Cambridge Centre for Risk Studies

Scenario Best Practices

DEVELOPING SCENARIOS FOR DISASTER RISK REDUCTION

Centre for
Risk Studies

UNIVERSITY OF CAMBRIDGE
Judge Business School

THE LIGHTHILL RISK NETWORK

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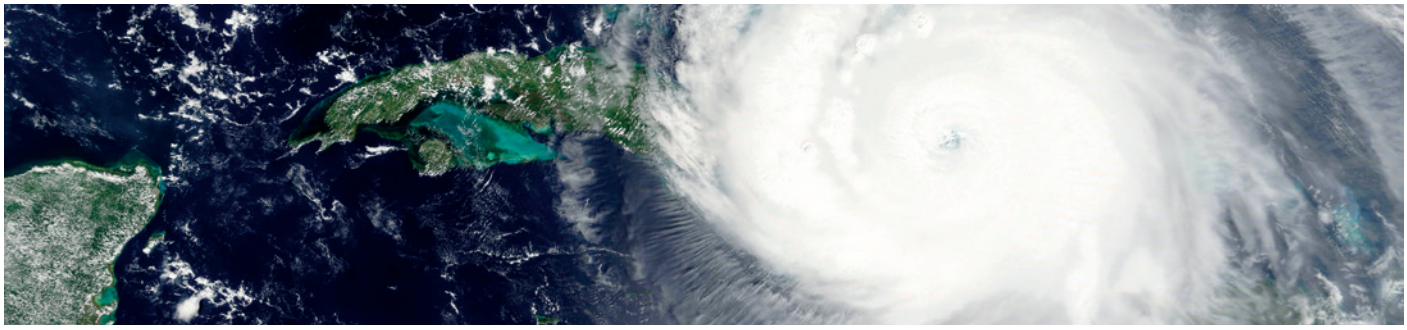


Mahawu volcano, Sulawesi, Indonesia

1. Introduction

1.1 The Global Risk Landscape

Major disasters are inflicting greater societal and economic impacts over time. Global population growth and economic development are driving an increase in the number of people, systems, and structures exposed to hazards, and the value of assets and investments with the potential for loss. Concurrently, climate change is forcing an increase in the frequency and magnitude of certain extreme weather events, as well as chronic trend risks including water stress, sea level rise, and environmental degradation. Novel and unprecedented anthropogenic threats (including technological, geopolitical, and financial hazards) also continue to emerge and intensify. These risks are connected with and exacerbated by environmental and social drivers, including climate change, globalisation, and the digitisation of economies. As a result, the global risk landscape is growing more complex and interconnected. The potential for disasters to cascade through systems is increasing, and the impacts of events have greater geographical and temporal reach. Existing and emerging risks present huge uncertainty about the future, and so demand new and improved strategies to reduce disaster risk and build resilience.

Disaster risk reduction (DRR) is the ambition and practice of reducing disaster risks through systematic efforts to address the causal factors of disasters, for example by reducing hazard exposure and the vulnerability of people and assets, environmental management, and improving preparedness. Thus, DRR incorporates management, mitigation, and preparedness disciplines, but also embodies sustainable development – which, to be achieved must reduce disaster risk. Conversely, unsound development practices increase disaster risk and the potential for loss.[1] DRR involves all dimensions of society, including various parts of the public sector at international to local levels, and the private sector. However, the DRR community often lack the tools and expertise to understand the potential impacts of disasters, and of the efficacy of decisions to address them. One means of addressing uncertainty about the future is using scenario analysis, which is now a widely advocated and implemented practice in this domain but remains a challenge to many stakeholders without experience in scenario development.

1. (UNISDR, n.d.)

Concepts in Disaster Risk and Resilience

Reducing disaster risk and building resilience is high on international development agendas, recognised by high-profile initiatives from local to global scales – namely the United Nations' Sendai Framework for Disaster Risk Reduction and Sustainable Development Goals, which share overlapping desirable outcomes towards resilience – and so involve a vast and diverse range of disciplines with often contrasting perspectives. Therefore, it is necessary to establishing working definitions of key concepts included in this report, as follows:

Disaster

A disaster is defined as a hazard event which seriously impacts the functioning of a community or a society due to its interaction with conditions of exposure, vulnerability, and capacity, leading to human, material, economic, and environmental losses and impacts.[2] The effects of a disaster can be immediate and localised, but are often prolonged and widespread, testing or exceeding the capacity of a society to cope using its own resources, and therefore requiring assistance from external sources.[3] That a disaster is defined by the exceedance of coping capacity implies the relatively infrequent occurrence of events of such severity in a given locality.[4] In this report, we consider disasters triggered by natural and anthropogenic hazards, and include both sudden-onset ('shock') events that emerge quickly or unexpectedly and slow-onset ('trend') phenomena that emerge gradually over time.

Disaster Risk Reduction

Disaster risk reduction (DRR) is a management practice aimed at preventing new risks, reducing existing risks, and managing residual risk. A long-term benefit of DRR can be the strengthening of resilience and reduction of disaster losses.[5] In recent decades, the global policy and research community has formulated multiple initiatives to continue reducing the impacts of disasters. Most recently, the Sendai Framework for Disaster Risk Reduction (2015-2030) builds on previous initiatives to set a development agenda with targets and priorities to reduce disaster risk.[6]

Disaster risk management (DRM) by definition aims to apply and operationalise the objectives of DRR, encompassing mitigation, preparedness, response, and recovery activities. However, the application of policies and strategies to further DRR is challenged by current social and economic developments which exacerbate the complexity and interconnectivity of the global risk landscape. Responding to these challenges and reducing disaster risk is the objective of disaster risk management (DRM), and requires a powerful and concerted effort from experts, practitioners, decision makers, and other stakeholders, including people, communities, and societies at risk, that comprise the DRM community.

1.2 Why Use Scenarios?

Scenarios are stories about how the future might develop, aimed to stimulate exploration, understanding, and discussion. Based on a coherent set of assumptions about key deterministic relationships and driving forces, scenarios describe plausible futures that are intended to be scrutinised and debated. In the context of risk, scenarios provide a tool to cope with uncertainty, especially in the case of risks that are not well understood or cannot be quantified or even identified. They provide a systematic method for exploring how a complex and diverse array of risks may impact a society; or in other words, how resilient these systems are to potential disruptions. Scenarios question whether organisations or communities can adapt to, and even capitalise on, future changes, and stress their existing capabilities to respond. This understanding can be applied to support and rationalise decision making about the future, and inform preparedness for, management, and mitigation of risks. Scenarios are valued for supporting creative thinking about plausible futures, rather than attempting to accurately predict individual outcomes.

