' between different decentralised and centralised modes of governance as a particularly significant capacity within the network. They highlight trust – established through the very acts of collaboration involved in making and maintaining the network – as one of the key enablers for this collaboration and the high reliability public emergency services that it enables.

Another research project investigated the extent to which private security workers' at an airport, had knowledge of or access to organisational contexts and to what extent this is necessary to solve emerging problems. Furthermore, it was investigated whether "open" communication between the organisations is practiced and common training processes are in place (pp. 22-23).[42] This single actor has a significant role in ensuring security at the airport, and thus also potentially on security in another country. But the security company is working in the highly reliable network of "airport security".

If we think now of a larger-scale transboundary network, it seems clear that not the individual actor but the reliability of the network is crucial, starting with knowledge of the network's dimensions and interconnections. Research on HRN is currently limited. Practical implementations are rare, and the potential for improving the reliability of networks, has not yet been fully explored. There are also no instruments yet available for checking the reliability of one's own network. Based on the analysis presented so far, we suggest that developing a transboundary resilience framework, learning from cross-border cooperations, and high reliability organisations and networks is a promising avenue for research and practice.

3   Developing transboundary resilience

Since the work of Perrow and the HRT researchers, the world has become a more complex and dangerous place. In response to the February 2022 IPCC Working Group II Report on Climate Change Impacts, Adaptation and Vulnerability, Mami Mizutori, Special Representative of the UN Secretary-General for Disaster Risk Reduction, stated:

> *The findings of the latest IPCC report are dire. Communities around the world are being affected by climate change at a magnitude worse than expected. The devastating impacts of climate disasters are affecting every part of the world.*[45]

Munich RE, one of the world's largest reinsurance corporations, reports that 'In 2021, natural disasters caused overall losses of US$ 280bn.' It has proved to be the second-costliest ever for the insurance sector. The reinsurance sector is particularly preoccupied by so-called "emerging risks". These are extreme events, which are very difficult to identify and to predict due to complex and partly unknown dynamics. Emerging risks show an upward trend and they are essentially global risks: Most of them are either adversarial risks on a global level, such as international terrorism or cybercrime, or they are the 'by-product' of accelerated climate change. Torsten Jeworrek, Member of Munich RE's Board of Management warns: 'Societies need to urgently adapt to increasing weather risks and make climate protection a priority.' But this is not happening. In the same paper in which Arjen Boin describes transboundary crises as the ultimate nightmare for crisis managers, he argues that the rise of transboundary crises poses a 'wide and deep challenge to the standing governance arrangements of democratic states' (p. 96)[4] and most are unprepared.

Society is not an organisation, it is a much more organic, emergent and diverse system.[46] However, there is much to learn from the normal accidents and high reliability studies of organisations and networks in a world where extreme weather disasters are becoming normal.

Transboundary resilience describes the capacity of complex socio-technical systems to address and absorb transboundary risks, crises and disasters by cooperating across geographical, organisational, functional, and temporal boundaries when preventing, preparing for, responding to, and recovering from crises. This provides a new way of thinking about security, PPDR and its role in the modern 'risk society' in a way that addresses the nightmare of transboundary crises. With his concept of the risk society, Ulrich Beck argues that the risk society is '*a catastrophic society. In it the state of emergency threatens to become the normal state'* (p.79)[7]. In a way, whole societies, not just PPDR organisations and networks, need to acquire a higher degree of transboundary resilience. This could be a matter of adapting the principles of HRO to build capacity for transboundary resilience across the many parts of society involved.

3.1   What could transboundary resilience be?

Researchers, practitioners, civil society actors, and industry are amongst the many actors who are driving innovation to support transboundary resilience from different perspectives. A brief and selective review of projects will allow us to take stock and identify challenges and directions for future work. Selection has been guided by a focus on relevance to practitioner-led innovation in PPDR in Europe.

In addition to research, legal frameworks and funding programs have evolved to support specifically cross border cooperation, such as INTERREG in 1989, INTERACT in 2008 and EURAC in 2009 (Russo, 2012). A broad spectrum of programmes and projects has developed that, we would like to suggest, can help develop transboundary resilience.

Table 2 presents a cross-spectrum selection of International Programmes and European projects devoted to promoting resilience and details their contribution, outputs and limitations.

