European Commission

EXECUTIVE SUMMARY

SCIENCE FOR DISASTER RISK MANAGEMENT 2017

Knowing better and losing less

Disaster
Risk
Management
Knowledge
Centre

This is the executive summary of the document "Science for disaster risk management 2017: knowing better and losing less"

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Want to learn more about the Disaster Risk Management Knowledge Centre (DRMKC) - http://drmkc.jrc.ec.europa.eu/

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Knowing better and losing less

EXECUTIVE SUMMARY

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FOREWORD

Dear policymakers, practitioners or scientists,

It is deeply encouraging to see how quickly the scientific community has mobilized to play its full part in implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 with the overall aim of reducing disaster risks and losses, and shifting the emphasis from managing disasters to managing the underlying risks.

The Sendai Framework clearly recognises the strong role that the scientific community can play in improved understanding of risk and communicating on new knowledge and innovation. The European Commission took the initiative early by launching the Disaster Risk Management Knowledge Centre in September 2015, just six months after the adoption of the Sendai Framework as a contribution to the Science and Technology Roadmap. Now we have this insightful publication as the first fruit of its labours.

The UN Office for Disaster Risk Reduction (UNISDR) and European Commission, Joint Research Centre (JRC) have been partners to stimulate new research and to encourage the use of available science by all stakeholders.

JRC was one of the co-organisers of the UNISDR Science and Technology Conference in January 2016, which produced an ambitious Science and Technology Roadmap and launched the Science and Technology Partnership.

The JRC has worked with over 200 top scientists, practitioners and policy makers from many fields to summarise the state of the science relevant to disaster risk management, and to make it accessible in this current report. The aim is to break out of the silos, demystify work from other disciplines, encourage potential synergies across disciplines, and to identify gaps in scientific knowledge for future research.

This report summarises the state of relevant science from a European perspective. We consider it as the start of a continuing process, the beginning of a wider, worldwide partnership to summarise knowledge globally, and make it available to the disaster risk management community.

The report is timely for the discussions at the Global Platform for Disaster Risk Reduction in Mexico in May 2017. It caters for the need to translate the wealth of available science into language understandable by stakeholders such as policy makers, practitioners and scientists from other disciplines.

We invite you to engage with us, now and in the future, to enhance the science-policy interface so that strategies for disaster risk reduction at national and local level, which will be put in place by the Sendai Framework deadline of 2020, are based on sound evidence and robust science.

Robert Glasser,
United Nations Special Representative
of the Secretary-General for Disaster Risk Reduction

Vladimir Šucha,
Director General,
European Commission, Joint Research Centre

PREFACE

The Disaster Risk Management Knowledge Centre has produced this flagship science report as a contribution to the Science and Technology Roadmap of the Sendai Framework for Disaster Risk Reduction.

This report is the result of the multi-sectorial and multi-disciplinary networking process and represents the combined effort of more than two hundred experts.

It will support the integration of science into informed decision making through synthesizing and translating evidence for disaster risk management and strengthening the science-policy and science-operation interface.

EXPECTATIONS

This report aims to provide reviews of scientific solutions and their practical use in various areas of DRM in Europe. It is comprehensive in scope but selective in topic and is written in a format that is intended to be accessible to all DRM actors. The reviews of the scientific evidence base are summaries of (1) recent advances/outcomes of EU research projects, (2) relevant national work and (3) relevant international work.

The report aims to bridge science and policy as well as operation communities. The intended audience consists of practitioners and policy makers in addition to experts from different scientific disciplines. It seeks to understand the scientific issues of relevance to their work; specifically civil protection operations and disaster risk policy, but equally climate adaptation policy. The audience includes government officials at EU, national, regional and local levels interested in finding better ways to use science, and also scientists to help them understand work in other disciplines that would allow the identification of possible cross-sectoral synergies and needs from practitioners.

THE PROCESS

The Disaster Risk Management Knowledge Centre has committed to producing a series of reports to analyse, update the state of the art and identify research and innovation gaps in the field of DRM. Each report will be multi-hazard, multi-disciplinary, and will address the full disaster risk cycle; it will have scientific-oriented contributions presenting the state of science, and practitioner-oriented contributions presenting the use of science.

The process started in January 2016, when the DRMKC working group defined expectations and developed the outline of this report, the first in the series. The process was run by the JRC Editorial Board of 4 members with strong support from the European Commission Advisory group of 79 experts in specific topics. The writing phase was carried out by Author teams consisting in total of 8 Coordinating Lead Authors, 3 Facilitators, 34 Lead Authors and 140 Contributing Authors. The drafts were circulated for formal review to 123 scientific experts, policymakers and practitioners. The preparation of the report succeeded in pulling together a network of 273 contributors from 26 mostly European countries and 172 organizations. It has been endorsed by 11 European Commission Services and will be officially released at the Global Platform for Disaster Risk Reduction in May 2017.

STRUCTURE

Understanding disaster risk to manage it is one of the main focus of Sendai Framework. This perspective already opens two big issues: understanding disaster risk with the focus on scientific evidence, and managing disaster risk with the focus on knowledge applied by different actors. In order to convey the DRMKC's mission of bridging science and the policy/operation community, the issue of communicating disaster risk has been introduced with a strong focus on how to successfully overcome barriers

The "Bridge concept"

to implementing knowledge in the field of DRM.

The scope of the report is divided conceptually into three distinct parts: understanding disaster risk, communicating disaster risk and managing disaster risk, forming the “bridge concept” of the report.

The “Understanding disaster risk” part has been split into two chapters: Chapter 2, covering risk assessment methodology and examples in general, and Chapter 3 that provides a comprehensive overview of hazard related risk issues, the structure of which follows the Sendai taxonomy of hazard classification. Chapter 4 on “Communicating disaster risk” tackles many issues on communication in different phases of DRM among different actors. Chapter 5 “Managing disaster risk” addresses the governance issues of the full disaster risk cycle.

The first and last chapter wrap the scope of the report into a whole. Chapter 1 “Current status of disaster risk management and policy framework” aims to explain why recent global and European initiatives are beginning to seek help to strengthen society’s resilience by using science and technology. The final Chapter 6 “Future challenges of disaster risk management” aims to inform decision makers and practitioners of existing science that should find its way into legislative form and practice as well as tackling a much more challenging purpose: to recognise knowledge gaps that could serve as valuable reference based input for a Horizon2020 call.

ACKNOWLEDGEMENTS

We wish to express special thanks to all the Coordinating Lead Authors, Lead Authors, Contributing Authors, Reviewers and EC Advisors. Without their expertise, experiences and a huge commitment to a cause, this report with such a holistic understanding of both disaster risk and disaster risk management could never have been completed.
It is our pleasure to invite you to explore the content of this report and we wish you pleasant and informative reading.

Disaster Risk Management Knowledge Centre

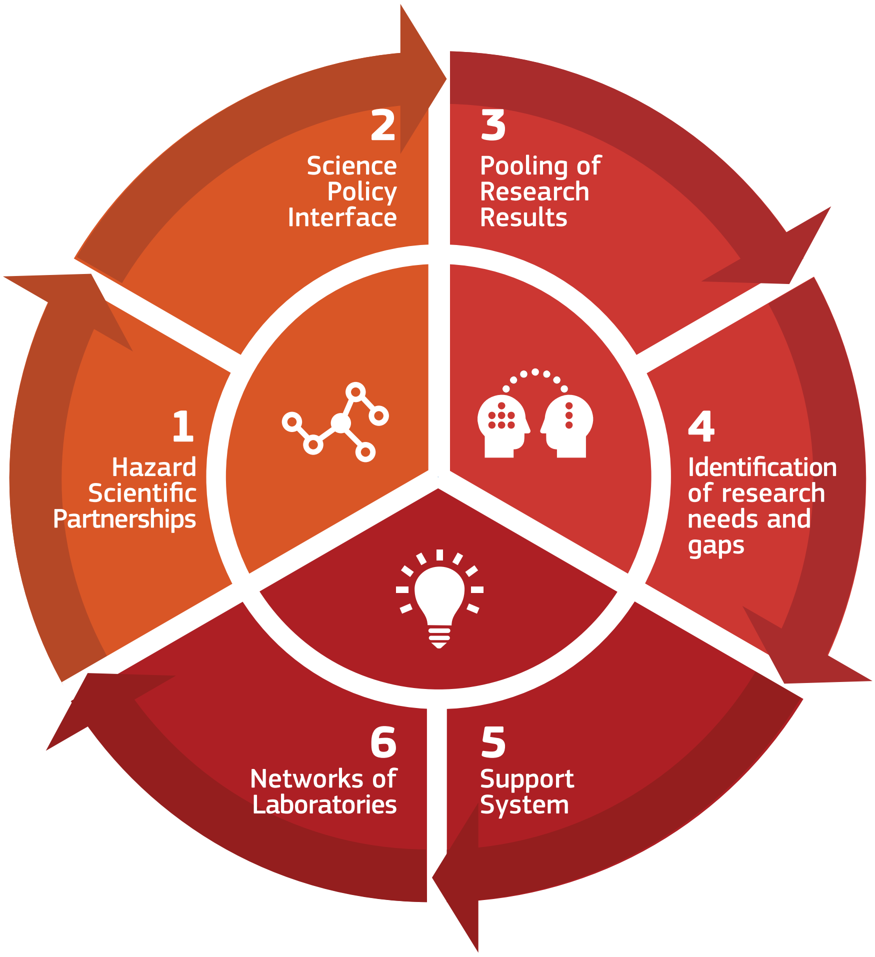
Enhancing the Knowledge base to support Disaster Risk Management

Faced with the risk of increasingly severe and frequent natural and man-made disasters, policy-makers and risk managers in Disaster Risk Management (DRM) and across EU policies increasingly rely on the wealth of existing knowledge and evidence at all levels – local, national, European and global – and at all stages of the DRM cycle – prevention; reduction; preparedness; response and recovery.