2. (UNISDR 2017) **3.** (UNISDR 2017) **4.** (Davies and Davies 2018)
5. (UNISDR 2017) **6.** (UNISDR 2015)

Resilience

The concepts of risk and resilience are often conflated but are distinct approaches to address the threat of unexpected societal and economic impacts and losses from disasters.[7] In practice, DRM addresses specific risks, and primarily attempts to mitigate or alleviate disasters before they occur, while in contrast, resilience aims to improve the broader capability of a system to cope with uncertainty. A resilience approach accepts the possibility of disruptions to a system regardless of the respective cause, and so focuses on strengthening its ability to recover and adapt to new conditions.[8] Societal resilience largely depends on good decisions. Those affected by disasters will attempt to reconstruct and adapt their society and economy regardless of external involvement, but all stakeholders must take an active role to facilitate swift and successful recovery and adaptation.[9]

This work adopts the UNSIDR definition of resilience as: *"The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management".*[10]

Resilience is therefore pursued through adaptive processes that facilitate the ability of a social system to reorganise, change, and learn from disasters.[11] This implies that increasing resilience to disasters can be achieved by risk reduction, and indeed resilience is a key concept in DRR.[12] However, resilience is multi-faceted and has been diversely adapted to various uses and contexts. Therefore, its interpretation and usage is ambiguous and has been fiercely disputed.[13] Resilience *is* often more a policy buzzword than an actual operational paradigm, and it is often unclear how policy makers and practitioners can translate the main notions of resilience into practical implementation.[14] Nevertheless, in the context of disasters, the term is effective in conveying the idea that the impacts to society of future disasters can be alleviated by becoming more 'resilient'. Resilience portrays a sense of merit in the context of disasters, in a similar way that 'sustainability' implies environmental merit.[15]

7. (Linkov, Trump, and Keisler 2018) **8.** (Linkov, Trump, and Keisler 2018) **9.** (Zack 2010) **10.** (UNISDR 2017)
11. (Coetzee, Niekerk, and Raju 2016) **12.** (Davies and Davies 2018) **13.** (Alexander 2013) **14.** (Mens 2017) **15.** (Davies and Davies 2018)

Scenarios have the potential to enhance understanding and provide new perspectives to uncertainty about possible future disasters, and so may empower communities to plan for their future. They are increasingly used by practitioners, decision makers, and other stakeholders in the disaster risk management community to better understand the characteristics and consequences of unknown, uncertain, or unexpected future events, and support planning and decision-making strategies to address them.

A critical distinction is made between scenarios that examine emerging trends, which are of concern for long-term views of sustainable development; and those that consider disaster events, which trigger severe, acute impacts and human, physical, economic, and or environmental loss. This report is primarily written to address the latter, and on the design and uses of shock risk scenarios, which are increasingly in demand to overcome the challenges posed in today's and the future risk landscape.

1.3 Report Rationale and Intended Audience

This report intends to provide an accessible guide to scenario analysis and applications for the DRR community, to facilitate the understanding, communication, management, and mitigation of disaster risks. A practical framework is provided to assist practitioners engaging with scenario development.

Within the report, we explore key features of, and commonalities and differences between, disaster risk scenarios and their associated development methodologies, and suggest how and for whom they can be used effectively. As a variety of scenario use cases have unique requirements and maturity in the practice, development methodologies do vary, and caution is taken to avoid prescribing specific 'best practices'. However, we propose that there is a general process which can be adapted and modified for these various uses. By providing key criteria and considerations for scenarios in the form of a scenario development framework, we hope to equip the reader with the necessary tools and context to develop coherent, comprehensive, and intelligible scenarios, which therefore effectively fulfil their intended purpose.

This report provides recommendations for scenario development specific to disaster risk management, and has been published in parallel with another report[16] which similarly outlines best practices for scenario development specific to the insurance industry. The insurance industry is considered to be an important stakeholder in DRR, with the capability to transfer risk and build resilience. The industry has a rich expertise in risk assessment tools to price risk, and regularly employs scenarios that tend to be expert-driven, scientifically supported, and product oriented. In contrast, within the diverse community of disaster risk managers, scenarios often serve to explore and incorporate the culture and experience of various stakeholders in a more participatory approach, for which emphasis is often placed as much on what is learnt in the scenario process as the end result. Developing the two reports in parallel has provided valuable insight into the merits of contrasting scenario approaches and has informed the best practices advocated in both.

Report Aims

This report addresses three core questions to consider when engaging in scenario development:

- **Section 2** addresses 'what is a scenario?' and considers the diverse range of scenario types and objectives commonly seen within the DRR space.
- **Section 3** explores 'who are scenarios supporting in disaster risk reduction?' and outlines various user profiles and case studies of scenario development and application.
- **Section 4** answers 'how do I make a scenario?' and proposes a series of recommendations and considerations to be applied during the development of a scenario.

16. Report titled "Developing Scenarios for the Insurance Industry" (Cambridge Centre for Risk Studies, in collaboration with Lighthill Risk Network 2020)

1.4 A Framework for Scenario Development

We propose a framework for scenario development that defines eight core steps, outlined in Figure 1 and discussed in further detail in Section 4. This framework is intended as a point of reference to assist and ensure efficacy in the scenario process, rather than as a prescriptive method that must be followed absolutely.

Further, while it outlines a linear step-by-step structure for clarity, we encourage the scenario process to be an iterative one, in which stakeholder engagement provides opportunities for review and revision to ensure it succeeds in fulfilling its aims.

Figure 1: Scenario development framework for disaster risk reduction

Favelas in Rio De Janeiro, Brazil

2. Understanding Scenarios

1.1 What is a Scenario?

Scenarios are descriptions of plausible events that may occur in the future, leading to a particular set of outcomes. They are based on assumptions about key driving forces, interconnections, and relationships, and can capture the uncertainties and complexities of a system in a coherent manner.

Scenarios are not intended to comprehensively describe the future, but rather to highlight focal elements of different plausible futures and to highlight the key factors that will drive future developments. Sometimes the terms scenario, projection, and prediction (as well as others such as forecast and outlook) are used interchangeably, but while all are tools to investigate the future, each is nuanced in its meaning. A prediction can be defined as a subjective (probabilistic) statement that something *will* happen in the future, while a forecast is the most likely expected development.[17] In contrast, a projection is a (probabilistic) statement that something will happen under certain conditions, allowing for significant changes in the boundary conditions that might influence a prediction. A scenario-based projection is a hypothetical construct of what *could* possibly happen conditional upon fundamental assumptions.[18] These assumptions allow some of the uncertainties that complicate more exact statements on the future to be set aside for the benefit of a scenario exercise. The dimensions of what constitutes a plausible event changes as external forces shift. As a result, the scenario process is inherently an evolving one, and scenarios which have been developed and are relied upon should be maintained and updated regularly to reflect current conditions.

The Probable, Possible, and Plausible

When considering the future, we often add 'probability', 'possibility', or 'plausibility' qualifications to emphasise relevance or importance. These notions are implicitly defined, but often not clearly differentiated and so are confused. Is a plausible future also probable? Can one future be more plausible than another? Should any conceivably possible future be considered? Care should be taken in using these terms in the description of scenarios. Key elements of the three qualifiers are summarised here to establish a distinction between them, but this concern cannot be resolved by reducing each to a definition. Scenario users should note that these terms do not have any universal value, and so should ensure the distinction between them is made sufficiently clear to be useful.[19]

Probability refers to the concept of chance and likelihood, leading to an ordinal ranking of more or less likely futures. Any future is possible, but the selection of a probable or improbable scenario depends on the application.

Possibility is a claim of reality; whether a future is potentially realisable or not. It is a binary distinction but may be challenged by absolute (violation of established laws) or contingent (lack of realism) reasons.

Plausibility addresses the structure of an argument and places value on the credibility of a future, which can hold true even though the future itself may be factually fallacious. This is therefore a cognitive notion. Scenarios are challenged by the difference in interpretation of plausibility between developers and stakeholders.

Sometimes scenario development and scenario analysis (also called scenario 'thinking' or 'planning') are differentiated. Development means speculating about the uncertainty surrounding the future and envisaging different plausible future outcomes, or, in other words, to create 'memories of the future'.[20] Scenario development is the necessary foundation for scenario analysis, and the two are closely linked. Scenario analysis can be understood as the integration of scenarios into decision making. Here, we explore both the scenario development and analysis together as the scenario process and use the terms collectively.

