The role of data interoperability in disaster risk reduction: barriers, challenges and regional initiatives

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INTRODUCTION

Modern society is facing an unprecedented revolution. As highlighted by the International Council of Science and the Committee on Data for Science and Technology (CODATA-ICSU, 2018) , the digital technology offers profound opportunities for science to discover unsuspected patterns and relationships in nature and society, on scales from the molecular to the cosmic, from local health systems to global sustainability. It has created the potential for disciplines of science to synergize into holistic understanding of the complex challenges currently confronting humanity; the Sustainable Development Goals are a direct reflectance of this. Interdisciplinarity is obtained with integration of data across relevant disciplines. However, a barrier to realization and exploitation of this potential arises from the incompatible data standards and nomenclatures used in different disciplines. Although the problem has been addressed by several initiatives, the following challenge still remains: to make online data integration a routine.

THE ROLE OF DATA IN DISASTER RISK REDUCTION

Timely and reliable information is required for effective and efficient response in emergency situations (Mansourian et al., 2006). Disaster risk reduction (DRR) is carried out collaboratively by non-profit organizations, government agencies and emergency units on various administrative levels. As all these require time and reliable information, there is a direct link between disaster risk reduction and data interoperability. However, several barriers to data interoperability are identified (Cutter, 2003). With respect to disaster risk reduction, lack of data interoperability shifts its status from an “unexploited potential” to a “critical issue”. Indeed, both natural hazards –such as floods, fires and earthquakes – and NATECH disasters – such as dam failures and reactor explosions – have devastating impacts on human livelihoods and territorial assets due to the lack of data interoperability, as prevention and preparation actions are precluded by lack of information or stagnant information flows.

THE BARRIERS TO DATA INTEROPERABILITY

Barriers to data interoperability arise due to complex and intertwined reasons. Although these reasons differ on local, national, regional and global scales, heterogenous factors can be identified. The first factor relates to the **high number of actors involved,** such as civil protection, firefighters, healthcare services, municipalities and non-profit organizations among others. Ensuring an effective cooperation among these actors through efficient data exchange and collaborative operations is essential to disaster risk emergency management. In a continuously globalizing world, this is particularly a challenge in international emergency management, where different actors use:

- different languages;
- different emergency management systems and software;
- different major disasters classification;
- different alert codes;
- different methods to qualify and quantify major disasters consequences;
- different protocols and regulations for intervention priorities;
- different means and resources management/deployment processes;
- different policies and decision-making chains (local and national actors with different roles and action field);
- different (and separated) communication strategies for people warning;
- and different radio frequencies to communicate.

Hence, effects of local and national disaster risk reduction and management strategies are linked to the broader field of international disaster management; local and national aspects limit potential exchange data, compromising the effectiveness of international disaster risk reduction.

A second factor relates to the process of **identification of data which can be used to effectively support disaster risk reduction oriented-actions.** The Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015) established four Priorities of Action:

- **Priority 1:** Understanding disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment.
- **Priority 2:** Strengthening disaster risk governance to manage disaster risk for prevention, mitigation, preparedness, response, recovery, and rehabilitation. It fosters collaboration and partnership.
- **Priority 3:** Investing in disaster risk reduction for resilience to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment.
- **Priority 4:** Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction, taking action in anticipation of events, and ensuring capacities are in place for effective response and recovery at all levels.

Depending on the considered priorities and the actors involved, various actions can be used to support global strategies for disaster risk reduction. Examples of such actions are: creating the footprint of a disaster, diffusing good practices on risk reduction measures and tools, delineating the socio-economic mechanisms to catalyze the engagement of new resources, and stimulate preparedness in advance of anticipated disasters. Each action can be supported by a number of data categories, such as:

1. Geo-referenced data: satellite and earth-observation images, demographic distribution, existing hazards and possible impacts, critical infrastructures, cultural heritage, terrain models.
2. Data on rescue intervention procedures, methodological approaches, means, resources, technologies and tools.
3. Data from damage assessments, including socio-economic impacts and local/national economic drivers, from governments, municipalities and citizens, health services and insurance companies.
4. Building data: BIM models, materials, technologies and security measures.