Better knowledge, stronger evidence and a greater focus on transformative processes and innovation are essential to improve our understanding of disaster risk, to build resilience and risk-informed approaches to policy-making, and contribute to smart, sustainable and inclusive growth.

The Disaster Risk Management Knowledge Centre (DRMKC) provides a networked approach to the science-policy interface in DRM, across the Commission, EU Member States and the DRM community within and beyond the EU. This Commission initiative builds on three main pillars:

Partnerships and networks to improve science-based services;
Better use and uptake of research and operational knowledge;
Innovative tools and practices for risk and crisis management;



Activities of the DRMKC support the translation of complex scientific data and analyses into usable information and provides science-based advice for DRM policies, as well as timely and reliable scientific-based analyses for emergency preparedness and coordinated response activities. It brings together existing initiatives in which science and innovative practices contribute to the management of disaster risks.

At a global level, the EU supports the Sendai Framework for Disaster Risk Reduction to promote a more systematic and reinforced science-policy interface to strengthen the contribution of DRM to smart, sustainable and inclusive growth globally.

In practice:

Partnership

To achieve the ambitious goal of fully exploiting and translating complex science into useful policy and applications in DRM, the DRMKC reinforces the development of disaster science partnerships and networks.

- ***Where knowledge begins***: Networks and activities are activated and promoted to improve the science-policy interface in prevention activities and to facilitate the translation of complex science into useful policy advice.

- ***Where knowledge applies***: Partnerships for operational preparedness and response to major natural disaster types in the EU are promoted to facilitate the information flow between the different partnerships, the Emergency Response Coordination Centre (ERCC) and Member States.

Knowledge

Scientific research results and operational knowledge gained from lessons learnt, exercises, training, peer reviews and other assessment tools need to be better exploited in the DRM cycle to mitigate risks and vulnerabilities and to improve response when disaster strikes.

- ***Where knowledge meets***: A common repository of relevant research and operational projects and results will be accessible through the DRMKC and its Web-platform.

- ***Where needs are identified***: A science advisory panel of experts and scientists at local, national and European levels provides analyses, updates and advice into research and innovation needs in DRM.

Innovation

Industry and the scientific community play an essential role in developing innovative methods, tools and technological solutions for the mitigation of disasters and their impacts. They facilitate the work of first responders and other operational actors in crisis management through innovative technologies and instruments.

- ***Where gaps are filled***: A Support System facilitates the use of existing expertise to help Member States meet risk management related obligations – DRM Capabilities Assessment, Disaster Loss Databases, Science-policy interfaces, National Risk Assessment.

- ***Where innovation is tested***: The DMKC assesses the current state of DRM science and technology in Europe and addresses technological and operational challenges to cover the existing gaps, and assists in building globally common standards, through the European Network for Innovation Test Beds (ENITB) and the European Crisis Management Laboratory (ECML).

The DRMKC is supported and coordinated by a number of Commission Services in partnership with a key network of Member States. A Steering Committee meets regularly to propose, discuss and establish the activities and priorities of the knowledge centre.

The DRMKC web-platform facilitates information and knowledge sharing, while enhancing the connection between science, operational activities and policy: http://drmkc.jrc.ec.europa.eu/

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SUMMARY

Chapter 1

Current status of disaster risk management and policy frameworks

Andrew Bower

1. Current status of disaster risk management and policy frameworks

A main challenge for policy-makers addressing natural and human-induced disaster risk management, across all EU policies, is to capitalise on the wealth of existing knowledge at all levels – local, national, European and global.

Natural and human -induced disasters present major risks to the economy, the security and well-being of citizens and society. Addressing these risks relies on robust evidence-based decision-making. A main challenge for policy-makers addressing natural and human-induced disaster risk management, across all EU policies, is to capitalise on the wealth of existing knowledge at all levels – local, national, European and global.

Disaster prevention and risk reduction are cross-cutting to a number of key EU policies. Ensuring efficient disaster risk reduction and prevention measures relies on a robust understanding and assessment of risks. Disaster preparedness and response measures depend on the support of tools and instruments to provide timely, relevant and reliable data for operational decision-making.

In order to improve all stages of the DRM cycle – prevention, reduction, preparedness; response and recovery – the knowledge and evidence base needs to be further improved, advances in relevant technology exploited, research results applied, and the interaction between researchers and end users enhanced. A risk-informed approach to disaster risk management is built upon a robust and extensive knowledge base: research, innovation and scientific projects are central components

At a global level, science and technology play a central role in many international agreements addressing DRM. The UN Sendai Framework for Disaster Risk Reduction calls for a strong interface between science and policy to build a strong knowledge of disaster risk; make efficient use of data to better understand the economic impacts of disasters; and develop adequate preventive policies to reduce the risks of disasters. The science and innovation contribute to several Sustainable Development Goals and their associated targets. In the context of the Paris Agreement on climate change), the importance of data collection, evidence-based approaches and the contribution of science was recognized.

Understanding the state of play of policy frameworks relevant to disaster risk management will help strengthen the interface between science and policy required to reduce the risk of disasters and enhance our prevention, preparedness, response and recovery.

Many policies at EU level, as well as political initiatives on a global scale, include a disaster risk dimension. Ensuring a robust DRM knowledge base is essential to inform these different policy processes and to work towards effective evidence-based decision-making.

Reinforcing the science-policy interface should allow better exploiting and translating the complexities of scientific results into useful and usable policy outputs, through: efficient access and uptake of knowledge and research; a networked approach across relevant stakeholder communities; and continuous efforts towards innovation and new technologies and tools.

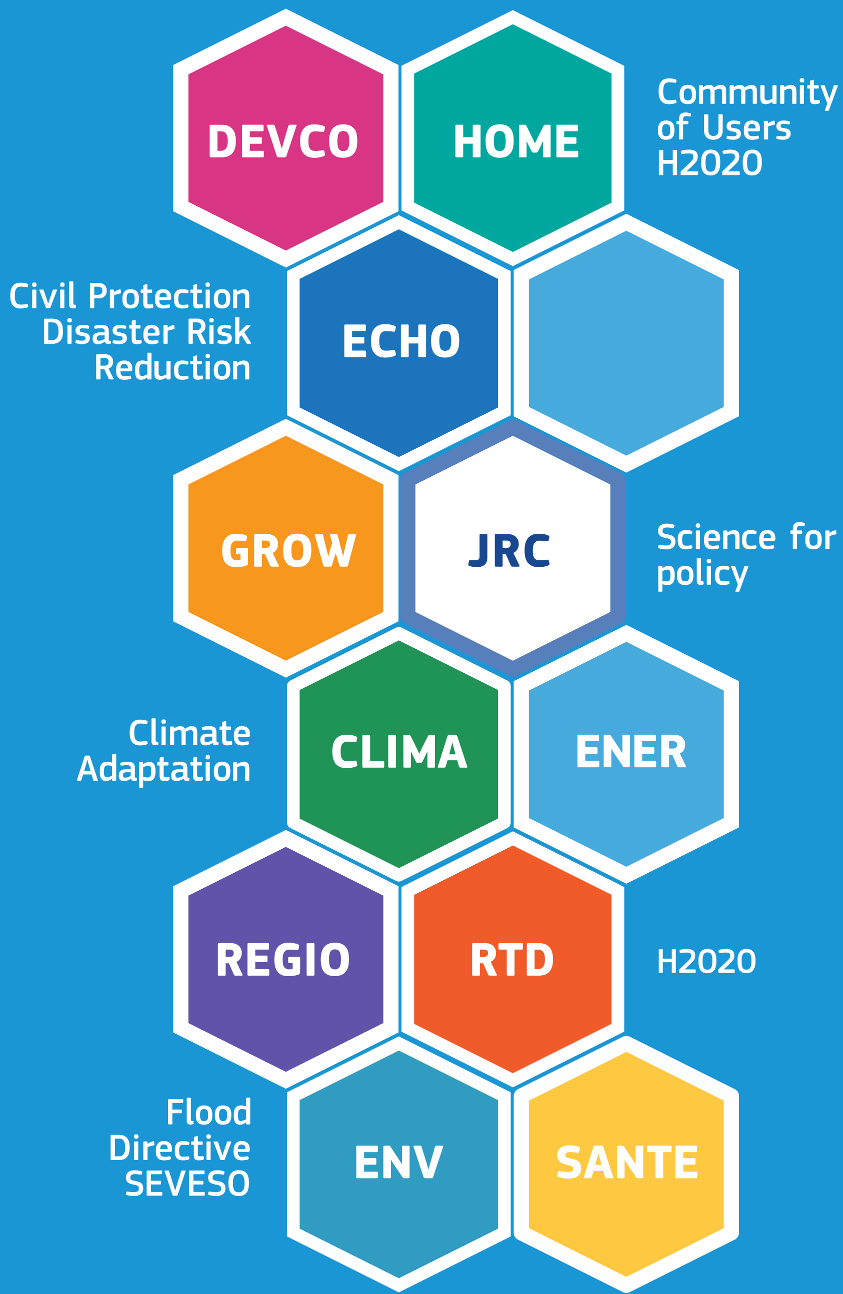
The Disaster Risk Management Knowledge Centre offers a valuable platform to meet these aims and further enhance the contribution of science to DRM policy making.