17. (MacCracken 2001) **18.** (MacCracken 2001; Van Vuuren et al. 2012)
19. (Van der Helm 2006) **20.** (Mietzner and Reger 2005; Schwartz 2012)

2.2 Scenarios in Disaster Risk Reduction

Scenarios have long been employed in the sphere of disaster (risk) management, although methods and applications have evolved with developments of paradigms in disaster management and risk. The emergence of emergency planning in the 1970's marks a key advance in the application of scenarios for this purpose, coinciding with an increased focus on civil protection.[21] The emphasis was initially on human-induced, technological hazards, but later grew to accommodate natural hazards. This coincided with the emergence of vulnerability studies, which flourished in the 1970's following research of extreme natural hazard risks.[22] The use of scenarios dramatically increased in the years following. Their applications and popularity as a tool to support disaster risk understanding and decision making amidst uncertainty continues to expand to a widening range of practitioners.

The disaster risk management cycle (Figure 2) is helpful to distinguish the various disciplines in which scenarios are applied, each with unique requirements and challenges, and demanding different scenario techniques. These four stages are briefly described below.

Figure 2: The Disaster Risk Management Cycle

Response

Disaster response refers to action taken immediately before, during, or after a disaster, in order to save lives, meet the needs of affected societies, and prevent further damage.[23] Response can include a variety of reactive measures, such as evacuation, search and rescue, damage and needs assessments, and provision of aid to meet the basic subsistence and health demands of affected people. Considerable efforts are taken to plan response actions in the preparation phase, often using scenarios, so that communities and officials are better prepared to react in the case of a disaster. In addition to identifying individual and organisational reactions to a crisis, stakeholders must also consider and coordinate with other response efforts undertaken by others beyond their immediate association. Scenarios are utilised at all levels of planning to aid in resource planning and stakeholder communication exercises, developing greater confidence to react during a disaster event.

21. (Alexander 2015) **22.** (Alexander 2015) **23.** (Wood, Boruff, and Smith 2013)

Figure 3: Scenario development framework for the insurance industry

The Duplication of Efforts to Combat Disasters

In the past 15 years, there has been a rise in the number of humanitarian agencies, private organisations, governmental bodies, and independent stakeholders who are invested in responding to crisis events. However, some believe that these collective agencies have been unsuccessful in consistently delivering effective responses, due to lack of coordination between the parties and repetition of response efforts. This is a recognised problem within the community and should be addressed in all phases of the DRM cycle. To support a common and united disaster response effort, each phase must support communication, cooperation, coordination, and collaboration between agencies.[24] There are various formal and informal ways of achieving this dialogue, and users are encouraged to follow whichever methodology best suits their interests. Within this report, we highlight participatory scenario planning as being a potential approach to address this concern.

Recovery

Recovery is the complex process of returning physical, social, economic, cultural, and environmental systems to their pre-disaster state or to a new stable norm.[25] The process strives for communities to return to *their* 'normal' quickly and successfully; however, what is deemed normal differs between individuals, communities, nations, and other groups. Further, recovery efforts must manage a balance between recovery as quick as is possible, and recovering, or adapting, to an improved level of resilience, which is likely to require more time and resource than a return to the previous state. Like the other disaster phases, affected communities must be take ownership of this process, to build the inherent capacity and local empowerment needed for a successful recovery.[26]

Recovery includes returning displaced populations to their homes, restoring or reinstating critical and nonessential public services, and enabling economic functionality. Dependent on the socioeconomic conditions prior to the event, the severity of disaster impacts, and the adequacy and speed of governance and finance, recovery can take an extended period of time to complete or may never be achieved at all.

24. (Martin, Nolte, and Vitolo 2016; Kopinak 2013) **25.** (FitzGerald et al. 2010) **26.** (FitzGerald et al. 2010)

2010 Haiti Earthquake Recovery

The recovery effort in Haiti following the January 2010 earthquake, which killed over 300,000 people and destroyed hundreds of thousands of homes, is yet to be completed. Nearly a decade later, residents remained displaced in some districts, and the economy had yet to return to its pre-earthquake condition.[27] Therefore, the disaster may be considered to be not yet over, as society has not returned or adapted to a new stable state.[28]

In contrast, the Maule earthquake that shook Chile a month later, in February 2010, demonstrated a deliberate approach to recovery, balancing speed and quality to achieve a successful recovery. The disaster damaged or destroyed some 370,000 houses, and while residents and local businesses demanded restoration of their lives as quickly as possible, the government showed strong leadership in implementing initiatives to improve resilience. Within two years, recovery was well underway, and 54% of homes had been repaired or rebuilt, with a further 30% under construction.[29]

Downtown Port-au-Prince following the 2010 Haiti Earthquake

Following an initial response after an event, the years following require significant resources, but as recovery slips down the policy agenda, too often recovery needs are not sufficiently met.[30] Recovery is perhaps the most complex component of the disaster cycle, due to its difficulty to measure, with a compounding range of controlling variables producing unique situations.[31] Scenarios can play a valuable role in understanding recovery, when planning for a disaster before the event or in the immediate aftermath as efforts transition from response to recovery, providing an opportunity for practitioners to experiment with different strategies amidst a range of possible outcomes. Fictional scenarios allow creative thinking to inform decisions while putting aside the constraints of politics and emotions, which may require careful negotiation in difficult post-disaster situations. This can lead to more productive and wide-ranging planning discussions.

Mitigation

Mitigation refers to the elimination or reduction of hazard impacts. The occurrence and severity of negative impacts vary depending on the hazard exposure and vulnerability of the society, and mitigation measures commonly concentrate on reducing fatalities, economic loss, and environmental degradation.[32] Mitigation measures are proactive and are broadly categorised as structural initiatives (such as protective barriers or earthquake-resistant buildings) or non-structural initiatives (for example, land zoning to prevent building in hazardous areas, such as on a flood plain or at the foot of an unstable slope). Risk reduction measures consistently evolve in response to changing hazards, vulnerabilities, and community needs. Increasing focus has been placed on ensuring disaster mitigation is a comprehensive, multi-disciplinary, and holistic process, and that a community's needs are considered and prioritised. Specifically, mitigation must consider the culture, fragilities, and capacities of all stakeholders, and be inclusive of their various requirements – scenarios provide a tool to explore measures that satisfy these various demands to reduce disaster impacts.[33] They are especially important when communicating mitigation proposals, which may not have immediately obvious benefits to individual stakeholders. Scenarios are effective in providing a contextually relevant platform to discuss such topics, making them relatable and tangible to the stakeholders involved.

Eruption early warning system at the Cotopaxi volcano in Ecuador

27. (Dieu-Nalio 2018) **28.** (Speiser 2018) **29.** (Platt and So 2017)
30. (Birnbaum 2008; FitzGerald et al. 2010) **31.** (Chang 2010)
32. (Dwiningrum 2017) **33.** (Dwiningrum 2017)

Preparedness

Disaster preparedness is the ex-ante actioning of knowledge and capabilities to anticipate and alleviate the impacts of a disaster. This typically requires an understanding current and future risks; and manifests by strengthening the ability of disaster responders. Resource and logistical planning are a primary mechanism to increase responders' capacity and can range from ensuring sufficient infrastructure and services to fulfil fundamental needs (i.e. food, water, shelter, etc.), to developing early warning systems and evacuation plans, and training response personnel to know their roles and act effectively in an event. Agencies benefit from coordinating with one another to ensure response efficiency. The ability to prepare for a disaster is highly dependent on the characteristics of a disaster risk, and the state of associated knowledge – it is difficult to anticipate for an unknown or poorly understood threat. As a result, societies are usually better prepared for events that have been previously experienced in living history and are less prepared for emerging risks for which knowledge and preparedness capabilities are limited. Scenarios are used to creatively explore plausible disaster impacts, from probable to remotely possible, catastrophic worst cases, and provide tangible pseudo experiences which people can consider and plan for such futures.