Table 2: European projects devoted to resilience[47]

Program/Project Title	Focus / Objective	Practical output	Unaddressed issues
UNISDR - LGSAT ARUP TISP	Assess and improve territories' resilience	Indicators and guidelines	Specificities of the cross-border regions are not considered
C2-SENSE	Increase interoperability	Profile based Emergency Interoperability Framework	
DISASTER	Better data exchange capability, possibly in neighboring countries	Development of a common and modular ontology, SOA algorithms	

IDIRA	Support regionally available emergency management capacities	Conceptual framework	
BRIDGE	Increase interoperability	Technical and organisational solutions	
DRIVER+	Evaluation of emerging solutions to increase civil societies' resilience	Evaluation framework and training solutions	
CRISMA, SICMA, INKA	Enhance cooperation between multiple stakeholders in disasters	Decision making models and simulation	Critical Infrastructures disruption
INKA	Optimise volunteers' integration into crisis response	Guidelines and good practices	
ALERT4ALL	Support intra and inter-agency collaboration	European shared alert system	Multicultural dimension of cross-border regions, volunteer's involvement
BESCU	Enhance emergency communication and evacuation procedures	Cross-culturally validated instruments and indices	Cross border region specificities and context
EDUCEN	Improve evacuation procedures in a multi-cultural context	Multimedia handbook	
IMPROVER	Measure the impacts of different concepts of countries for societal, organisational and technological resilience of CIs, including cross-border examples	Risk-evaluation techniques, reviews, and test of the effects of dependencies.	Volunteers' integration
SEMPOC, MIA, FACIES, RISKGIS, Failure Prediction, and MICIE	Identify general interdependencies between CIs and risk management	Methodologies, simulations	Operational issues in disaster response
EMBRACE	Assess resilience of multiple actors	methodologies for evaluating, modelling and assessing resilience of different actors	Cross-border region specificities and context
COMRADES	Improve the quality of alerts and information	Open-source, community resilience platform	

	provided by the population		
RESILENS	Identify resilience best practices	European Resilience Management Guideline & interactive web based decision support platform	
ICRED	Support decision-making for resilience	conceptual framework, socio-economic surveys, a scenario builder, and GIS	
CORE	Increase risk awareness to build citizen and organisational resilience	Common metrics for different natural and man-made disaster scenarios, and the impact particularly on vulnerable groups	Cross-organisational specificities and contexts
EPISECC	Establish a Pan-European Information Space to Enhance security of Citizens	Developing a concept of a common "European Information Space"	Multicultural dimension of cross-border regions, volunteer's involvement
SecInCoRe	A Pan-European inventory of past critical events and disaster and their consequences focusing collaborative emergency operations and real-time decision making while taking ethics, law, social practices and privacy into account	Identify data sets, processes, information systems and business models used by first responders and police authorities leading to a dynamic and secure cloud based 'common information space'	Multicultural dimension of cross-border regions, volunteer's involvement
BroadWay	A Pan-European interoperable broadband mobile system for Public Safety and Disaster relief organisation's, validated by sustainable testing facilities'. This project implements a Pre-Commercial Procurement (PCP) with the purpose to realise innovative solutions for the implementation of the 'SpiceNet Reference Architecture' as defined by the BroadMap project.	Take the first procurement steps to enable 'interoperable next generation of broadband radio communication systems for public safety and security' to improve Public Safety and Disaster relief organisation's (PPDR's) service to Europe's citizens, and enhance interoperability across borders	Multicultural dimension of cross-border regions, volunteer's involvement

3.2   Key aspects of innovation in transboundary resilience

The projects listed in Table 2 develop a range of key features of transboundary resilience, which we explore in more detail below.

3.2.1   Cross-border aspects and multiagency response

Taking a look at cross-border issues, multiple projects are aimed at enhancing the technical interoperability and the resource planning process among the many actors involved in operational emergency management. These projects are almost exclusively focused on bridging the gap of technical communication in a multiple agencies environment, which is an important precondition for disaster resilience. For example, the EPISECC, SecInCoRe, BroadWay, and DISASTER projects target better data exchange capabilities for stakeholders who may also be located in neighbouring countries. IDIRA aims at providing a conceptual framework that allows supporting and augmenting regionally available emergency management capacities. This can also be used for resource planning in operations across national borders. The BRIDGE project aims at developing technical and organisational solutions to ensure interoperability, harmonisation and cooperation among stakeholders. Likewise, ALERT4ALL aims at a shared alert system within Europe. Although these projects also did not fully take into account cultural issues, volunteer involvement and decision support tools were developed to support intra- or inter-agency collaboration. In the BRIDGE project this also included the development of an agent-based dynamic workflow composition and communication support system.