Disaster Risk Management Knowledge Centre

DRMKC

Large scientific community for **DRM**

EC Directorates



SUMMARY

Chapter 2

Understanding disaster risk: risk assessment methodologies and examples

David C. Simmons

2. Understanding disaster risk: risk assessment methodologies and examples

It is a moral duty and good policy, as well as a potential legal responsibility, to properly identify the risks that society faces.

We live in a society where the duty of care that governments and civic authorities owe to their citizens has never been clearer.
In many jurisdictions, the possibility of legal action by those affected by a catastrophe event where either preventative action was not taken or the event response was deemed inadequate is now a credible reality.

It is a moral duty and good policy, as well as a potential legal responsibility, to properly identify the risks that society faces, to understand them; to assess their likely probability; assess the vulnerability of populations and buildings and then, as far as possible, to understand their potential severity. Based upon such knowledge it is possible to provide a framework for decision making, evaluating the cost and value of preventative strategies, and to design and implement contingency plans to minimise the impact of events as they occur.

The framework for assessing risk is now well established:

- Identify possible hazards that could give rise to catastrophic events
- Understand these hazards: potential likelihood, intensity and geographic scope
- Identify what is at risk from these hazards: people, buildings, infrastructure, nature
- Understand the vulnerability of the exposed items to the hazards
- Assess the potential impacts, in a quantitative form if possible
- Evaluate the above: is the risk acceptable? If not, consider actions and strategies that bring the risks within acceptable bounds and quantify their costs and benefits

Risk is complex. Some hazards, such as floods, can have multiple causes and many factors can determine the event's severity - some natural (e.g. soil saturation, upstream precipitation or snow melt, tides), some man-made (e.g, canalisation of rivers, building in flood plains, poor drainage). Other hazards may cause secondary events that may ultimately be as damaging or more so: earthquakes causing tsunamis, urban fire-storms, landslips resulting in dam-bursts. Hazards are dynamic and can occur in combination, compounding the damage and impact upon lives and livelihoods.

If hazards are hard to understand, it is not always simple to understand what is at risk. Buildings and infrastructure do not move or change rapidly but often little is known about their location, size, construction, maintenance and use. The contents of buildings, i.e. personal possessions, fittings, stock and machinery, are a further source of uncertainty. If buildings and contents present a challenge then people, who move and react, are even more difficult to assess. An earthquake affecting a downtown area of a city in business hours will affect many more people than one that occurs in the night. The environment and eco-systems are harder still to identify and subsequently evaluate what is at risk.

But vulnerability is perhaps the hardest to assess. How will a building react to a flood, an earthquake, a storm? Something that is robust to one hazard may be vulnerable to another. Indeed, what are the key attributes of a hazard that may give rise to loss and can we properly understand and capture them in order to assess the likely impact? The dynamics of a flood event provide a pertinent example. Damage may be linked to flood depth, flood duration, flow rate and water contamination – or a combination of all. Two neighbouring buildings can be affected differently: if one has a cellar and the other not; if one has flood protection and the other does not; if one is one metre higher than the other; if one has electrical sockets near the ground and the other does no; if one has wooden floors and the other concrete – the comparisons are numerous. Assessing potential economic loss introduces further challenges: how quickly can lost production be restarted and whether markets will be lost to producers with production shifting elsewhere either locally, regionally or globally.

An analysis of past events and their impacts can help to begin to understand these factors, but it is important that information about the event causing the damage, the exposure at risk and the consequent impact is presented in a form that is both consistent and also allows relationships and conclusions to be drawn. Experience learnt from historic events can be compared and augmented by theoretical data, for example design standards and engineering reports, to get a better understanding of the risk process.

There have been huge advances in recent years in all of the key areas of risk: hazard, exposure and vulnerability. The science base in Europe is a rich source of information and data. Initially there was often a culture clash between the needs of industry for practical useable information within tight timetables, perhaps just re-presenting what is known, compared to academia's focus on research and discovery with necessarily longer time horizons. With greater exposure and encouragement, including EU research grants promoting partnerships between the public and private sectors and academia, scientists and practitioners are now more attuned to working closely with each other. Similarly, methodologies have now been developed to categorise risk, model risk and present the results of risk assessments and analysis in forms that enable decision makers not only to decide the right course of action but also to provide transparency around the decision-making process.

There have been huge advances in recent years in all of the key areas of risk: hazard, exposure and vulnerability.

The process of risk understanding is not simple and, as we have seen, data are always partial and flawed. Initial models and analysis may be viewed as simplistic, particularly in retrospect. The discrepancies in data quality are sometimes asserted an excuse to delay risk analysis and modelling, but it is infinitely better to embark on a risk assessment and analysis process from the outset than wait until better data become available. A "1 in 100 event" could happen tomorrow, it is better to have tried, and commit resources to develop a greater understanding of the risks as far as possible now (and so identify key weaknesses and data gaps) than postpone action until better data are collected. For some industries, for example insurance, the necessity of increasingly enhanced risk understanding has been transformational, making the industry more professional, better engaged with science, more sustainable and so better able to serve its customers and pay their claims. Arguably it is the process of risk assessment rather than the model results themselves that have brought about this transformation.

Risk is subjective. Not only is there necessary uncertainty within risk assessment, there are also differences between how cultures, individuals and corporations both assess risk and react to it. A process of risk assessment and analysis can act as a catalyst to cast light upon opinions and assumptions that previously were implicit or unsaid. This brings a transparency to both assessments and decision-making: discussions can be focused upon identified assumptions, not just broad opinion (however well informed). This is not to diminish the role of the expert; expert opinion is always required to validate or challenge assumptions, but rather in such a way as to allow a wider and more systematic dissemination of their expertise. Indeed, properly run, a risk identification, assessment and analysis project can draw a range of stakeholders into the process, increasing ownership and acceptance.

Risk assessments and risk models cannot make decisions but they can inform policy.

Risk assessments and risk models cannot make decisions but they can inform policy. Policymakers may reject the advice of a risk model but if they do so, they should be able to articulate why. In practice no model includes all factors; decisions based upon broader considerations are often valid. But there is no doubt that encouraging and developing a culture of risk identification, risk understanding, risk assessment and risk modelling ultimately benefits society, making it more resilient and saving lives, livelihoods and property.

SUMMARY

Chapter 3

Understanding disaster risk: hazard related risk issues

Gerassimos A. Papadopoulos

Peter Salamon

Virginia Murray

Elisabeth Krausmann

3. Understanding disaster risk: hazard related risk issues

Section I
Geophysical risk: earthquakes, volcanic activity, tsunamis

The first step towards understanding, and eventually mitigating, the risk that geophysical risks pose to society is in reviewing when/where earthquakes, volcanic eruptions and tsunamis occurred in the past, and what was their impact. There is no doubt that the largest and most frequent destructive geophysical events occur in the Pacific rim where lithospheric subduction takes place at large extent. However, the Indian Ocean, the Caribbean Sea as well as the North East Atlantic and the Mediterranean region are also characterized by a high level of seismic, volcanic and tsunami activity due to subduction or other geodynamic processes. Even large earthquakes may cause disaster in their vicinity only, while volcanic eruptions may cause local to global impacts. The effects of tsunamis may scale from local to transoceanic. However, since large geophysical events tend to occur infrequently and may appear benign for generations, the risks may be underestimated. Therefore, the assessment of risks posed by earthquakes, volcanic eruptions and tsunamis first requires a good knowledge of the type, magnitude and frequency of past events. To this aim significant contributions come from geological evidence, which are revealed by methods applied in paleoseismology and similarly in paleovolcanic and paleotsunami studies. Today monitoring of geophysical phenomena is performed with well-developed instrumental recording networks extended at global, regional, national and local levels. However, there is important room for further improvement of monitoring systems and their geographic expansion in less well covered areas.

The assessment of risks posed by earthquakes, volcanic eruptions and tsunamis first requires a good knowledge of the type, magnitude and frequency of past events.

Understanding disaster risk requires the characterization of the physical, social and economic environment. These data provide information concerning the spatial distribution of populations as well as properties and their susceptibility to suffer damages or losses. The combination of exposure, vulnerability and hazard allows risk to be estimated, i.e. the potential for economic and human losses, which can support decision makers in the development and implementation of risk reduction strategies.

The hazard assessment related to geophysical events is based on event catalogues, both historical and instrumental. Such catalogues should be as complete and homogeneous as possible. However, this happens only for the recent instrumental period, while in the historical period the event record is quite incomplete. Deterministic and probabilistic approaches can be followed for the assessment of hazard. The deterministic method is based on the development of scenarios of future event occurrences taking into account extreme or other characteristic past events. The probabilistic method is based on the utilization of event catalogues covering as long a time interval as possible and requires the selection of complex mathematical formulations to account for uncertainties in event size, location, and time of occurrence. The outputs relate various levels of one or more parameters of the future event that may be observed at a site, and their corresponding exceedance probabilities in a given time period. Time-dependent and/or time-independent approaches are available depending on the data availability. However, in most regions of the world the existing information about large event occurrences in the past is limited and, therefore, the hazard assessment practice is dominated by time-independent approaches. The preparation of hazard maps is a good practice not only for decision makers but also for citizens who would like to know where the hazardous areas are situated and what types of hazards threaten their community.