Mapping the required data to support each specific disaster risk reduction-oriented action is thus a complex, non-standardized process, which can strongly affect the interoperability of emergency management actors. A third factor relates to the process of **data collection and data quality assessment**. Even when actors are aligned, and perfectly aware of the data which are needed to support their planned DRR actions, end-users of data must be aware of:

a) *where and how the selected data can be acquired,* identifying and taking notes of eventual restrictions and constraints. Required data may be stored in number of different databases. Depending upon factors as data type, data owners, the cultural and geographical context, etc. data can be classified/stored/reported in a number of different ways and by a number of different stakeholders. This granular distribution creates a significant barrier against data accessibility and interoperability. The challenge is even harder when involving disaster risk assessment processes, where such granular distributions pose high barriers to a common understanding of risks and a systematic inclusion of disaster risk in the policy-making, decision-making and investment-making processes and strongly affects the efficiency of transboundary cooperation, or emergency response operations.

b) *how to assess* data reliability, completeness, and compliance with the DRR action requirements.

c) *how to use them,* identifying and mitigating any potential obstacle against data usability, such as: country languages, ontology (different terms meaning/semantics), data model (how the data are structured), type (GIS-data, metadata, ordinary databases), format (XML, GML), and so on.

d) *how to apply them,* understanding the practical processes needed to use the data to support the delineated action, such as: downloading, visualizing, sharing, making them readable /interoperable with eventual already existing software, etc.

e) *how to verify their effectiveness,* measuring their effectiveness of data with respect to the action purposes.

Another factor relates to the **availability of data to support the realization of new initiatives in disaster risk reduction.** Over time, humanitarian aid for disaster risk reduction has evolved into two distinct branches: long-term disaster risk reduction and emergency relief. This has left a gap in humanitarian aid for disaster risk reduction right before a natural disaster occurs; forecast-based financing is a financial mechanism recently developed by *The International Federation of the Red Cross* and *National Societies* to reconciliate long-term disaster risk reduction and emergency relief.

Forecast-based financing consists of i) a forecasting system, with data, models and forecast dissemination, ii) forecast thresholds to trigger release of pre-allocated funds for humanitarian aid and iii) standard operating procedures describing actions to be taken once funding is released (Wilkinson et al., 2018). In principle, forecast-based financing can be implemented with respect to any forecastable natural hazard; what is needed, is a reliable forecasting system and pre-allocated funds (see Figure 1).