Models and simulations to enhance the cooperation between different stakeholders in crisis management are topics of the projects CRISMA and SICMA. The CRISMA project aimed at developing a simulation-based decision support system for modelling crisis management, which allows simulating potential impacts depending on the factors that are driving the crisis development. The SICMA project has similar objectives and aimed at providing decision-making modelling and analysis tools to improve insights about the collective behaviour of crisis response organisations. This also includes human crowd behaviour in organisations. Furthermore, DRIVER+ focuses on evaluating emerging solutions for society resilience, responder coordination, training and learning. This project also involves the evaluation of the solutions regarding their improvement in coordinating the response efforts and their benefits for cross-border operations. In addition, there are projects including EPISECC, SecInCoRe, and BroadWay focussing on the establishment of Pan-European information networks.

Our analysis shows that besides technology and exchange on procedures and operations between the various organisations in line with high-reliability theory, in this paper we argue that also cultural understanding and a common identity are drivers for resilience. However, most projects barely address cultural issues in managing disasters as well as stakeholder involvement. Multi-agency and cross-border aspects are not always considered. A stronger focus on cultural aspects in a multi-agency environment in disaster situations is taken by the coordination and support action EDUCEN. The objective of the project is a multi-level, multi-media handbook to support the general interplay between all involved stakeholders. But the specificities of cross-border aspects as well as the involvement of volunteers are not considered. Cultural aspects of the responses from affected people were specifically addressed in the BESCU project. The project aimed at enhancing emergency

communication and evacuation procedures by better understanding the cultural response. Based on psychological tools and evaluations of past events, BESCU investigated cross-cultural and ethnic differences in human behaviour during crisis. The output of the project are cross-culturally validated instruments and indices, which identified differences and similarities in prevention, knowledge, and safety culture habits.

In addition to the selected research projects, there are several Interreg initiatives taking a focus on cross-border collaboration. These include the IKIC-Project aiming to strengthen cross-border resilience through an "International Knowledge and Information Center in Public Safety". For this purpose, e-learning modules were developed for emergency response personnel in the three countries Germany, the Netherlands and Belgium. Included are learning materials on differences in disaster management structures, cultural differences, legal differences and modules for specific topics such as radiation protection. Another project focusing on the operational cooperation is the CrossFire Project[48], which was a study of feasibility for a shared inter-municipal cross-border fire station. As the projects outcome was positive on the feasibility, it is now being continued for the purpose of implementation. Two fire stations only 2.3 km apart are being merged and then operated jointly, by both fire departments. Here, the cities of Bochhold (Germany) and Aalten (Netherlands) have cooperated and supported the project. Such exchange on a daily basis is also the objective of the 'River Risk Control Training Center'[49], a modern training center for firefighters specialised in tactics and technology for averting danger on inland waterways such as ship accidents, chemical risks in the context of dangerous goods transport or ship fires. Designed on a ship, it is located on the Rhine river and moves between the ports in Strasbourg and Mulhouse-Illzach in France as well as Mannheim, Germany. Thus, it supports the exchange between French and German fire brigades and allows to train jointly developed tactics. In addition, the *Europa 1*, which was the first binational firefighter boat, is also operating in this area on the Rhine river.[50] Many more initiatives targeting the facilitated cooperation are seen in different border areas such as 'prevention of hazards without borders' at the German-Denmark border or 'Fire and disaster protection' at the German-Poland border. A current project Pandemric[51] was initialised in response to the Covid-19 pandemic. Regulations for citizens but also for the emergency forces in the context of crossing the border into one of the neighbouring countries were summarised, which changed at the beginning of the pandemic and were implemented differently in the countries. Furthermore, a dashboard with case numbers of COVID-19 infections and vaccinations numbers with Corona was compiled for the border region. In addition, support for crisis management actors was offered and thus, for example, a stronger networking of the intensive care units of different hospitals was made possible.