Exposure and vulnerability are next crucial components for the assessment of disaster risks. By taking into account definitions of terms proposed by the United Nations Office for Disaster Risk Reduction the term exposure to a geophysical hazard may express people, property, systems or other elements present in geophysical hazard zones that are thereby subject to potential losses. As a consequence, the characteristics and circumstances of a community, system or asset (e.g. people, buildings, infrastructures) that make it susceptible to the damaging effects of a geophysical hazard is termed vulnerability. Empirical vulnerability functions can be derived either "directly" from regression on historical loss data, through the elicitation of expert opinion (heuristic), or analytically using numerical simulations. Vulnerability functions can also be derived "indirectly" from the combination of a fragility function and a damage-to-loss model. Therefore, risk assessment should combine hazard and vulnerability assessments and, if possible, an estimation of the economic value which is exposed to the hazardous event.

Rescue reports from past earthquakes indicate that over 90% of the successful rescues occurred within the first 24 to 48 hours. As regards tsunamis, a global statistical analysis concluded that about 80% of the victims occur within the first hour of wave propagation. Therefore, for saving lives during the catastrophic geophysical event or soon after its occurrence, of particular importance is the operation of systems for early warning or for rapid damage assessment combined with preparedness, immediate rescue operations and public awareness. If appropriate monitoring is in place, it may be possible to issue early warnings for different hazards and to provide short term forecasts of likely future activity. The assessment of event scenarios can play a critical role in the development of risk management and risk reduction measures, such as elaboration of emergency plans, development of infrastructure to support the affected regions, or risk awareness campaigns.

Investments in earthquake, volcano and tsunami monitoring, including local observatories, as well as in civil protection and risk mitigation actions have contributed to a reduction in fatalities due to geophysical events worldwide. However, although mechanisms for regional or global reporting of earthquakes and tsunamis has been established this is not the case for volcanic eruptions. Recently, the ARISTOTLE project (2016-2018) supported through a pilot project funded from EU budget aims to create a unified platform for global immediate reporting of potentially destructive geophysical and meteorological events to enable timely humanitarian response by The Emergency Response Coordination Centre.

Section II Hydrological risk: floods, landslides, wave action, storm surges and coastal flooding

Next to meteorological disasters, hydrological disasters cause significant socio-economic impacts worldwide. To improve the hydrological risk management a coordinated effort is needed to strengthen all components of the risk management cycle including prevention, preparedness, response and recovery.

Developing adequate hydrological risk maps is key for the short term (emergency response) as well as the long term planning (urban and rural development) to increase society's resilience to those risks. Flood hazard maps are calculated by assessing the probability of any particular area being flooded.

Developing adequate hydrological risk maps is key for the short term as well as the long term planning to increase society's resilience to those risks.

Usually, it is undertaken with respect to a particular level of flood; for example, the 0.01 Annual Exceedance Probability threshold. Flood risk takes the flood hazard and combines this with information on the potential damage to society, such as vulnerability and exposure of assets and populations in the floodplain. Approaches can be different depending on the temporal and spatial scales at which the flood hazard and risk assessment are applied, on the modelling tools and data available and on the type of flood hazard (e.g., if it is a fluvial, surface water, or coastal flood).

Landslides mapping is a challenge due to the extraordinary breadth of the spectrum of landslide phenomena. No single method exists to identify and map landslides and to ascertain landslide susceptibility and hazard. The most common forms of landslide mapping are (1) landslide inventories, (2) landslide susceptibility maps, which show the probability of spatial occurrence of slope failures, given a set of geo-environmental conditions, or (3) landslide hazard map, which is the probability that a landslide of a given magnitude will occur in a given period and in a given area.

Fully comprehensive hydrological risk maps require a great deal of data including long time series of events, and/or a chain of models and assessments that reflect our level of understanding of the complex physical processes controlling hydrological events. As all of these factors have related uncertainties, the risk maps also have associated uncertainties. It is therefore important that risk maps are in harmony with user needs and requirements, so that decision makers can understand and act upon the information provided.

Another key element for preparedness are forecasting and early warning systems that can be implemented at local through to continental and global scales. The predictability of hydrological systems varies because of the large number of non-linearities in these systems, the challenges in the observability of the state of the hydrological variables, the presence of outliers (rare occurrences), the variability of external forcing and the numerous interactions among processes across scales. Different types of floods are predictable with different time ranges. Flash floods driven by convective rainfall are notoriously challenging to predict ahead in time to produce effective early warnings, whereas slower developing floods in large catchments can be predicted several days ahead with the use of probabilistic flood forecasting systems. Real-time monitoring and rapid mapping of floods based on satellite data have been implemented at a variety of scales and by a number of different actors in order to detect flooding severity and extent in affected areas. For instance, the Copernicus Emergency Management Service - Mapping integrates satellite remote sensing and available in situ data to provide stakeholders with timely and accurate geospatial information in emergency situations and humanitarian crises. Furthermore, it also includes cross-border continental and global scale flood early warning systems that provide an important benefit to the hydrological risk management by complementing the national, regional and local capacities.

Early warning systems for landslides are based on reliable continuous monitoring of relevant indicators (e.g. displacements, rainfall, groundwater level) that are assumed to be precursory variables for triggering or reactivating landslides. When values for these indicators exceed predefined thresholds, alarms are transmitted directly to a chain of persons in charge of deciding the level of warning or/and emergency that must be transmitted to the relevant stakeholders, following a predefined process. Landslide early warning systems have greatly improved since the beginning of the 21st century because of the progress in electronics, communication and computer treatments for monitoring and imaging. In addition, the innovations of satellite technologies and ground remote sensing have greatly improved the capacity of remote imaging measurements vs in situ point measurements.

The majority of recent scientific studies indicate that hydrological risks will increase overall even for warming levels of 1.5°C. According to the IPCC it is very likely that the rate of global mean sea level rise during the 21st century will exceed the rate observed during 1970-2010 for all Representative Concentration Pathway scenarios. It is estimated that about 70% of the global coastlines are projected to experience a sea-level change within 20% of the global mean sea-level change. Along with the changes in climate and weather patterns, demography, land use, and other factors driving the hydrological risk are changing rapidly. The projections through the 21st century for Europe indicate that societal changes will lead to an even larger increase in the impacts from natural hazards than climate change impacts only. The uncertainty associated with all those factors requires the consideration of flexible adaptation pathways. No matter the sources of uncertainties, more needs to be done in hydrological risk management policy and practice to make our societies more resilient and to prepare for future changes.

Section III

Meteorological risk: extratropical storms, tropical cyclones, extreme temperatures

Climatological risk: droughts, wildfires

Biological risk: epidemics

In terms of meteorological risks, hazards from different types of storm systems as well as extremes of temperature are considered. There are two types of storm in meteorology; firstly the hazardous weather phenomena themselves (such as windstorms, rainstorms, snowstorms, thunderstorms and ice storms) and secondly the meteorological features in the atmosphere or storms systems which are responsible for the adverse weather. This includes tropical cyclones, extra-tropical cyclones and convective systems. Temperature extremes are rare high or low temperature events that may occur over a range of time and geographical scales. They usually occur because of a change in the weather pattern over a few days or several weeks.

Climatological risks include droughts and wildfires. Droughts result either from a shortfall in precipitation over an extended period of time, its inadequate timing compared to the needs of the vegetation cover, or from a negative water balance due to an increased potential evapotranspiration caused by high temperatures. Wildfires refer to fires affecting grasslands, shrub-lands and other non-forest land covers. Although they are mainly initiated by human actions, their intensity and the effects they cause are mainly driven by fuel condition and availability, vegetation structure and prevalent meteorological and topographic conditions, and so are termed a natural hazard.

An epidemic is the widespread, and often rapidly extending, occurrence of an infectious disease in a community or population at a particular time. A pandemic is the extension of an epidemic to many populations worldwide or over a very wide area, crossing many international boundaries and affecting a large number of people.

These hazards are all inter-related: they often interact with or influence one another. For example, prolonged droughts and heatwaves dry out fuels, and help create the conditions for uncontrollable wildfires.

With regards to storms, extra-tropical cyclones, tropical cyclones and convective storms can be distinguished from each other by their mechanism of development (growth), their structure, their geographic location, spatial scale and typical lifetime. Mitigation of the risk associated with specific storm systems involves the planning and execution of steps to limit damage to infrastructure and to reduce potential for loss of life prior to the event, and understanding the adverse conditions that are likely to be encountered after the event and acting to alleviate these. In such situations weather forecasting plays a key role. It is particularly important to understand how far into the future reliable forecasts can be made and in particular, how this varies with the type of storm system that is anticipated. For example, the potential for damaging winds from an extra-tropical cyclone may be foreseen further in advance than the lightning and flash flooding from a severe convective storm. Furthermore, consideration of when and how information about a potential hazard may best be presented is required to balance the need for public awareness against the potential for reducing public confidence through false alarms. Moreover, understanding impacts is also critical if we want to reduce harm to lives, livelihoods and health.