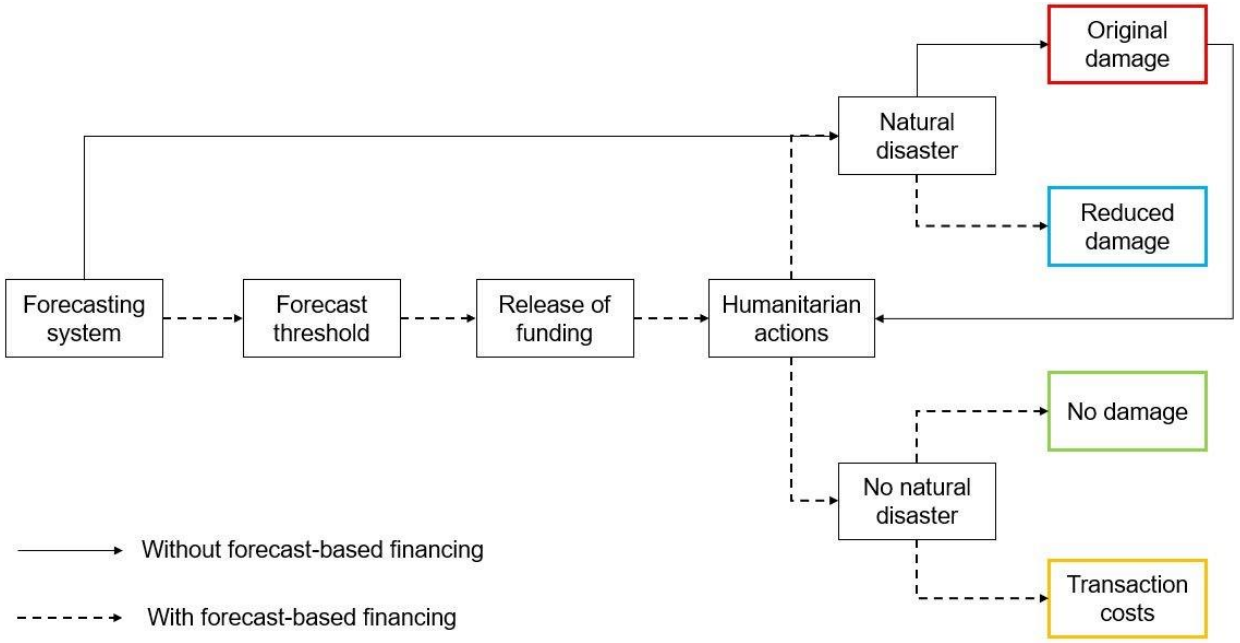

Figure 1: Principle of forecast-based financing for disaster risk reduction (Hagen, 2018).

Several pilot projects have been implemented to reduce disaster risk in the "window of opportunity" arising before an anticipated event materializes. Pilot projects have been implemented in several countries, including Togo (Suarez, 2017) , Uganda (Coughlan de Perez et al., 2016) and Peru (Lopez et al., 2018) – and more pilot projects are planned in, for instance, Haiti, Nepal and the Dominican Republic. As an example, a flood forecasting system was set up at Nangbéto Dam in Togo, downstream of which people suffer from flooding yearly following the West African Monsoon. Pre-allocated funds have been secured by the German Red Cross with governmental support (Coughlan de Perez et al., 2015). With defined triggers (forecast thresholds) for release of pre-allocated funds, the Red Cross is able to provide humanitarian before flooding occurs. Examples of humanitarian actions described in standard operating procedures include distribution of water purification tables, temporary emergency shelters and canned food.

Worldwide, support is given by the American Red Cross, the Australian Red Cross, the Belgian Red Cross, the British Red Cross, the Danish Red Cross, the Finnish Red Cross, the Netherlands Red Cross and the German Red Cross. More recently, *The International Federation of the Red Cross* has extended the scope of the global financial instrument, the *Disaster Relief Emergency Fund*, to provide flexible funding for forecast-based financing. However, forecast-based financing is limited to pilot projects, currently in seventeen countries. To significantly contribute to reducing global mortality rates (Global Target A of the Sendai Framework for Disaster Risk Reduction), forecast-based financing needs upscaling. As previously mentioned, one of the largest constraint in implementation of forecast-based financing is **data availability**. Data is needed to set up and run models in forecasting systems and to understand causal relationships between [forecasted] natural hazards and resulting damage. As an example, flood forecasting with hydrological models requires weather forecasts, generated with atmospheric models, and a large number of parameter values, obtained from optimization procedures or in-situ measurements. Consequently, problems arise where data records are sparse (Bárdossy, 2007; Li et al., 2018; Nash & Sutcliffe, 1970). However, even when sufficient data is available for setting up, calibrating, verifying and operationally running the models, the formulation of forecast thresholds must be justified. Why should a certain forecast threshold trigger release of funding? What type of humanitarian actions would be needed? To justify forecast thresholds as triggers for release of funding, data on impacts are needed. However, impact data is usually collected in the aftermath of an event in terms of economic damage; data collection of impacts during natural disasters is both unsystematic and sparse. Furthermore, crowd-sourcing of data during the "window of opportunity" can help optimize disaster risk reduction by enhancing communication and flow of information between various agencies, organizations and stakeholders involved (Machalek & Dunlop, 2016). In other words, systematic data collection and data interoperability are strongly needed. The ability to anticipate adverse effects and prepare accordingly in the "window of opportunity" before a natural disaster materializes can significantly contribute to enhancing disaster preparedness (Key Priority 4 of the Sendai Framework for Disaster Risk Reduction) and reduce global mortality rates (Global Target A). Climate change, population growth, migration and land use change are all external drivers potentially increasing natural hazards, vulnerability and exposure in the future. While the future is uncertain, it is certain that disaster risk cannot be completely eliminated. However, disaster risk reduction can increase resistance and resilience and reduce vulnerability and exposure. With the rise of forecast-based financing, the need for systematic data collection and data interoperability is evidently urgent; not only to reduce the economic damage following natural disasters, but to save lives before they strike. The above-mentioned factors are only examples; numerous barriers to data interoperability exist. Categorizing these barriers is challenging, as they can belong to several domains.