3.2.2 Critical infrastructures (CI) risks and dependencies

Since we argued that transnationality captures several aspects besides cross-border considerations, this section outlines the interdependencies and potential cascades with regard to critical infrastructure. A large spectrum of projects contributed to a better understanding of intra-infrastructural issues in specific sectors or to insights into risks related to CIs' interdependencies, including SEMPOC, MIA, FACIES, RISKGIS, Failure Prediction, and MICIE. Although these projects' results can be used in decision-making, they hardly address operational issues in disasters. The project CascEff focused on interdependencies and cascading issues in crisis management, in particular cross border crisis situations in which collaboration between multiple responders becomes

necessary. In addition, CascEff considered first responder tactics, human activities, and interactions to develop an incident evolution tool. Models for CI performances and stakeholder actions were used in the projects IMPROVER and RESILENS. The IMPROVER project aimed at measuring the impacts of different concepts of countries for societal, organisational and technological resilience of CIs, including cross-border examples. This is realised by the development of risk evaluation techniques, reviews, and a system-of-systems approach to test the effects of interdependencies between individual critical infrastructures and sectors. The RESILENS Project aimed at identifying best practices by turning the theoretical resilience framework into practice. Therefore, a European Resilience Management Guideline in combination with an interactive web-based decision support platform is being developed to enhance the resilience of CIs by measuring and benchmarking preparation levels against cascading effects.

The Interreg Project QUARZ-SAND[52] is dedicated to increasing the security of the medical staff and to improve the quality of medical care in a widespread disaster (level 3 or 4 medical situation). As these are rare events, the readiness to react is trained by simulation and real exercises with the medical service units and thereby the project focuses on the improved reaction in response to transboundary disaster situations.

3.2.3 Community resilience building and inclusion of spontaneous volunteers

In order to develop the potential of disaster preparedness provided by networks, transnationality also includes the consideration of communities and volunteering. Such bottom-up initiatives can be a pragmatic way of facilitating preparedness for transnational disaster situations as they directly have a picture of the situation and can communicate the needs, but also provide local, fast response capacities. There is a variety of projects, which share the objective to measure community vulnerability and resilience to be better prepared for upcoming disasters. The EMBRACE projects focused on a conceptual and methodological approach of indicators and models to provide advanced methodologies for evaluating, modelling and assessing resilience of different actors. A technical support for community resilience developed by the COMRADES project. It aims at a collective platform for community resilience, which should help communities to reconnect, respond, and recover from crisis situations in particular with the help of tools that use social media applications. The ICRED project provides a conceptual framework, socio-economic surveys, a scenario builder, and GIS to enable the development of decision support tools by measuring performances and resiliencies of systems. The results can be applied to different hazards and provide insights in physical infrastructure and socio-economic dimensions as well as in different spatial and temporal scales. Interdependencies between network infrastructures are also considered by an integrated model. Although the models enhance the community resilience building process, specific topics such as CI interdependency, cross-border issues and stakeholder involvement were not considered specifically. A rather recent focus is taken on the inclusion of spontaneous volunteers. In this regard, the KUBAS project[53] is set up to improve coordination of spontaneous volunteers via registration so that the professional disaster response actors are able to monitor the availability of volunteers as well as their skills, which supports the optimal assignment of tasks to them. Moreover, the DRIVER+ project addresses this topic in one of its sub projects titled 'civil society resilience'. On a national level, the German INKA project focused on optimal solutions

regarding the integration of volunteers. The project provided insights and discussion about ways to increase the engagement of volunteers before and in crisis situations.

3.3 Emerging challenges

As outlined, a large spectrum of programs already supports transboundary resilience from different perspectives. These initiatives have been or are currently providing insightful guidelines, methodologies and tools. However, there are still important challenges that bring uncertainty and vulnerabilities, which we detail below.