2.3 The Benefits of Scenarios

The common primary objectives of disaster scenarios can be summarised with a number of general aims, for all phases of the disaster risk management cycle. A scenario process should address at least a few of these aims concurrently.

Improve Understanding of Risks

Fundamentally, scenarios are used to better understand the various dimensions of a risk, including the hazard, exposures, and vulnerabilities of the concerned systems, and explore the range of plausible resulting consequences. Some risks are known to exist, but are difficult to articulate, in terms of their likelihood, timeline, magnitude, and their potential scope, scale, and severity of impacts. Extreme and highly unlikely events (or 'tail risks') are particularly difficult to understand, with limited historical precedents to learn from, and are inherently difficult to predict. Scenarios offer an agent to articulate and improve familiarity with possible futures, and perhaps make them plausible to someone who has not previously considered such an event. These scenarios assist in answering the hypothetical question "what if?" and provide a reference point to build from.

Explore Emerging Futures

In addition to known risks, whether well understood or not, uncertain, emerging risks must be considered in planning efforts. An emerging risk is a new risk, changing risk, or novel combination of risks for which the broad impacts, costs and optimal management strategies are not yet well understood. The term is frequently used in enterprise risk management (ERM) by organisations, such as insurers, in the private sector, and describes systemic threats that arise as our global systems rapidly evolve. Environmental risks are not typically considered to be emerging, but are changing in response to amplifying external global drivers, such as climate change, economic development, and new technologies. The growing interconnectivity between geographies and socioeconomic systems is affecting the dynamics of environmental hazards and human vulnerabilities, and this growing complexity gives rise to emerging risks from novel sources. A 'multi-threat' approach is critical to understand the hidden and cascading impacts beyond the expected – for example, the 2011 Tohoku earthquake triggered a tsunami that caused the meltdown of the Fukushima Daiichi nuclear reactor[34]. Scenarios provide a platform to imagine and develop hypothetical events and consequences, exploring plausible futures for which there is no representative historical precedent. This provides a gauge of the potential hazard severity or scale, and what management and mitigating measures could be taken to address them.

Critical damage to reactors at the Fukushima Daiichi nuclear power plant following the Tohoku earthquake in 2011 (Photo: Flickr; naturalflow)

34. (Zastrow 2019)

Address Uncertainty

Scenarios expand understanding of a range of plausible outcomes relating to disasters, each supported by a defining sequence of events. Humans inherently expect that change will occur gradually and that the future will reflect the past. By generating deeper insight into the underlying drivers of change, scenarios may demonstrate how and why changes could develop quickly and otherwise unexpectedly, and which drivers do or do not have the ability to cause consequential change.[35]

Deep uncertainty exists when the various parties involved in a decision do not know, or cannot agree on, the system in question and its boundaries, the probability distributions of the inputs to these models, or the consequences of interest and their relative importance. Decisions which adapt over time in response to dynamic interactions with the system cannot be considered independently.[36] Deep uncertainties persist for a myriad of external drivers of global change and their impacts. Further, in addition to these environmental conditions, societal perspectives and preferences may also change over time, including stakeholders' interests and their evaluation of plans. As the future unfolds, plans are adapted to developments, so decisions are part of the storyline and an essential component of uncertainty.[37]

Systems Thinking

The capability to capture interconnectivities between complex systems, or 'system of systems', is critical to scenario planning. Systems thinking is a holistic approach to address complex interconnections and causal relationships, rather than on snapshots and independent aspects, of a problem. Given the abundance of resources on this topic, only a brief overview is provided here, with an emphasis on the importance of wholly understanding systems when using scenarios. The approach exposes that which is not immediately obvious, providing a lens to detect underlying controlling forces and relationships between individual components, to understand the entirety of a system. The iceberg analogy[38] (Figure 4) is a useful way to illustrate systems thinking and enable practitioners to appreciate the deeper perspective. As humans, we typically notice events in the world around us (the 'tip' of the iceberg) in a reactive and counteractive mode, only seeing a small part of the underlying dynamics. Only when we look below the (water) surface for patterns of behaviour can the event be better understood with scenarios that explore how interconnectivities may control the future. Delving further into understanding these dynamics at a structural level enables exploration of the structural level of various risks facing an organisation.[39]

Supporting Decision Making

Scenarios can be highly effective tools in support of decision making in DRM, offering a creative and structured mechanism to test and validate decisions in a scenario planning process. When practitioners make decisions about disaster risks before or after an event, they must be proactive in anticipating the evolution of a situation and use this information to decide on measures to address it. Scenarios facilitate discussion on how risks can be planned for and be managed or mitigated effectively with robust decisions and strategies. There are often multiple stakeholders involved in the response and recovery process, requiring individuals to consider both themselves and others. Scenarios can be used in planning exercises to identify the various stakeholders, and coordinate response efforts across multiple parties. Further, decision makers must factor in the associated risks on the belief of a certain set of assumptions, the validity of which scenarios test.

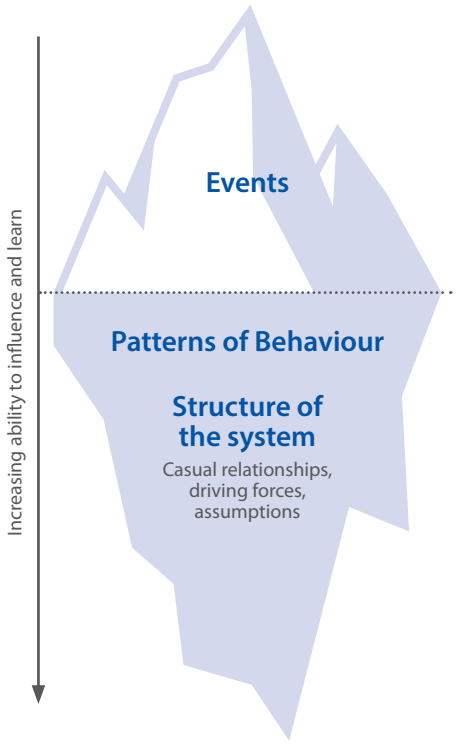


Figure 4: Systems thinking – the iceberg analogy (adapted from Senge, 1990; Van der Merwe, 2008)

35. (Roxburgh 2009) **36.** (Kwakkel, Walker, and Haasnoot 2016; Hallegatte et al. 2012)
37. (Haasnoot et al. 2013) **38.** (Kauffman 1980) **39.** (Van der Merwe 2008)

Robust Decision Making

Innovative analytical approaches[40] of 'decision making under deep uncertainty' are emerging to cope with uncertainty, and to help decision makers evaluate robust and adaptive management strategies. They help to build a consensus between stakeholders with different values, priorities, and solutions, who can agree on a decision for very different reasons.[41] The process reveals future threats, as well as opportunities, confronting each plan. This paradigm relies on exploratory modelling, typically involving scenario approaches that harness speculation and imagination to consider 'unknown unknowns'.[42]

There is an emerging consensus that deep uncertainty in a complex system must be addressed by making robust decisions. Robust decision making (RDM)[43] is one example of a defined approach for analysing deep uncertainty, which uses iterative, model-based scenario analysis.