Some barriers can affect the **social domain**: low public awareness about risks, mistrust towards central institutions, lack of risk assessments, cultural impacts on risk perception, inadequate training and aversion towards technology are interesting examples of social barriers. Also, the continuous evolution of society constantly creates new drivers, interests and catalysts for disaster risk reduction: some data on disasters which today are fundamental for risk analysis, were perhaps not even considered some years ago; this results in sparse data records with respect to historical archives. Other barriers are linked to the **political domain**, arising from the lack of standardized procedures for data collection, distribution and information security, or the reluctance to share data across borders. Clearly, the **economic domain** strongly affects all aspects of data handling – starting from data collection to processing and distribution. INSPIRE Directive application cases (Migliorini et al, 2015) shows us that a relevant effort is required from public and private local data owners to align already existing datasets to European data model standards, making funds availability an important driver to enable interoperability. Furthermore, private actors such as insurance companies are collecting and using risk assessment data to plan their business strategies, so are often oriented to classify those data and maintain them restricted. The **technological domain** is one of the most relevant: the heterogeneous scenario made by different data models, formats, resolutions, software (including GIS platform), user-interfaces, storing hardware is a crucial barrier against data interoperability and accessibility. The recent model of cloud-computing data introduces a further barrier, e.g. the need for internet access during emergencies. Data is hence the inaccessible if connection is lost – and internet communication is often affected during emergencies with power outlets or physical damage to infrastructure. Furthermore, the constant evolution of data-related technologies and their capacity (in accordance with Moore's Law (Schaller, 1997) contributes to create further technological barriers. Other barriers can be connected to the **geographical domain**, such as language, unbalanced data collection (data collection is generally scarce in developing countries in comparison to developed countries) and geographical distribution of disasters (vulnerability and exposure to certain disaster types are higher in some countries, leading to a higher expertise and a refined system to collect and assess data related to those disaster types). Another relevant barrier concerned with the geographical domain is spatiotemporal scales (on local, regional, national, international and global level).

The **scientific domain** reflects present and past paradigms. The paradigms differ in time and across disciplines. This also gives rise to barriers. While a gap exists between scientists and practitioners, data, information and knowledge may reside in either domain without offering practical use to drive scientific research and practical applications further. Sharing data, information and knowledge can add value to both scientific research and practical applications while at the same time giving rise to positive feedback effects – like guiding science towards new areas of research (for instance by identifying short-comings or knowledge gaps in emergency management) and using scientific insight optimize disaster risk reduction (for instance by using knowledge of spatiotemporal variability of vulnerability and exposure).