Temperature extremes usually occur because of a change in the weather pattern over a few days or a longer period such as several weeks. High or low temperature extremes that last for longer than 2-3 days are often referred to as heat- or cold-waves. Phenomena such as the North Atlantic Oscillation or the El Nino Southern Oscillation can be important in changing the probability of temperature and other climate extremes. Because of improvements in medium to long-range forecasting, it is becoming increasingly possible to predict the occurrence of temperature extremes and thus integrate predictions into early warning systems. Human induced climate change may well change the likelihood of high and low temperature extremes in the future which may have a number of impacts on society. Amongst a range of possible physical, socio-economic and environmental impacts of extreme temperatures, human health and safety is of particular concern. Building knowledge about human vulnerability to and probability of temperature extremes will assist with establishing general levels of risk associated with periods of extreme heat or cold now and in the future.

Measuring drought hazard includes estimating the location, duration, intensity and frequency of water deficits over land. Adequate drought risk management requires practitioners and policy makers to distinguish between different drought types as well as between drought, aridity, and water scarcity. While drought is triggered by climate variability (precipitation, temperature and atmospheric water demand), understanding river basin control, exposed assets, sectors and people and their vulnerabilities are essential for risk assessment.

While drought has long been mainly perceived as posing agricultural risks, it still remains a 'hidden' hazard in many other sectors. Drought-related impacts have been reported for many sectors (e.g. farming and livestock, public water supply, industries, power generation, commercial shipping, recreation, forestry, health, wildfires, ecosystems and biodiversity) and several studies have tried to link drought impacts to drought severity to assess drought risk. Clearly, drought-related impacts on health, ecosystems and water resources need to be considered. Since droughts are natural and cannot be prevented, societies need to adapt to the hazard by decreasing their vulnerabilities and by strengthening their resilience and adaptive capacities. Pro-active and efficient drought management therefore requires the design and implementation of national drought policies, detailed risk assessments, adequate early warning systems, and regionally adapted drought management plans respecting different contexts. In order to assess drought risk, region-specific hazard, exposure and vulnerability need to be analysed for different sectors. Early warning systems require different components of the hydrological cycle to be monitored at continental, national and local scales, as well as reliable forecasting.

Data analysis is a key component of assessing risk: systems are needed from the local to the global level given that these hazards frequently cross national boundaries.

Fire hazard can be derived as the combination of the presence of ignition sources, fuel availability and conditions for fire ignition and spread. Due to the many factors that affect fire risk, the issue of scale is highly relevant in the assessment and management of risk.

At local to national scales, assessment of wildfire risk is accompanied by mitigation measures aimed at reducing risk by increasing prevention and preparedness. At the supranational and global scales, assessment aims at reducing the negative impacts of wildfire by establishing international guidelines and agreements for best practice among the wildfire management organizations. The involvement of a large number of organizations in fire management, from national to local level, means that clear definition of authority, functions, tasks and responsibilities, together with an effective coordination of their inputs is essential.

Epidemics and pandemics, especially of severe emerging diseases, may occur suddenly, spread rapidly and inflict disruptive societal, economic and political impacts. An understanding of the triggers and impacts of epidemics and pandemics is essential to managing and mitigating their risk. While modern medicine and immunisation programmes have contributed substantially to decreasing the burden of some common infectious diseases, other rare, sporadic and outbreak-prone diseases have proven more difficult to manage. Globalisation has greatly enhanced the speed of disease spread across the world, necessitating a more comprehensive approach to event-based surveillance. It has required an improvement in standards of clinical practice, including infection prevention and control, as well as an understanding of the utility and limitations of other public health measures such as isolation, control of social mixing, and quarantine.

In order to mitigate the effects of all of these hazards, an understanding of their origin, behaviour and evolution is critical. Data analysis is a key component of assessing risk: systems are needed from the local to the global level given that these hazards frequently cross national boundaries. Early warning systems often entail the collection, integration and analysis of different types of information. It is therefore important to create and maintain harmonised and interoperable systems which facilitate the exchange of robust data, as multidisciplinary working and information-sharing is essential to reducing the impacts of these hazards.

Preparedness plans should be clear, flexible, and regularly tested in order to provide a timely, appropriate and effective response. Of critical importance is building the knowledge on how to strengthen community resilience to hazards. The generation of knowledge and evidence to address research gaps around risk will enable a shift towards a more pro-active approach as opposed to the prevailing reactive approach, and improve understanding of the effectiveness of responses in reducing any adverse outcomes.

Forecasting the onset or likely evolution of hazards is becoming more accurate through the use of new technologies; however there remains a degree of uncertainty which can be problematic for decision-makers as it can be difficult to strike the right balance between the risk of missing the opportunity for early warning and the risk of raising too many false alarms. Improvements in forecasting will be driven by the interaction and partnerships forged between different fields; for instance with droughts, cooperation between meteorological and hydrological services is necessary, while for epidemics, multidisciplinary working and information-sharing between health and other sectors such as animal health is fundamental to preventing their spread. Sensitive surveillance systems therefore form the backbone of risk management strategies. One of the global targets of the Sendai framework is to: 'Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030', which will help to reduce this uncertainty.

Section IV
Technological risk: chemical accidents, nuclear accidents, Natech

The last years set a record in the number of natural disasters accompanied by major damage to industrial facilities. These events demonstrated the potential for natural hazards, such as earthquakes, floods, storms, etc., to trigger fires, explosions and toxic or radioactive releases at installations that use or store hazardous substances. These so-called Natech accidents are a recurring but often overlooked feature in many natural-disaster situations. In addition, chemical and nuclear activities are an increasingly important source of risk due to more industrialization and urbanization.

Unfortunately, disaster risk reduction frameworks have not commonly addressed technological risks. The Sendai Framework for Disaster Risk Reduction recognizes the importance of technological hazards and promotes an all-hazards approach to disaster risk reduction. This includes hazardous situations arising from man-made activities due to human error, mechanical failure, and natural hazards.

The Sendai Framework for Disaster Risk Reduction recognizes the importance of technological hazards and promotes an all-hazards approach to disaster risk reduction.

Chemical accidents continue to occur relatively frequently in industrialized and developing countries alike, which raises questions as to the adequacy of current risk-reduction efforts. The causes underlying chemical accidents in current times are largely assumed to be systemic. Most chemical accidents today are caused by violations of well-known principles for chemicals risk management which has led to insufficient control measures.

From the forensic analysis of chemical-accident reports a number of underlying causes have emerged, one or several of which can affect a chemical installation to create conditions conducive to disaster. These causes include:

- A lack of visibility due to a lack of published statistics on accident frequency and a reporting bias towards high-consequence accidents which are a mere fraction of the many smaller chemical accidents occurring each week.
- The challenge to manage across boundaries where chemical and mechanical engineers commonly assigned to chemicals risk management have little training in human or organizational factors.
- A failure to learn lessons from past accidents and near misses.
- Economic pressure and a trend towards optimization which can undermine risk management when decisions are made without due consideration of their impacts on safety risks.
- Failure to apply risk-management knowledge by both individuals and organizations due to a lack of awareness and education, or inattention to inherent safety.
- Insufficient risk communication and disconnection from risk management due to the globalization of hazardous industries, which places a distance between corporate leaders and the sites they manage.
- Outsourcing of critical expertise or distribution of limited expertise over many sites, making it less accessible when needed.
- Governments commonly do not proactively engage in managing chemical-accident risks until after a serious accident, and accident management is focused on emergency preparedness and response rather than prevention.
- Complacency in government and industry due to the wrong perception that chemical accidents are no longer a threat, thereby causing a decrease in resources for enforce-

ment and risk management.

- Based on the identified accident causes, a number of areas for further study and experimentation to reduce chemical-accident risks should be explored, and it is recommended to:

- Motivate corporate and government leadership by exploring new models for risk governance, and promote a positive safety culture by fostering risk awareness. Enforcement will need a new strategy to drive industrial safety practice.

- Promote systematic accident reporting, data collection and exchange to raise awareness of the potential consequences of chemical accidents. This information should be used for learning lessons from accidents and near misses.

- Develop strategies to combat labour market deficiencies related to process-safety expertise.

- Create cheap and easy access to risk-management knowledge and tools, including to the risk-assessment competence urgently needed in all areas of the world.

- Build awareness of chemical risks and how to manage them in developing countries.

- Foster regional and international networks and collaboration on chemical accident risk management to create pressure and give developing countries easy access to expertise and technical support.
-

Accidents at nuclear facilities, regardless of the accident trigger, have the potential to cause disaster. In the European Union, a nuclear safety framework aims to ensure that people and the environment are protected from the harmful effects of ionizing radiation. The basis of this framework is the defence-in-depth approach, a key concept to reach an appropriate level of protection from nuclear risks, and an adequate safety culture.

After several major nuclear accidents, safety assessment methodologies have been continuously improved, and the design of a nuclear power plant follows a set of rules and practices that ensure a high safety level. At the design stage a set of accident conditions is identified that can result from different initiating events, and this set is examined using a conservative, deterministic safety assessment. This is complemented by a probabilistic safety assessment (PSA) which provides a methodological approach to identifying accident sequences that can follow from a wide range of initiating events, as well as to determining accident frequencies and consequences. The challenge is to make certain that the list of considered initiating events is complete.