The RDM methodology helps decision makers to identify and improve robust strategies by testing them against a very large exploratory scenario set (of hundreds of possible futures) to reveal their strengths and limitations. Statistical analyses of model iterations identify the key conditions under which strategies fail to satisfy their objectives. RDM also has a participatory component, with stakeholder deliberation used to define (un)desirable outcomes, and to rule out implausible scenarios.[44]

Robust strategies will satisfy decision makers' objectives in many scenarios, rather than being optimal in any single future.[45] In other words, they are 'good enough', rather than optimal options, aiming to minimise regret rather than maximise expected utility. RDM also helps to compare strategies along other dimensions such as cost, feasibility, and social acceptability.[46]

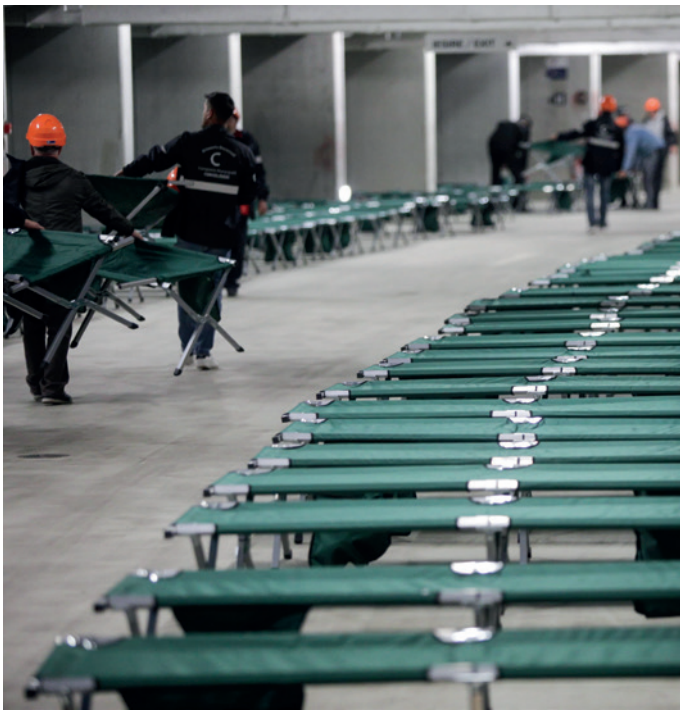
RDM has been widely applied to explore where deep uncertainty exists, including in the domains of climate change[47] and risk and resource management[48]. An important consideration of RDM is that it requires large amounts of quantitative information and a high degree of expert knowledge.

Aid Communication

Scenarios are an effective communication tool, facilitating the sharing of ideas, risks, and responses. There are a broad range of stakeholders who should be involved in discussions concerning DRM, and each brings their own expertise and experience. Well-crafted scenarios enable discussions between stakeholders, providing a communal point of reference that everyone can access and reflect on. Scenarios are especially valuable when discussing abstract ideas, or complex risks, as they provide examples and context to the issue, ensuring a consistent interpretation and understanding. Communication may occur formally during the distribution process, or more informally during the development and research phase.

Resource Allocation

Scenarios assist the DRR community in identifying and testing what and where finite resources can most effectively be allocated, through a cost-benefit analysis of different measures to address risk. Scenarios provide a greater appreciation of the direct and indirect future impacts of decision choices made in the present. For example, where to allocate personnel and prioritise aid in the immediate disaster response phase – to victims most severely affected, or most accessible, or most vulnerable according to given criteria ? – or how to allocate a public budget designated to rebuild in the recovery phase – to rapid rebuilding of homes or critical services, or towards reinvigorating the economy? Scenarios can be a valuable means of visualising these decisions and balancing hypothetical alternatives.



40. See (Haasnoot et al. 2013; Kwakkel, Walker, and Haasnoot 2016) for discussions of various approaches to support decision making under deep uncertainty
41. (Tuck 2016) **42.** (Olabisi 2017) **43.** See (RAND Corporation 2019) for detailed use cases **44.** (Olabisi 2017) **45.** (Rozenberg et al. 2017)
46. (Rozenberg et al. 2017; R. J. Lempert et al. 2013) **47.** (R. J. Lempert, Popper, and Bankes 2003; R. Lempert 2011)
48. e.g. (Sayers, Galloway, and Hall 2012; Beven and Alcock 2012; Popper et al. 2009)

Identify Biases

Scenarios provide a platform to identify potential (dis)inclinations or partialities that individuals and organisations have towards certain situations and decisions. Taking a broad set of scenarios mitigates well known behavioural effects like confirmation and availability biases (See Section 4.3). Such an approach also allows for alternative responses to be compared to a baseline. By setting these processes up in advance, decision makers can be mindful of these issues and take proactive measures to ensure that the process remains objective. This yields a systemic benefit that is realised over time.

2.4 Types of scenario

Scenario design and development processes can be commonly distinguished and classified, based on the development process, their purpose, or certain characteristics.[49] In practice, these typologies are rarely binary or independent, and instead can be imagined as a multi-dimensional matrix with unique outcomes.

This section proposes a series of distinctions which are commonly used in scenario development. We encourage readers to consider them as they construct scenarios in the context of their aims, within the process of 'Framing the Scenario(s)' (Step 3 in the Scenario Development Framework).

Trend Risks Versus Shock Risks

Scenarios can be developed to consider either sudden-onset hazards that emerge quickly or unexpectedly, or slow-onset, trend phenomena that take a long time to produce emergency conditions. The type of hazard dictates how the scenario is developed and how it may be used.

Sudden-onset shocks are abrupt events that trigger impacts that materialise rapidly and interact with conditions of exposure and vulnerability to result in a disaster. The focus of these scenarios is to identify and express events which might shock a community and cause human, material, economic, and or environmental impacts and loss. Typically, these impacts require immediate attention in the response phase of DRM. Examples of sudden-onset hazards include natural hazards such as earthquakes, floods, or storms; or human-induced hazards such as civil conflict or a disease epidemic. The scope of this report focuses predominantly on scenarios to address such disaster events.

In contrast to shock events, slow-onset, trend risks are of concern for holistic risk reduction, mitigation, and adaption planning, within a broader agenda of sustainable development. This requires users to consider temporality and identify both short-term signals and long-term impacts. The latter are likely to be less noticeable than short-term events, as changes materialise gradually over a prolonged period, although early warning signals do exist if you know where to look. If effective action is taken, there is the benefit of having enough time to determine the best method to mitigate or alleviate the risk. An example of a trend risk is climate change, which presents physical risks from environmental change as well as transition risks as society evolves towards a low-carbon economy.

49. E.g. (Mietzner and Reger 2005; Henrichs et al. 2010; Van Vuuren et al. 2012)

Climate Change: Driving Shock and Trend Risks

Climate change is increasing physical risks around the world. These risks include both chronic trends as average climatic conditions evolve, such as sea level rise, rising temperatures, and water stress; and acute shocks, as certain extreme weather events – including extreme temperatures (heat and cold waves), floods, storms, and drought – become more likely and more severe over time.