BIG DATA: A COMPLEX RESOURCE

The growth of social networks (ISSD, 2018) and the accelerated pace of modern communications have placed a renewed emphasis on global interconnectedness and scale in the international development field. These notions are particularly relevant to understanding the complex nature of vulnerability, as well as the ability of systems – such as individuals, households, communities or countries – to cope with, adapt to, and potentially transform in the face of shocks and stressors, i.e. “resilience.” As previously mentioned, the information and communication technology (ICT) revolution has been accompanied by an increasing emergence of very large datasets. Data is a driver of growth and change. Big Data has emerged as a multifaceted phenomenon that is dramatically changing data collection and processing (Crawford et al., 2013). The term is commonly used to refer to unprecedented volumes of data that are so large or complex that traditional data processing applications are inadequate to deal with them, but has evolved to encompass more than that. Later definitions highlight the “four Vs” of Big Data: volume, velocity, variety and veracity (Laney, 2001), which have allowed new approaches to predictive analytics, user behavior analytics, and other methods to visualize and to extract value from data. More recently, the Data-Pop Alliance defined Big Data as follows: a new socio-technological phenomenon resulting from the emergence and development of an ecosystem made up of the new kinds of data “crumbs” about human behaviors and beliefs generated and collected by digital devices and services, ever more powerful computing power and analytics tools, and a vibrant community of actors in this field (Data-Pop Alliance, 2015) . While there is a growing body of literature and practical experiences at the intersection of Big Data and development (Letouzé, 2012) particularly in the field of humanitarian emergencies (Ali et al., 2016) and the Sustainable Development Goals (UN Global Pulse, 2017) there is a critical knowledge gap regarding the use, potential and challenges associated with the use of Big Data in resilience programming. The massive amounts of data being collected both passively and opportunistically through technological tools and devices requires resilience practitioners to rethink key questions that arise from the design, implementation, monitoring and evaluation of projects, including the role of ethics, privacy and security, technology access, governance and sociocultural contexts in data collection and analysis (ISSD, 2018) .

THE ROLE OF DATA IN THE SENDAI FRAMEWORK MONITORING PROCESS

Data is not only a relevant tool able to support the implementation of disaster risk reduction strategies, but also to **monitor** such implementation. In adopting the Sendai Framework for Disaster Risk Reduction 2015 – 2030, UN Member States committed to the systematic and cyclical measurement, monitoring and reporting of progress in achieving the outcome and goal of the framework. At the global level, progress is to be measured against the seven global targets and associated indicators. The indicators were developed in 2016 by the Members and observers of the Open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction (OIEWG), to be able to capture progress in the prevention of new, and the reduction of existing risk, and the strengthening of resilience of persons, businesses, communities and countries. Effective monitoring of progress in achieving the global targets of the Sendai Framework and disaster- related Sustainable Development Goals, is predicated on the availability, accessibility, quality and applicability of multiple datasets. These data are collected from multiple sources via numerous mechanisms, including but not restricted to national disaster loss accounting systems, national statistical systems, household surveys and routine administrative data. Qualitative and quantitative data will be required, and could be supplemented by Earth observations (EO) and geospatial information (GI). To assess the current state of play, UNISDR conducted a review of the readiness of countries to report against the global targets. In contributing to this Review, 87 Member States across all regions assessed their state of readiness to monitor and report, and specifically, the availability of national disaster-related data, disaster-related data gaps and the type of resources required to fill data gaps identified. In terms of availability, with well-established disaster loss accounting protocols in many countries, the loss data environment is reasonably populated, although data are typically more available on physical damage and human impact, and less available on economic losses, losses of specific assets and infrastructure, cultural heritage and disruptions to basic services. The challenge of data availability is greater in countries where there is no national system for disaster loss data collection. Data quality is also essential to facilitating effective monitoring, reporting and informed decision-making for implementation of the Sendai Framework and the SDGs. Here, it is important to note that the integration of disaster-related data within national statistical systems can bring quality dividends through applying the fundamental principles of official statistics, and at the same time, facilitate integrated reporting to the SDGs and the Sendai Framework using multi-purpose data sources; thereby reducing the reporting burden on Member States. Accessibility and interoperability are considered as key elements. Data may be available, but access to the data may be impeded, for instance by being subject to a tariff or payment (for which there are no resources). In other circumstances a lack of access to existing datasets may simply be a function of established (mal)practice or the absence of data-sharing protocols, mechanisms and appropriate data governance arrangements. Based on this status, UNISDR developed and launched the Sendai Framework Monitoring System in March 2018, with the aim to offer a user-friendly online platform, interoperable at the global level with quantitative data fully compliant with the indicators agreed by Member States. The Sendai Framework Monitoring System allows national authorities to configure the data collection process in line with their existing national structures for data collection. Each indicator of the Sendai Framework can be treated independently by the national agency or institution responsible (i.e. Ministry of Economy and Finance, Ministry of Agriculture, National Statistic Office, etc.). The principles of the system also encourage the systematic disaggregation of data, which is a core component of risk understanding. In the case of the Sendai Monitoring System, the objective is to ensure the systematic collection of data losses by geographic location (at the municipality level), by age, gender, level of income and potential disabilities. In order to achieve the global Sendai Framework Monitoring process, UNISDR supports the implementation of national disaster loss data collection systems. These tools, compatible with the Sendai Framework Monitoring System (i.e. DesInventar Sendai) enable local and national authorities to systematically report intensive and extensive disasters, on the basis of data entry cards for each event. Aligned with the indicators and the terminology agreed by Member States, these tools include all mandatory fields for accounting losses and disaggregating information. The use of compatible national disaster loss data collection system allows to automatically export data to the global monitoring systems such as Sendai Framework and SDGs. These systems also facilitate exchange of information among countries, transboundary cooperation and progresses at the regional level.