Many different protective activities are at the basis of ensuring the safety of nuclear facilities, both during normal operation and in case of accidents. However, the nuclear industry still faces a number of challenges that need to be addressed. It is therefore recommended to:

- Further assess the impacts on the safety of nuclear activities of human and organizational factors (e.g. training, management of change, evolution of regulations and associated requirements, etc.), of ageing effects on nuclear facilities, and of financial concerns.

- Improve knowledge on the identification and modelling of natural hazards to support safety studies for nuclear facilities.

- Share good practices on emergency response at local, national and international level between nuclear and non-nuclear industrial activities to increase the efficiency of emergency-response plans.

- Promote research on the resilience of human organizations in the face of complex situations in nuclear and other areas with similar requirements.

Natech accidents are a technological "secondary effect" of natural hazards and have caused many major and long-term social, environmental and economic impacts. National and international initiatives have been launched to examine the specific aspects of Natech risk and to support its reduction.

The forensic analysis of Natech accident records has allowed the preparation of lessons learnt to be formulated that support the reduction of Natech risks across different triggering natural hazards. This includes the setting up of a dedicated Natech accident database to foster the easy and free sharing of accident data. Accident analyses also show that there is an increased risk of cascading effects during Natech accidents. In general, Natech risk reduction pays off, and several structural, as well as organizational accident prevention and consequence mitigation measures are available.

Studies on the status of Natech risk management in the EU and the OECD have highlighted deficiencies in existing safety legislation and the need to consider this risk more explicitly. Conventional technological risk-assessment methodologies need to be expanded to be applicable to Natech risk assessment and only a very few methodologies and tools are available for this purpose.

With respect to the effective reduction of Natech risks, several research and policy gaps still need to be closed in a collaborative effort between regulators, industry and academia. Public-private partnerships could be helpful in this context. More specifically, it is recommended that:

- Existing legislation that regulates hazardous industrial activities should be enforced. Where missing, legislation for reducing Natech risks should be developed and implemented.

- Risk communication on Natech risks should be improved between industry and all levels of government to ensure a free and effective flow of information that enables a realistic assessment of the associated risk to be made.

- Governments should promote and facilitate the sharing of Natech accident data for future Natech risk reduction.

- An inventory of best practices for Natech risk reduction should be set up and disseminated to all stakeholders.

- Research should focus on the development of Natech risk assessment methodologies and tools, as well as guidance on Natech risk management for industry and at the community level.

- Competent authorities and workers at hazardous installations should receive targeted training to be able to handle the challenges associated with Natech accidents.

- Further awareness-raising efforts are needed to help stakeholders recognize the vulnerability of hazardous industry to natural-hazard impact. In this context, the effects of climate change on natural-hazard frequencies and/or severities need to be factored in.

SUMMARY

Chapter 4

Communicating disaster risk

Kees F. Boersma

4. Communicating disaster risk

Disaster risk communication is a growing field in disaster science, and highly relevant for policy makers, practitioners and citizens.

Disaster risk communication aims to prevent and mitigate harm, prepare populations of vulnerable areas before a disaster strikes; and to validate, share, disseminate and combine information from various sources both at times of disasters and in the recovery phase. This chapter highlights the latest developments in disaster risk communication and shows that:

- there is a relation between how people perceive risk and the way they respond to risk communication. For people to react and respond to risk communication they need to feel a sense of urgency. Both cognitive (belief) and affective (feelings) factors are important predictors of attitudes towards risk communication;

- there is not a one size fits all in risk communication, as the local context (e.g. local cultures) and histories (e.g. previous experiences with disasters) matter. Having a clear view on the objectives of risk communication and the target group are key factors for a successful communication strategy. Framing, i.e. the way messages are constructed and delivered, is agenda setting as it defines what is or is seen as important in terms of risk perception and what is not.

- risk communication based on a one-way approach that tells people how to prepare and to respond to a disaster is rarely effective. Instead, a two-way mode of communication is more likely to lead to a situation in which people become more engaged in risk communication. This engagement increases the likelihood that someone can successfully cope with a situation of uncertainty.

We live in an information age, and digitalization influences the way we deal with disasters. Technological innovations have a profound influence on decision-making at times of uncertainty. The use of tools such as enterprise resource planning systems (ERPs), Global Positioning Systems (GPSs) and Radio Frequency based Identification (RFID) are potentially useful to overcome lack of information about the disaster, the affected population and areas. It can create improved situation awareness and lead potentially to better informed decision making. At the same time, these tools cannot be considered to be neutral. They provide more and 'bigger' data, leading to a new decision space, but the use of new technologies also creates new uncertainties and unintended consequences. It means that:

- decision making in disaster situations is increasingly relying on adequate information management. The increased digitalization asks for a reflexive attitude: we cannot take the (semi-automated) data collection, analyses and information sharing practices for granted. Instead, we need to critically access how the data was collected, analysed and shared;

- when there is a decision taken, there is power involved. Power can be visible and actual in the sense that one group in disaster management (e.g. those in charge of information and communication means) controls, dominates and manipulates the behaviour of others. It can also be more hidden and latent, for example if a certain framing of a disaster situation is used to enforce choices in the decision making process;

- unintended consequences of new technical tools include privacy violation and big data analytics used for mass surveillance. Privacy-by-design is an approach that allows designers and users to understand and anticipate how new technologies might have an impact on privacy. Multi-stakeholder involvement in impact assessments is a way to detect privacy issues as early as possible.

One of the challenges in crisis information management is the lack of reliable information systems and the coordinating mechanisms. Early warning systems (EWS) and risk communication enabled by information and communication technologies play a crucial role in both survival and recovery of populations affected by disasters. Various tools, including Geographic Information Systems (GIS) and Global Positioning Systems (GPS) can allow organizations and affected communities to gain information. Coordinating mechanisms including Incident Management Systems (IMS) have the potential to provide new ways of decision making. Last mile communication (LMC) in this respect is the capacity of the local community to take action in response to an early warning and refers to the adaptive capacities of local responding institutions. In the context of LMC:

- any EWS relies on effective communication systems, which comprises: 1) a robust, reliable and redundant infrastructure; 2) reliable and clear warning messages. The link between the critical communication infrastructure and the capacity of the affected population to respond relies on the coordinated participation and commitment of a wide variety of organizations and communities;

- the people centered approach to EWS is promising, and it implies that the focus is on risk; communication should be on how people understand risks, how they receive, create and spread information and how they become engaged in the adoption of protective actions. Social media can be an enabling force to encourage interaction and dialogues between formal responding organizations and affected populations, to overcome centralization in decision making;

- engagement will lead to more resilient communities since resilience must be understood as the community's ability to respond to, withstand, and recover from disaster situations. It is important to pay attention to the diversity of the population, for example in terms of age and mobility, as some are more vulnerable than others. Disasters also highlight the problem of information divide: some are more digital literate than others.

The complexity, scale and scope of disasters and new types of response including the use of new information and communication technologies have led to many new practices. The most important one is that of decentralized approaches and citizens' involvement. Digital technologies and social media platforms are innovative means of delivering better and actionable risk information to diverse publics. (Big) data mining techniques, crowd sourcing and 'people as sensors' are innovations that create new information ecosystems.

These innovations come with new challenges, including the verification of data, information overload, and the question how to engage the (diverse) population in data sharing. Innovative collaborative approaches in risk communication can:

- enable real time information through the use of social media platforms. The real time information of how a disaster evolves can increase (shared) situational awareness of the responders

- be a helpful means in reaching out to particular demographic groups. For example, younger people (millennials) are more likely to access social media information than traditional media as the main source of information. To trust the information is key and people, in particular the younger ones, are more likely to use multiple channels to cross reference and check the quality of the information. As the population in Europe becomes more diverse, multi-lingual and multi-cultural communication becomes important.

- provide messages that are culturally adapted to different local settings. For example, people will pay more attention to information about a type of disaster that has occurred before in their local environment, such as a flood.

The key challenges in risk communication lie not so much in developing new tools and innovations but in the implementation of social mechanisms by which such innovations become embedded in actual communication practices.

Adequate disaster risk communication and management requires the collaboration of a variety of stakeholders including policy makers, practitioners and citizens/inhabitants.

SUMMARY

Chapter 5

Managing disaster risk

Emily Wilkinson

5. Managing disaster risk

The holistic understanding of disaster risk management focuses on all four phases of disaster cycle.

The disaster management cycle commonly includes four types of measures needed to manage disasters: mitigation and preparedness (before a disaster), and response and recovery (after disaster). Depending on type of hazard efficient solutions come in place in different phases of DRM. The chapter on Managing Disaster Risk shows how could be scientific solutions implemented from legal, governance and financial aspect.

Risk information plays an important role in assessing the appropriateness of risk management activities/ strategies in anticipation of future risk conditions. The information requirements about risk and the kind of assessment applied may differ depending on the needs of the decision maker.

Disaster prevention expresses the concept and intention to avoid the potential adverse impacts of hazardous events. Mitigation relates to lessening or limiting the adverse impacts of a hazardous event once it occurs so that their scale or severity can be substantially lessened by various strategies and actions. Both measures aim at reducing vulnerability and exposure. Based on an analysis of the benefits arising from avoided losses, mitigation and prevention measures are widely considered more cost-effective than ex-post disaster interventions. However, data on indirect costs are not always readily available. Accounting for the benefits of any mitigation or prevention activities is also a challenge since a project may show the potential for benefits to a local area, while it may not show benefits nationally.