There is an emerging research field addressing the influence of human activity on individual extreme events. Today, there is overwhelming evidence that the likelihoods of extremes have been affected by human-driven climate change.[50] The growing field of 'extreme event attribution' is critical in establishing public awareness of climate change, because of the power it has to link the seemingly abstract concept of global climate with our own tangible experiences of the weather. Extreme event attribution therefore plays a key role in stimulating management, mitigation, and adaption of climate change risks.

The future of physical risks related to climate change remains highly uncertain, since short-term, extreme weather shocks are highly volatile and so difficult to forecast on medium- and long-term time horizons with scientific modelling. Scenario analysis is a critical tool to address such uncertainty, through the exploration of a range of plausible futures without the requirement to forecast the most probable future outcome.

Exploratory Versus Normative

An important distinction concerns the purpose of scenario development. Scenarios range on a continuum between exploratory, with the purpose of educating and expanding awareness of possible futures, to normative, with a primary aim to facilitate decision making. Often, the goal is to concurrently balance exploratory and decision-based functions.

Exploratory efforts ask, '*what if?*', as a helpful way to create a 'future memory'.[51] This approach explores a wide and contrasting range of plausible futures as a function of diverging assumptions (in other words questioning '*what would happen if this happens?*'), with the aim of widening the scope of options considered by users and stimulating imagination and creative thinking about the future. The focus here is on learning about the process under analysis, raising awareness, developing a descriptive assessment of plausible futures, and taking a specified issue or environment as the subject of analysis.[52] Exploratory scenarios often apply a forecasting approach, defining scenarios on the basis of a set of imposed rules defined from the base year onwards.[53]

In contrast, normative scenarios primarily ask, '*what for?*'. To utilise such a scenario for decision making, a more narrowly defined set of criteria and objectives must be explicitly defined.[54] A normative approach typically uses scenarios that are formulated in technical, quantitative terms (and thus have less emphasis on narrative) so that the paths to desirable, or undesirable, futures can be analysed. The intention is to evaluate the impact of a set of variants concerning specific interventions (behaviours and decisions) relative to a baseline, based on some form of valuation.[55] Such efforts tend to focus on delivering a product, in the form of a specific alternative to address a problem, or an advising tool for evaluating alternatives.[56] A normative approach can be more easily combined with a backcasting approach (as opposed to forecasting), defining scenario pathways only after first describing the end-points and reasons back from these end-points, and exploring short-term decisions to make these changes happen.[57]

50. See (Carbon Brief 2019) for a catalogue of over 230 peer-reviewed studies of extreme event attribution
51. (Tourki, Keisler, and Linkov 2013) **52.** (Riddell et al. 2018; Tourki, Keisler, and Linkov 2013) **53.** (Van Vuuren et al. 2012)
54. (Birkmann et al. 2015) **55.** (Henrichs et al. 2010; Tourki, Keisler, and Linkov 2013) **56.** (Tourki, Keisler, and Linkov 2013)
57. (Robinson 1990; Dreborg 1996)

Participatory Versus Expert-Driven

Another divergence in scenario design concerns who 'owns' the process, with a key distinction made between top-down, expert-driven (or 'analytical') approaches and bottom-up, participatory approaches. Both have advantages and disadvantages, and each may serve different purposes, although they are not necessarily discrete, with effective scenarios often including elements of both. We emphasise the importance of participation in the scenario process, incorporating the needs, values, and experience of individuals and communities at risk in addition to the knowledge of various other 'expert' (or other) stakeholders.

Expert-driven approaches have the objective of providing rigorous descriptions of plausible futures, including details that are well supported by available science.[58] Such approaches are oriented towards decision makers, and as a result tend to neglect other stakeholders. They are analytical in approach and allow for exploration of large-scale phenomena which would not be possible using participatory approaches.

In a participatory approach, scenario developers work together with stakeholders, namely the people potentially affected by scenario outcomes, rather than delivering scenarios as a top-down means of education. Participation targets and integrates stakeholder needs and values, and while scientific and technical knowledge remains important, such approaches makes use of cultural perspectives, knowledge, and experience beyond the involved experts to dissect complex issues. No group knows everything, and each will learn from others through the scenarios. Effective communication of scenario information is much easier than accurate communication of technical information (such as probabilistic risk). Such diverse engagement is effective in developing community understanding and investment in decision making, builds trust, and encourages broader acceptance of the ultimate scenario outcomes.[59] Participatory approaches enable scenario developers to understand, examine, and discuss the links between phenomena at different scales – for example how global or sub-national trends relate to the vulnerability in specific regions or municipalities.[60]

Scientific and technological developments have driven an increasing role of technology and expertise in scenario approaches but demands for improved participation and accountability; and criticism of technical expertise, have also grown.

Further distinctions can be made, aligning with exploratory or normative, and participatory or expert-driven approaches, as follows:

1.4.1.1 Intuitive Versus Formal Processes

Process design refers to how scenarios are developed, or their methodological aspects, ranging from intuitive to formal approaches. Intuitive processes focus on qualitative knowledge and are participatory, incorporating many perspectives from a wide range of backgrounds and knowledge bases.[61] In contrast, formal processes regard scenario development as an analytical and systematic exercise, and so depend on quantitative inputs to build conceptual or computational models. They are exclusive in the way they only incorporate views from specific stakeholders or areas of expertise.[62]

1.4.1.2 Process Versus Product Orientation

The scenario development process can be at least as important for the user as the product, for example if a scenario is intended to support a specific decision. A process-oriented scenario includes the user in development, so that they may learn from the experience and feedback to enhance scenario efficacy. However, in many contexts, scenarios are instead communicated in a linear process, with an end product deliverable such as a report. In this case the product is typically more important than the process, with the potential advantage of reaching a wider and more diverse range of users beyond those participating in the process. If this is the case, quality, transparency, and legitimacy need to be important scenario features in order to ensure they are relevant to the user community and can be readily used for planning and decision making.[63]

1.4.1.3 Qualitative versus quantitative

The distinction between qualitative and quantitative information is clear in scenario development, but the contrasting methods may be, and perhaps should be, combined. Qualitative information, specifically narratives, provide logic to scenario assumptions and help to define plausible future developments in situations where formal modelling is not possible. They provide an effective way to derive information at different scales or for different topics (for example regional scenarios nested within global narratives). Quantification, via modelling, adds scientific rigour to scenarios, expanding on numerical estimates of future developments (often based on simulation tools) where relevant and reliable information is available. Quantitative outputs can strengthen communication through clear definitions and rules.[64]

58. (Star et al. 2016) **59.** (Star et al. 2016) **60.** (Birkmann et al. 2015)
61. (Van Notten et al. 2003; Tourki, Keisler, and Linkov 2013)
62. (Tourki, Keisler, and Linkov 2013) **63.** (Van Vuuren et al. 2012) **64.** (Henrichs et al. 2010)

Deterministic Versus Probabilistic

Scenarios are also characterised as either deterministic or probabilistic. A deterministic scenario is created by selecting a specific set of parameters and conditions, while a probabilistic scenario considers a multiplicity of outcomes, each with its own probability of occurrence, depending on the probability distribution of the input parameters and conditions.[65] A deterministic scenario treats the probability of occurrence as finite, whereas probabilistic modelling is intended to address the uncertainty with a 'complete' probability distribution of synthesised events.

Deterministic scenarios are recognisable by their focus on the causal chain of circumstances that will give rise to unusual or extreme outcomes. They are an effective means of exploring phenomena speculatively or hypothetically when they are not very well understood or there is a high degree of uncertainty. They can also be very valuable for exploring emerging risks, specifically where market or policy responses are uncertain.