As of 1st August 2018, 48 countries have already started reporting in the Sendai Framework Monitoring System, acknowledging their capacity for identifying, obtaining and using relevant data linked to disaster losses and disaster risk reduction activities. Even if several reasons can explain the status of the remaining 147 countries, there is no doubt that the availability and reliability of data-sets is a part of the challenges faced by authorities. Therefore, the sustainable efforts made by the scientific community, the governments, the international community and the other stakeholders for improving the availability, use and interoperability of disaster data is a core factor of the overall process for disaster risk reduction and increased resilience. It is relevant to highlight that many of the barriers against data interoperability overviewed in the first part of the present paper can thus affect not only the proper implementation of risk reduction strategies, but also the monitoring process of such implementation. Identifying those barriers across Sendai Framework Targets and Indicators, categorizing them and finding solutions to overcome them seem thus to be a major priority.

DATA-ESTAG: A EUROPEAN INITIATIVE TO ENHANCING DATA INTEROPERABILTY FOR DISASTER RISK REDUCTION

The European Science and Technology Advisory Group (E-STAG) was established on 25 April 2018 in Sofia (Bulgaria) UNISDR and the European Commission's Joint Research Centre to tackle new emerging challenges, focusing in particular on improving disaster risk knowledge in 55 countries across Europe and Central Asia. The E-STAG role embraces the following:

- to work in coordination and linkage to national and regional DRR platforms, partners or networks;
- to advise national, regional and global DRR platforms to integrate S&T actors in their bodies and events;
- to identify and showcase key scientific information, knowledge and case studies that can be applied by policymakers and practitioners;
- to catalyze new efforts and partnerships to generate new knowledge and contribute to capacity building for scientists particularly in developing countries;
- to enhance efforts through the links to existing regional science and technology networks.

The Data for Resilience Group of European Science and Technology Advisory Group (Data-ESTAG) is contributing to the expected E-STAG outcomes by gaining a detailed understanding about the role of data in supporting the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030.

Starting from the Sendai Framework targets and related indicators, the Data-ESTAG is focusing on delineating the mechanisms, the requirements and the conditions needed for ensuring that data are compiled and used as an effective tool to support the implementation and monitoring of the DRR strategies.

The Data-ESTAG defines specific guidelines to facilitate “DRR data searchers” (intending public and private stakeholders which may have a role in collecting, assessing and using data for policy-making process, risk-informed decisions and to support the implementation of disaster risk reduction oriented-actions) in igniting those conditions and mitigating existing barriers to interoperability and knowledge exchange.

In particular, the Data-ESTAG aims to:

- stimulating DRR data searchers to increase their effectiveness in collecting, assessing and using data which can support the implementation and monitoring of Sendai Framework principles;
- providing guidance to DRR data searchers in the operations of data finding, mapping, reporting, assessing, exchanging, verifying, etc. with the aim to create a common baseline approach.
- supporting DRR data searchers in getting in contact with (and maximizing the benefit taken from) existing core European and international data-related resources able to support the implementation and monitoring of Sendai Framework principles, including platforms such as Data Risk Hub and Desinventar Sendai.
- Enhancing the valorization of the good practices and lessons learnt by DRR data searchers, with the aim to increase data exchange and interoperability at global level, and fostering the transfer of such knowledge to policy makers.