3.3.1 Crisis and emergency infrastructures and management

Despite harmonisation efforts between different functionalities and systems, different structures in the civil protection systems still prevail, which can aggravate cooperation difficulties. In particular, situation awareness and awareness of potential cascading consequences within the complex system of critical infrastructures need improvement. This also includes openness concerning each other's handling of issues and the creation of a common operational picture. Cooperating forces across borders should mutually understand command chains and practices from the other side to allow effective response. On a further step, a review should be performed examining the points on which it makes sense to align procedures and to allow exchange of data. In order to prevent an information overload, it might be useful to think about the relevance of data and information for the work of the respective organisation in advance. To organise data exchange in the next step, data protection issues need to be juristically regulated and interfaces between the number of actors and their systems should be aligned. To achieve synchronised information flows and similar levels of information, among others, the DISASTER project (Data Interoperability Solution At Stakeholders Emergencies Reaction) aimed at providing means to improve information transmission. Based on end-user requirements, a methodical basis for connecting IT-based emergency management systems was developed.[54] However, emergency response does not only depend on formal infrastructure. Power relationships, informal practices and rituals, despite their seeming invisibility, deeply impact information transmission.

For transboundary resilience, regular information exchange, trainings and mutual awareness are prerequisites for a high level of interoperability, which goes well beyond bilateral coordination. International coordination must occur at all (system) levels and take into account both the high complexity and the high diversity of the systems involved. Resilient multi-party systems, like CI-networks, which span across a large number of countries, require technical, organisational, social and cultural adaptability in order to function flexibly together. Harmonizing information systems therefore requires awareness of informal differences between disaster management in various disciplines. Overall consistency of procedures and operations is crucial to support collaborative awareness in crisis management.[55] But as the objectives and functionalities of the actors can even be contradicting, this still is a challenge. To derive a highly effective network among the involved organisations most of which are high reliability organisations, one could start creating an awareness of this differences and build on a better understanding of the various procedures, functions and targets This can be performed bottom up and by trusted relationship. However, a precondition would be the voluntary involvement of different parties and the readiness to work on an increased transboundary resilience.

3.3.2   Acceptance of resilience capabilities building policies

Communities have specific cultural backgrounds that fundamentally influence how their members interact and behave in facing disaster risks. This is reflected by diverging beliefs, feelings, behaviours, traditions, social practices, and technological arrangements to manage disaster risks, even in neighbouring countries. For instance, the citizens of Switzerland, Austria, and Germany share German as a local language, similar economic and education standards, and many other cultural characteristics. In 2016, a broad public debate was unleashed in German-speaking countries after the German federal government published the novel strategic policy for civil protection[56]. The updated policy aimed at increased resilience and self-help-capacity of citizens but encountered an unaware audience, which ignored the policy's recommendation with respect to water and food stockpiling. A public debate resulted from this reaction, which led print and online media in Switzerland and Austria to survey the stockpiling issue among their readers.[57] This survey revealed significant contrasts: in Austria and Switzerland, the population endorsed the stockpiling recommendation as part of disaster prevention in Germany, in contrast, citizen expressed aversion or strong reservation. Although Switzerland, Austria, and Germany share many cultural similarities, their populations revealed unexpected and surprising differences when it comes to disasters. Such divergences in resilience capacities can have severe implications for disaster management. Cross-border authorities and organisations involved in disasters in such regions do not always understand and remain aware of these differences, which can lead to a diverging vulnerability among neighbouring communities. However, if a cross-border region faces a disaster, one community will need external assistance earlier than others. Better prepared communities may be able to assist the most suffering ones. Hence, authorities can approach divergent levels of acceptance and preparation among populations as an opportunity to stimulate cross-border resilience through a better exchange of resources. However, cross-border organisations remain in the need for a better understanding of divergences between cross-border communities as well as means to transform them into fruitful interactions.

3.3.3   New technological avenues to resilience

Social media have contributed to widespread changes in communication patterns and basic knowledge within crisis response networks. In cross-border contexts, they can be specifically useful in reducing the language barrier and promoting cooperation.[58] However, occasionally, social media have also proven to contribute to confusion and hostility among actors. Therefore, organisations and citizens involved in cross-border disasters crucially need insights and training to better use such technologies.

New tools also afford communication blueprints during a specific event which can support a crisis management system's continuous improvement through long-term share and capitalisation of experienced knowledge - from multiple sources like use cases, examples of national accidents and scenarios to be tested and implemented. Therefore, reflexivity – including testing- over national plans is a prerequisite to cross-border cooperation. In addition, supra-national supervision can help support extensive information and knowledge sharing. For example, the Financial Stability Forum promotes international stability through cross-border information exchange and cooperation between financial firms, banks and regulatory agencies.