In comparison, production of a probabilistic scenario is possible when the underlying process is well understood, and the causal parameters can be characterised with estimates of their occurrence rates and distribution. Each step in the causal chain has a defined distribution of outcome likelihoods, and the model stochastically samples from this distribution in many simulations. The probability of an outcome and its uncertainty structure is very sensitive to the assumptions made for the input parameters.[66] By incorporating random variations into the model, stochastic outcomes show a range of scenario outcomes, and the likelihood of these permutations. Techniques for probabilistic modelling are well understood and documented, and are used in analysis, such as natural catastrophe modelling, where the subject phenomena have been comprehensively studied and for which it is possible to estimate the uncertainty distributions of the underlying variables.

It is also important to note that probabilistic scenarios are only useful when understood, and where decision makers are not familiar with the theory, it may be unhelpful or even misleading. For example, return periods, or recurrence intervals, are standard calculations for describing the magnitude of potential events – such as a 1-in-100-year flood – but are prone to misconceptions and misuses that are well acknowledged but still widespread.[67] In cases where communicating scenarios to non-experts is required, it may be that probability should not be depended on, and a deterministic approach could have greater value, providing tangible reference points within a probability distribution.

There is overlap in deterministic and probabilistic scenarios. For example, probabilistic modelling can be used to generate a deterministic scenario, typically such as the worst, best, or most likely case events. Caution should be taken when comparing the two types, as probabilistic scenarios still contain deterministic attributes. Specifically, probabilistic scenarios require all potential outcomes to be defined, yet in practice the universe is not a closed system. There are outcomes of future probabilistic scenarios which cannot be recognised at present; thus, it is not possible to achieve a perfect probability estimation.

65. (Renard, Alcolea, and Ginsbourger 2013) **66.** (Lorenz 1963) **67.** (Serinaldi 2015)

Aftermath of Cyclones Idai and Kenneth in Mozambique in 2019

3. Scenarios to Support Disaster Risk Reduction

3.1 Who is responsible for disaster risk and resilience?

Reducing disaster risk and building resilience demands a powerful and concerted course of action. Progress depends on the involvement of all stakeholders associated with disasters, before, during, and after an event, including experts, practitioners, decision makers, financers, and those at risk. These can be broadly grouped into: governments (at national, regional, and local levels), including specialised disaster management authorities; the private sector, including the financial sector; nongovernmental (NGOs) and civil-society organisations (CSOs); education and research institutions; international organisations (IGOs); international financial institutions (IFIs); the media; and individuals and communities, in particular those at risk.[68] Collectively, we term these stakeholders the disaster risk management community. Financial services (including credit, savings, investment, and insurance services) are a critical component of DRM, whether provided by the (formal) private financial services sector, or semi- or non-market institutions, such as other financial institutions, government, NGOs, IFIs, or local CSOs.[69] Therefore, this report includes financial service providers in its intended audience, although a separate report concerning scenario best practices specific to the insurance sector[70] includes specific recommendations on scenario development oriented towards insurers with significant exposures in their underwriting portfolio to a range of risks.

3.2 Scenario User Case Studies

A key question that was asked during this report's consultation process concerned identifying who the users of scenarios are, and the many ways scenarios were being used. The following section provides case studies of scenario applications in the following user categories:

- Government Organisations
- Inter-Governmental Organisations (IGO)
- Non-Governmental Organisations (NGO)
- Private Sector Organisations
- Local Communities

68. (UNISDR 2018) **69.** (Warner, Bouwer, and Ammann 2007)
70. (Cambridge Centre for Risk Studies, in collaboration with Lighthill Risk Network 2020)

Government Organisations

A Full-Scale Simulation Scenario Case Study

Government organisations are a collective of people who are acting on the interest of a municipal, provincial, or federal government. Examples of government organisations include a nation's military, health departments, or institutions such as an international development office.

> A simulation exercise is a participatory process, in which practitioners can test and practice responses in a safe and controlled environment.

An example of governmental use of scenarios is taken from Rwanda, where a full-scale simulation exercise was taken to strengthen preparedness against a potential Ebola Virus Disease (EVD) outbreak.[71] The exercise focused on testing the regional and federal response to a potential outbreak and identifying areas for future improvement. Predetermined tasks were assigned, and potential stressors such as public anxieties and community resistance were also included.

As Rwanda has never faced an emergency of this type before, the simulation exercise provided community members an opportunity to trial the national EVD preparedness plan and identify potential gaps to date. The simulation exercise was organised in collaboration with the Rwandan ministry of health, Rwanda biomedical centre, and the WHO country officer. See Wilson (2018) for further information about the exercise.

Ebola outbreak simulation exercise in Rwanda (Photo: https://www.afro.who.int/news/evd-rwanda-conducts-full-scale-simulation-exercise)

71. (Wilson 2018)

Inter-Governmental organisations

A Computer Simulation Scenario Case Study

An inter-governmental organisation (IGO) is an 'entity created by treaty, involving two or more nations, to work in good faith, on issues of common interest'[72] The establishment of a treaty is what differentiates an IGO from other international working groups, as they are enforceable agreements which are subject to international law.[73] The United Nations, European Union, and African Development Bank are all examples of current IGOs.

> A computer simulation exercise generates multiple simulated futures for use in scenario analysis that tests the benefits of alternative planning measures relative to their resource requirements.

An example of an IGO's scenario application is taken from the World Bank, who used scenario methodologies when prioritising interventions in Peru's road network.[74] As Peru's cargo is highly dependent on road systems, the logistical impacts can be severe when a road is damaged by the country's extreme weather. Policy makers are working to make the system more resilient but have needed to identify where interventions would have the most prominent impact. The World Bank has proposed a methodology to identify which roads are most critical for Peru, and of those, which are most exposed to a natural disaster. This was achieved through computer simulations.

The World Bank first developed a Geographic Information System (GIS) road network in Peru, which weighted the relative importance of the road to the wider network. The road network then faced a hypothetical natural disaster, and the estimated disruption was measured. The simulation was repeated many times under different potential interventions to identify which intervention would have the most substantial impact. Notably, the scenario exercise uses Robust Decision Making (RDM) in its methodology, which intends to find the result best suited for a wide host of outcomes, not a single catastrophic event. This is particularly important when addressing deep uncertainty, where there is inadequate information about future events. See Rozenberg et at. (2017) for further information regarding the methodology and results of the modelling.

Peruvian road network (Photo: Flickr; Douglas Fernandes)

72. (Harvard Law School 2019) **73.** (Harvard Law School 2019) **74.** (Rozenberg et al. 2017)

Non-Governmental Organisations

A Gameplay Scenario Case Study

Non-governmental organisations (NGOs) are not for profit voluntary citizens groups, which co-exist between state and market. They are formed independent from government organisations, and can exist at community, national, and international levels. Members of an NGO are typically working towards a common goal, which can vary widely depending on the organisation.

> Gameplay activities embody participatory scenario planning, using engaging and simple games to explore complex risks via an accessible platform that does not necessarily require expert knowledge.

An example of an NGO's use of scenarios is taken from the International Federation of Red Cross and Red Crescent Societies (IFRC), who have been supporting the reduction of climate change impacts on vulnerable populations. To support education initiatives, the IFRC has developed a series of games aimed at encouraging active engagement and simplifying complex systems.[75]

The games encourage participants to explore various crisis and response options in a widely accessible platform. Examples include the Race for Risk Reduction[76], which tests participants in their ability to respond to a crisis, and the Social Protection Shuffle[77], which explores the effects of cash transfer and resilience.