From a practical point of view, the Data-ESTAG is moving alongside three operational activities:

1. Starting from Sendai Targets, identifying the barriers playing against the interoperability and effective use of data to fulfill requested indicators. An extensive data collection will be performed through webinars, interviews, and surveys to relevant experts and representatives of Authoritative Bodies operating in the field of data collection, assessment, and use to implement disaster risk reduction oriented-actions.
2. Analyzing and categorizing the identified barriers, linking them with respect to different Sendai Framework Targets and Indicators.
3. Identifying resources and knowledge elements (best practices, tools, European core datasets and data services, etc.) which support the overcoming of the identified barriers.

Identifying and categorizing the barriers are only a first step towards obtaining data interoperability. The real challenge lies in overcoming the barriers. While barriers can be categorized, the solutions as to how to overcome them are not generic, due to the fact that barriers are interlinked and differ from place to place, country to country and region to region. Moreover, several natural hazards may materialize concurrently. For instance, storm surges often occur concurrently with hurricanes. In these cases, several agencies work concurrently and a wide range of data (and models) are needed. For dissemination of timely and reliable information to all stakeholders involved in disaster risk reduction and emergency management, data interoperability is essential. Due to the aforementioned barriers to data interoperability, solutions may be both case-specific and local, while regional strategies may provide frameworks under which specific solutions can be formed.

Some initiatives have already been established with the aim of enhancing data accessibility and interoperability. With support from UNEP[1] and UNISDR[2] , a web-based geoportal called Project for Risk Evaluation, Vulnerability, Information and Early Warning (PREVIEW) – Global Risk Data Platform aims at facilitating access to geospatial data

[1] United Nations Environmental Program
[2] United Nations International Strategy for Disaster Risk Reduction

(Giuliani& Peduzzi, 2011). The PREVIEW – Global Risk Data Platform provides interoperable access to over sixty datasets on tropical cyclones, storm surges, droughts, earthquakes, wildfires, floods, landslides tsunamis and volcanic eruptions. However, if limitations and needs on end-user level are not taken into account, data interoperability fails to enhance disaster risk reduction (Cutter, 2003). This highlights the need for a bottom-up approach with close collaboration between practitioners and scientists, in which the most important research questions are derived from practitioners.

Another example of initiative to support the collection of standardized data for DRR strategies is the Roadmap, Showcase and Guide form part of a suite of new tools for practitioners developed by UNISDR and its partners for the Making Cities Resilient Campaign (IDIR, 2016). These include an updated Disaster Resilience Scorecard for Cities and a Quick Risk Estimation (QRE) Tool. These tools are all oriented toward the Ten Essentials for Making Cities Resilient, a ten-point checklist developed for the Making Cities Resilient Campaign by leading urban resilience experts. The Ten Essentials serve as a practical framework to support a city's commitment to improving its resilience. Over 3,500 cities across all global regions have signed up to the Campaign and to using the Ten Essentials and Disaster Resilience Scorecard for Cities in their resilience building. There are three types of Essentials: enabling, operational, and building back better. Each one of the 10 falls under one of these types, acting as critical and independent steps toward implementing the Sendai Framework for Disaster Risk Reduction 4 at the local level.

A third initiative worth mentioning is the work performed by GVM and IAVCEI, which was jointly commissioned by UNISDR to contribute reports on volcanic hazard and risk for the Global Assessment Report (GAR) 15 study. Volcanoes have not been considered in previous GAR reports so this was a unique opportunity for the international volcanological community to make a broad global assessment of volcanism in the context of DRR and to present the state-of-the art in volcanic hazards and risk assessment. The work represents an example of integration of data on volcanic hazards and risks worldwide.

However, while regional initiatives on data integration do exist, the primary challenge addressed in this paper still remains: How can online data integration for disaster risk reduction become a routine? Data-ESTAG is an attempt at answering – if not fully, at least partly – this question, laying down foundations on which further regional initiatives can build. The final output of the Data-ESTAG will be a set of guidelines for DRR data collection and dissemination to identify, assess and overcome barriers against data interoperability with the aim of strengthening the fundamental role of data in disaster risk reduction, particularly targeting implementation and monitoring of the Sendai Framework.

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