A common distinction is made between structural and non-structural measures. Structural measures are commonly derived from the engineering and physical sciences and include building codes and their enforcement and structural protection measures. Non-structural measures are generally described as 'soft methods' and include land-use planning and zoning measures.

Prevention and mitigation requires buy-in and action from across a variety of institutional bodies, political entities and stakeholders. The list of barriers and challenges for a greater ex-ante focus on mitigation and prevention can be summarised as: financial, political, technical and sociocultural. An increase in mitigation investment has occurred in some European countries, but the lack of public and therefore political interest in prevention and mitigation remains a problem. This is particularly evident in the context of land-use planning where mitigation and prevention are often seen as a burden, detrimental to short-term growth and development efforts. Engaging with communities at the local level can foster the adoption of risk reduction techniques by individuals engaged in that community.

Risk information plays an important role in assessing the appropriateness of risk management activities/ strategies in anticipation of future risk conditions.

In disaster preparedness and response planning there is a trend towards greater professionalization of emergency management across all Europe supported by evolution of legislative and regulatory frameworks.

Cooperation between regional, national and international communities is needed for preparedness and response planning given the complex and transboundary nature of modern day disasters. Ethics, legal and social issues are dimensions of disaster risk management that need to be addressed together with practical efforts to prepare and respond.

A move away from command-and-control approaches to managing disasters has opened up more opportunities for citizens to participate in preparedness and response. Strong bonds and trust within and between communities facilitates a more effective response in emergencies and can be harnessed by the authorities. Social media can also be used to enhance self-organised mobilisation and coordination of local resources, knowledge, and efforts for disaster preparedness and response.

Research and innovation in process-oriented approaches to ethics, legal and social issues will improve collective experimentation and collaborative design, to address issues as they emerge in the dynamic contexts of disaster preparedness and response.

Most disasters are difficult to predict in the short term, but research to quantify the impacts and to understand the recovery processes can help reduce the uncertainties associated with these events.

The recovery process is multidimensional, including economic, structural and psychosocial issues. It progresses at different rates for different people, businesses, institutions, and places affected by a disaster. Institutional fragmentation and short term planning can hinder recovery and often result in new risks being created. Thus, cross-scale and longer term strategies are needed in recovery, integrating different stakeholder perspectives and knowledge and coordinating across policy domains.

However, the recovery period is also an opportunity to facilitate economic, social, and physical development long after the disaster; and the promotion of social and intergenerational equity is a key principle for sustainable recovery.

Recovering from damage, losses and social disruption involves different types of activities. Categorizing the impact can provide focus for both planning and research activities. Common recovery sectors are: reconstruction of buildings, restoration of livelihoods, system repairs, human and social rehabilitation, and to restore society back to being a well-functioning community.

Recovery is more effective when it takes into account the interests of local populations, the cost involved and the future benefits. In recovery there is what is often referred to as a 'window of opportunity' to do things differently or 'build back better' to reduce the effects of future events.

A comprehensive strategy for disaster financing can moderate the impacts of natural hazard risks, speed up recovery and reconstruction, and harness knowledge and incentives for risk reduction. The private financial sector plays an important role, along with governments and civil society organizations, in designing innovative financial protection goals and sharing knowledge and capacity.

Insurance is the most common form of financial protection against risk of contingent losses. However, not all risks are insurable or covered by insurers. Climate change amplified natural hazard risks and rising vulnerability may make financial protection unaffordable for some people and business, and risks uninsurable in certain places. Insurance and other financial instruments can contribute to reducing disaster risk, if designed and implemented to this end. The reinsurance industry has driven the development of catastrophe risk analytics over the last 30 years, moving from a position where hazards mechanisms, their impacts and comparative risks were little understood to one where sophisticated integrated stochastic catastrophe models have become the norm in the industry.

Insurance can help dissuade policyholders from risky behaviour and incentivize risk reduction. Premiums and policy terms can be adjusted to reward good risks and penalise bad. Harnessing insurance for disaster risk reduction becomes particularly significant in the context of increased frequency of disaster events, larger economic exposure, rising vulnerability and climate change. Comprehensive strategies for risk financing help to shed light on impacts of disaster risk on economy and society, and facilitate identification of actions to minimize them. They allow decision makers to integrate adaptation and risk reduction with economic development and sustainable growth.

Public-private partnerships are a model for a joint bearing of responsibilities and efficient risk-sharing, capable of increasing insurance coverage and penetration, and guaranteeing a strong financial backing in view of uncertain probabilities of risk.

Chapter 6

Future challenges of disaster risk management

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6. Future challenges of disaster risk management

Introduction

The work of summarizing knowledge in disaster risk management is not only to communicate what we know. It is equally important to recognize what we don't know. Knowledge gaps, once identified, can be addressed by future research and development projects.

We've asked all lead authors and coordinating lead authors to critically look at their fields of expertise and identify the future challenges. Some relate to forming the right partnerships. Other challenges are about creating new knowledge - the classical research projects. A third category of challenges are about applying new knowledge, i.e. innovation. This bottom-up approach brought to light a wide spectrum of future challenges and emerging issues.

This chapter provides a summary of these key messages to various reader communities on the key challenges: all DRM actors, scientific experts, policymakers and practitioners.

ALL DRM ACTORS

Partnership

- The Sendai Framework signals a clear mandate to the science, technology, and innovation community to work together with governments in developing and sharing the knowledge and solutions needed to improve the resilience of communities. Stronger partnerships among disaster risk science, policy and practice are necessary. The benefits of collaboration are recognized throughout this book by all three communities.
- To tackle **systemic challenges** related to disaster risk reduction, a **transdisciplinary and holistic approach** in is necessary involving science, policy makers and practitioners. Resilience building needs to start at the level of **individual households and communities**. Partnerships are particularly useful for **building awareness** of available knowledge in the communities and build trust to exchange experiences, skills and knowledge.
- Scientists, practitioners and policy makers must work together to create **evidence-based narratives** for reconciling short- and long-term objectives of risk management, such as economic and social benefits, in order to enhance the business case for investment in prevention and mitigation.
- There is a need for **dedicated platforms** at local, regional, national and international level for science-policy-practice interface adapted to the local context. These platforms need to link and cooperate.

Knowledge

- Two key challenges in the scientific world are increased complexity and acceleration. Ever more science is produced and is available at a mouse-click. Ever more actors from different disciplines and policy areas are involved. For practitioners, policy makers and even for scientists themselves, the challenge now is to **find the relevant science**, from multiple disciplines, and make sense of it, for multiple policies.
- A fundamental building block is **understanding the risks** being faced; as well as making sense of

the relevant science this also requires enhancing the **use of local knowledge**.

- In such a complex policy area, **knowledge management** is essential. Relevant science must be synthesized for different target audiences. Science must be made available in useful format.

- Knowledge is not only the realm of scientists. Evidence in evidence-based policy making is much wider than scientific knowledge only. **Experience of practitioners** must be collected and fed back to scientists (for analysis) and policy makers.

Innovation

- The main areas for innovation lay in **risk governance**, including better communication among the communities, engagement and clear roles for all actors, and accountability and transparency throughout the system. The **interface between scientific knowledge and pragmatic decision making** must continuously be improved, e.g. through secondments of scientists into government and vice versa.

- Practitioners can benefit from many **unexploited research results**. Hurdles for innovation must be tackled through training, exercises, demonstrations, pilot projects, etc.

- **Vast amounts of data** are being produced from many sources – e.g. earth observation is expected to bring 10TB of free and open data per day. New approaches are needed for data handling and processing. Early warning systems (EWS) play an important role in saving life and property and should benefit from the **data revolution** combined with more robust modelling in order to help reduce the time required for the warning activation and improve the warning information.

SCIENTIFIC EXPERTS

Partnership

- **Synthesis of scientific knowledge** across disciplinary boundaries requires the development of networks where mutual learning can happen and trust can be built. It is important to be transparent on context, terminology, assumptions and limitations.

- To tackle **systemic challenges** related to disaster risk reduction, a **transdisciplinary and holistic approach** in science is necessary to integrate natural, social and health sciences with ICT, economics, engineering, legal and policy frameworks and operational practice. A shift from mono-disciplinary silos to transdisciplinary networks is required but challenged by differences in risk frames, objectives, terminology, methods and funding mechanism.

- Science needs to produce **coherent advice**, during emergencies and for long term risk management. **Pre-established mechanisms to access scientific experts** from all disciplines are necessary for effective risk governance. Scientist must be ready to engage with such mechanisms, and translate their expert knowledge for non-technical communities. For emergencies, **impact-based multi-hazard early warning systems** must be developed to assess the likely impact of any hazard on population, economy and society.

- **Partnerships should be effective**. Measuring the effectiveness of partnerships is a scientific challenge in itself. Social network analysis and other techniques should continuously monitor the effectiveness of partnerships, including their depth, reach and growth, connectivity to other networks, scientific innovation and impact on policy and practice.