In addition, technologies like artificial intelligence and virtual reality can support disaster management. Forecasting, early warning systems, and training exercises can already support the prevention and preparedness phase of disaster response and allows to detect anomalies in complex systems so that they are advantageous for increased transboundary resilience. However, the data is needed on a common basis, and these technologies also come with the risk of misinterpretation of data or overfitting of models, or detecting changes too sensitively. It is a future challenge to find suitable application of these technologies and to make their results better traceable and transparent.

3.3.4 Vulnerable citizens

Borders can be impacted by massive migration flows related to climate change and political instability. After years of opening policies in relation to borders – especially in Europe – nations seem to be tightening controls, which increases the vulnerability of illegal immigrants.[59] Other vulnerable parts of the population comprise the elderly and the disabled. How to identify the most vulnerable parts of a cross-border population is an important question. How to communicate with these groups? is an equally critical question. Urban cross-border regions are often characterised by high density and difficulties to identify vulnerable populations. Which factors complicate the strengthening of self-help capacities in a cross-cultural context and how can this be facilitated? Is there a higher need of coordination between emergency medical assistance services, emergency physicians and the accident and emergency units of hospitals on both sides of the border? The ideal picture could be a full coordination, which comprises the coordination of emergency interventions based on a joint planning of capacities (personnel and technical equipment).

4   Conclusion: Transboundary resilience and societal high reliability

Several decades ago, the European Union pioneered many resilience innovations. It has been characterised as a security community-building institution, which implies a broad transboundary definition of risk and a commitment to cooperation that rests on 'a compatibility of values and mutual responsiveness' (p. 676).[36] Through INTERREG projects, the EU has supported boundary-spanning economies and (socio-technical) cohesion. As we are writing the paper, more than 12 cooperation projects are currently funded and supported on the effects of climate change on borders and resilience.[60] This is a timely way of taking responsibility for future challenges. The work done so far highlights the transboundary nature of climate related crises and calls for deeper political engagement, partnerships, and networks. European research and practitioner projects are currently pursuing a large spectrum of socio-technical innovation, coming from AI to simulation, virtual reality, data ecosystems and social innovations.

However, lessons can be learned from past and ongoing projects and we adopt a cautionary stance of their impact on transboundary resilience. First of all, one can easily notice the redundancies between some of the projects. Despite a strong effort from communities and organisations to capitalise on the knowledge and techniques produced by existing projects, each cross-boundary region is unique in terms of history, cultural and resources. This means that transboundary resilience is difficult to enact. Second, subsidiarity represents a major challenge. Institutions promote transboundary resilience at national and international levels. That said, it also strongly relies on local

cooperation and ties. For local actors, the injunction for resilience emanating from distant and abstract institutions can be perceived as irrelevant given their immediate needs. For instance, currently in the Roya Valley European leitmotif for technological innovation might fade given the crucial need for material and physical rebuilding to secure electricity access. Finally, cultural transformation towards resilience represents a major challenge. Transboundary resilience corresponds to organisational, societal, operational and institutional capacities. Its appropriation requires time, collective reflection and experimentation. Hence the question becomes whether transformation towards transboundary resilience (involving the production and diffusion of knowledge, experimentation and appropriation of technologies and methods at all levels) will occur soon enough to tackle dramatic challenges posed climate change.

In this Whitepaper, we have compiled a large number of possible approaches and ideas already tested in projects that address key aspects of transboundary resilience. Key initial findings show that in the transboundary context, the establishment of interoperability, the exchange of information and experience, the joint simulation and creation of scenarios, the involvement of volunteers, and the strengthening of regional and community self-help capacity are of particular importance. However, we believe that, first, these approaches must be brought together and work at all system levels (e.g., on a country and regional level, as professional task and as civic engagement, in an organizational and social domain etc.). Second, we need to learn to understand these systems of systems better, along with their complex network properties. Where transnational networks are already in use as CIs or will increasingly be, they should meet the standards of High Reliability Organizations. Finally, we need to better understand how socio-technical systems function in a transboundary context and how an understanding of cultural factors can be integrated into everyday life. All of this places high demands on both responsible decision makers and every citizen. The resulting increase in security, the improved protection of life, and the opportunity for improved living conditions, especially for future generations, should be worth this effort.

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