Knowledge

- This report shows that a wealth of knowledge exists, but each discipline still has its own scientific challenges. For instance, **natural sciences** seek to improve modelling of bio-physical processes of the Earth and atmosphere to anticipate extreme events for early warning and under climate change. **Engineers** must keep improving standards, cost-benefit methods, green and gray prevention solutions, retrofitting and other engineering challenges. **Social scientists** should better understand decision making under uncertainty, improve risk communication theory, harness social networks and include ethical and legal issues. Measuring effective risk governance (including ethical and legal issues) is an outstanding challenge, as are assessing science-policy interfaces and metrics for the impact of science on DRR. **The information communication technology** (ICT) community must harness rapidly developing technology, including big data, artificial intelligence, and augmented reality for better human-machine interaction. **Economists** see further challenges in disaster financing, including loss estimations, cost-benefit methods and understanding economic recovery, given the diverse scales at which impacts are felt and potential problems created by external intervention for local economies post-disaster. **Health sciences** should be more involved in the DRM community, advancing their understanding of outbreaks and pandemics, health impacts of all hazards, but also advances in data collection.

- **Transdisciplinary research** is in its infancy and should be encouraged. The most difficult challenges in disaster risk management cannot be solved by a single discipline. Specific challenges identified in this report include better handling of **uncertainty**, a more coherent approach to **data** across disciplines (open data, big data, social data) balancing openness with privacy, development of science-based **standards and guidelines**, and development of **methodologies** for all-risk mapping and management.

- There is a clear need for more **systematic knowledge management**. Access to synthesised knowledge of other disciplines is important for scientists, practitioners and policy makers.

Innovation

- More innovation is needed in in-situ, sea-borne, air-borne and satellite sensors to increase the completeness and timeliness of **earth observation**. Scientists help develop better, cheaper and robust instrumentation, allowing pervasive deployment also in poorly monitored areas, which should yield the necessary data to drive new scientific developments. Similarly, scientists must develop and exploit social networks to gather **fine-grained socio-economic data** on vulnerability and resilience of people, communities, economies and societies. More **technological innovation** is necessary to enable "total conversation" among citizens and authorities.

- A comprehensive strategy for **disaster financing** can not only moderate the impacts of natural hazard risks, it can speed up recovery and reconstruction, and harness knowledge and incentives for risk reduction. More research is needed on how these incentives could work more effectively.

- To foster adoption by public authorities, technological innovations must be **tested and demonstrated** to end-users with clear criteria for evaluation. The policy-impact of innovations need to be measured and, if relevant, mechanisms for **institutionalizing innovations** are necessary. It is challenging to make **global solutions available at local level**.

- **Fostering innovation** involves all actors, including funding agencies, researchers, practitioners and policy makers.

POLICYMAKERS

Partnership

- **Continuity of partnerships** is particularly challenging. As interlocutors both on policy maker side (rotation) and scientific side (projects end, new projects start over) change often, there is a continuous learning curve. Establishing well-funded, long term partnerships may be beneficial.

- A partnership should first agree on the **principles of risk governance**. If risk tolerance and risk ownership are clear, science can contribute more easily with appropriate methods and appropriate thresholds for acceptable risks.

- There are two key challenges for the public sector: (1) obtaining timely advice during emergency management and (2) obtaining reliable advice for policy making. Both rely on **well-defined and sustainable science-policy interfaces** drawing from the best expertise available. Communication among the communities is particularly challenging, and should not be biased by skewed power relations.

- Participation of policy makers in existing partnerships should be encouraged. These include knowledge centres, alliances of research institutes, national DRR platforms, Community of Users, etc.

Knowledge

- More knowledge is needed on **integrated policy making** in the area of disaster risk reduction. A clear understanding of related policies, but also of legal, scientific and ethical aspects is required. Policy makers must both implement and shape regional and global frameworks (Sendai).

- The scientific community must **summarize and translate science** into policy language. The policy community must formulate long-term research challenges for the R&D community. This can help prioritize research funding.

Innovation

- **New approaches to risk governance must be tested**, including early warning and emergency management. The balance between national and European/regional systems must be optimized continuously, seeking to optimize cost-benefit, quality and effectiveness.

- A key challenge is to evaluate the (long-term) impact of science-based policies. There is a need for **quantifying the economic, social and humanitarian gains** of better incorporating science.

- New ways of **prioritizing research funding** should be sought based on proven needs of policy makers.

PRACTITIONERS

Partnership

- A key challenge for disaster risk reduction is to apply **global solutions to local problems**. Partnerships between scientists and practitioners can enable transfer of knowledge and practice necessary to implement available solutions. Scientists should be aware of the wide variety of social, legal, linguistic, physical and political contexts in which disaster risk management is practiced.

- Where possible, **trans-border agreements** should be put in place in advance, to foster joint exercise and prepare to face the real events. Such mechanisms can lead to harmonisation in preparedness and response planning.

- Preparedness planning should be comprehensive and involve multi-agency partnerships in order to make the transition from disaster management to risk management. The process should involve **collective action** by scientists, government, essential services, businesses, the media, other public, private and voluntary organisations and communities to help mitigate potential impacts. **Effective communication of risk**, considering power relations among actors, is an important challenge for scientists.

- **Existing Public Private Partnerships** and **Public Public Partnerships** show clear benefits in terms of efficient risk-sharing. Virtuous feedback loops lead to increased insurance coverage and penetration, investments in disaster risk reduction and innovative risk financing.

Knowledge

- Further research in **crisis management** is essential for practitioners. Developing new technology and infrastructure and improved models for **sensemaking** of chaotic situations is necessary to allocate scarce resources more effectively during a crisis.

- Development or implementation of **standards** (e.g. on data formats or protocols, such as the CAP protocol, but also on hazard and risk assessment methods) can improve interoperability of the crisis management actors. Scientists, practitioners and policy makers must collaborate to develop practical standards.

- Understanding of **direct and indirect costs** is crucial to selecting and investing in preventive measures, as well the stakeholders to be involved, their roles and responsibilities. The private financial sector plays an important role, along with governments and civil society organizations, in designing innovative financial protection goals and sharing knowledge and capacity.

- The opportunities and challenges that the crisis information systems and social media brings to development of disaster risk management foster a process that builds principles for action for communities of practice, creating a '**space of meaning**' with theories for action, social change and instruments for implementation.

Innovation

- **Training, exercises and education** are essential to transfer scientific knowledge to practitioners.

- The **Internet of Things** is expected to provide citizens and emergency authorities with information and knowledge in real time. This will allow for new tools to be developed for a more resilient society. A balance needs to be struck between surveillance and privacy concerns.

- It is necessary to develop well-trained **downstream components** in early warning systems, incorporate volunteered geographical information.

- Rather than generating innovative approaches, **embedding and diffusion of innovations** is the key area that both policy and practice must address. Strong bonds and trust within and between communities favours a more effective response in emergencies and can be harnessed by authorities. Social media can also be used to enhance self-organised mobilisation and coordination of local resources, knowledge, and efforts for disaster preparedness and response.

Conclusions for European research

The EU and in particular its successive Research Framework Programmes (FPs) have actively supported various scientific research projects that, step by step, have contributed to a better understanding of risks in all their dimensions. Multinational and interdisciplinary research in the field of natural and technological disasters has led to the development of innovative tools and methodologies to forecast and monitor natural and human-induced hazards. In addition, research efforts in support of risk and crisis management have largely contributed to the preparedness for, and the response to, major crises and therefore helped reduce the toll on human lives and economic assets.

Since the 7th Framework Programme and now Horizon 2020, the EU research has become more multidisciplinary and has promoted a systemic-risk approach. The report highlights how research projects have been instrumental in delivering a deeper insight into the complex interactions between the hazard element and the natural and the built environment. New research avenues will further address the multi-risk impacts of physical hazards (floods, droughts, forest fires, etc) and the cascading effects of those hazards in order to integrate this information into the overall assessments.

EU-funded demonstration projects and other instruments (e.g., Public-Private Partnerships) are supporting the development and the awareness of risk mitigation and adaptation approaches (e.g. ecosystem-based Disaster Risk Reduction), as well as demonstrating their added value in terms of co-benefits for local economies, social cohesion and the broader environment.

One of the priorities of the EU Action Plan for Disaster Risk Reduction is to foster green growth through promoting risk-proofed investments and building the capacity of local and national authorities and communities. Solution-driven research should help to explore how best to transform evolving challenges and problems into new opportunities and potential markets. Climate services, nature-based solutions for more resilient cities or territories and dynamic Earth observation are examples of promising sectors. A strong evidence base on the damage caused by disasters, the benefits of adaptation and mitigation measures, and the costs of inaction constitute key information that supports the science-policy interface and provides planners, designers, engineers and decision makers with appropriate tools for risk management.

Conclusions for UNISDR Science and Technology Roadmap

In response to a strong call in the Sendai Framework to "enhance the scientific and technical work on disaster risk reduction" (25(g)), the science and technology community, as well as other stakeholders, came together at the UN Office for Disaster Risk Reduction (UNISDR) Science and Technology Conference held 27- 29 January 2016 in Geneva. The conference produced a “Science and Technology Roadmap to Support the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030”, which includes expected scientific outcomes, actions, and deliverables under each of the four priority of actions of the Sendai Framework.

This report is a contribution to the Science and Technology Roadmap, and specifically addresses, from a European perspective, topic 1.1 “Assess and update the current state of data, scientific and local and indigenous knowledge and technical expertise availability on disaster risks reduction and fill the gaps with new knowledge.”

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