The games are particularly effective in improving stakeholder participation, accelerating dialogue on otherwise complex issues, and revealing systemic shortcomings. Pablo Suarez, associate director for research and innovation at the Red Cross Red Crescent Climate Centre, recounts a game played by illiterate Ethiopian farmers who didn't have a word for 'insurance' in the local language. The farmers partook in a game with dice and beans which was designed to help them learn about parametric insurance bundled with credit.[78] Suarez states: "Games offer familiar structures designed to allow us to play with the unfamiliar, enabling us to re-imagine the space of possibility latent in our shared futures."[79]

75. (Red Cross Red Crescent Climate Centre n.d.) **76.** (Red Cross Red Crescent Climate Centre n.d.)
77. (Red Cross Red Crescent Climate Centre n.d.) **78.** (Suarez 2017) **79.** (Suarez 2017)
80. (Lloyd's of London 2015)

Private Sector Organisations

A Stress Test Scenario

The private sector is a broad term that encompasses non-governmental, for-profit companies and individuals. The private sector is an umbrella term which can include many types of economies, such as sole proprietorships, small and mid-sized businesses, large corporations, and trade associations.

A stress test scenario is specifically aimed at testing the resilience of individual organisations or an entire sector against events which have the potential to cause substantial, and perhaps systemic, operational disruption and financial losses.

An example of the private sector's use of scenarios is taken from the insurance market, who routinely use scenarios to explore potential impacts of extreme risks. Lloyd's of London, the specialist insurance market, utilise scenarios to explore insurance exposures and potential markets. For example, the 'Food System Shock' scenario[80] considers the impact of a sudden disruption to the global food supply chain. The scenario proposes a strong warm-phase of the El Niño Southern Oscillation (ENSO), which triggers severe weather events such as floods, droughts, and landslides. The events lead to production shocks in maize, soybean, wheat, and rice. The scenario explores potential reactions that the population may have to such an event, including a rise in political tensions, political and civil unrest, food riots, or wider supply chain interruptions. The report examines insurance claims that might be triggered by such events, and potential changes which may occur within the global regulatory and business environment in the aftermath. See the Lloyd's Emerging Risk Report (2015) for further information regarding the methodology and results of the modelling.

Local Communities

A Full-Scale Simulation Scenario Case Study

When discussing Disaster Risk Reduction, local communities are defined as the people who live and work in the areas exposed to disaster risk. Local communities are the experts of the community space and play a fundamental role in the community's resilience.

> Public participatory scenarios engage community stakeholders to address risk, incorporating the needs, values, and experiences of individuals with perspectives on risk to find solutions that are both effective and culturally appropriate.

An example of a local community's use of scenarios is taken from the Surkhet District of Nepal.[81] The Surkhet District is at risk of strong earthquakes and flooding, and the architecture of many buildings in the area makes them highly susceptible to collapse. The community is also home to a 40-bed medical referral unit. In 2013, the staff underwent scenario training in earthquake response and patient influx. The scenario involved a surge of casualties of various severities attending the hospital, and a series of triages and treatment areas being established. The intention of the scenario was to prepare local staff with leadership roles and a command structure which would be sufficient in the case of a disaster.

The scenario stimulated planned and spontaneous leadership and provided guidance on how to respond in a real disaster event. As literacy levels varied across staff, the ability to simply distribute a disaster plan was limited. Instead, the training events and scenario exercises provide an opportunity to impart knowledge of emergency plans to all staff. See Filmer and Ranse (2013) for further information about the scenario and its community impacts.

Nepal's significant earthquake risk demands coordinated disaster risk management efforts

81. (Filmer and Ranse 2013)

4. How to Build a Scenario

During the literature review and consultation process for this report, which included input from public and private disaster planning, risk management, and resilience experts and organisations, a wide variety of scenario practices were identified to address a range of issues while managing various constraints.

Nevertheless, successful scenarios share common characteristics, and this section provides recommended checkpoints to consider as a practitioner works through the scenario process.

4.1 Key Considerations

The following three general criteria ensure scenarios are useful and applicable to their purpose:

1. Scenarios should be plausible, describing a rational route from 'here' to 'there' that makes causal processes and decisions explicit;
2. Scenarios should be internally consistent;
3. Scenarios should be sufficiently interesting and exciting to make the future 'real' enough to elicit strategic responses.[82]

4.2 A Scenario Development Framework: Step by Step

Scenarios generally follow systematic and recognisable steps (Figure 5). Users should adapt the following methodology to create scenarios which work best for them, given their audience, resources, and desired use. Although this section outlines a linear step-by-step structure for clarity, we encourage the scenario process to be an iterative one, in which stakeholder engagement provides opportunities for review and revision to ensure it succeeds in fulfilling its aims.

Figure 5: Outline of the scenario development framework for disaster risk reduction

82. (Birkmann et al. 2015)

Step 1: Scope the Risk

Contextualise the objectives and desired decisions of the process. It is logical to approach the scenario process with the statement of a problem or research question to be answered, most simply by defining a specific disaster risk. A research question typically starts broadly (e.g. 'what risks threaten a community?') and is developed into a more specific question (e.g. 'how exposed, vulnerable, or resilient is a community to a severe (defined) magnitude earthquake?'). The scope will be refined throughout the research process.

Where the risk is uncertain or unknown, the research question should instead aim to define the issues or vulnerabilities that the scenario exercise aims to expose. In this case, the desired outcome of the scenario process is likely to identify one or more risks facing a community. An alternative way of framing a question or problem is to instead focus on the hypothetical point of failure that would severely impact a community and stress DRM capabilities. The scenario then forces users to identify the vulnerabilities which exist and might cause such an effect. This approach is helpful in identifying the potential for strategy and planning failures and addressing any false sense of security concerning the robustness of a decision or plan and its resilience to a shock.

Step 2: Conduct Background Research

Background research should include consultation of the relevant sources of knowledge, including the academic literature for a scientific understanding of the topic, as well as the knowledge of experts and associated stakeholders. Each dimension of risk should be considered: the hazards, whether acute, shock events, or slow-onset, trend phenomena; exposure of an individual, community, or geographic region to a hazard; and vulnerabilities at each of these levels that have the potential to drive loss.

Various stakeholders beyond the assumed 'experts' provide nuanced advice specific to certain risks. Incorporating localised experience and expertise can provide a valuable perspective on different perceptions of risks, vulnerabilities, or potential impacts. A public participatory exercise alone may be valuable in widening the view of known unknowns, highlighting risks that do not yet feature on an organisation's radar.

Step 3: Frame the Scenario(s)

Here, framing the analysis refers to definition of the key aims, benefits, and characteristics of the scenario process. It is the process of determining what type of scenario is most appropriate for the current use case. As discussed, to be effective, scenarios should blend approaches and typologies to fit their purpose. Figure 6 intends to guide this framing with a series of questions that aim to provoke consideration of key practical decisions in the process.

What is the purpose of the scenario in DRM?

Disaster Response	Disaster Recovery	Disaster Mitigation	Disaster Preparedness
To assess strategies to alleviate disaster impacts during an event	To assess strategies to quickly and effectively return affected systems to 'normal'	To develop measures to alleviate the impacts of future hazard events	To build knowledge and capabilities to anticipate and alleviate disaster impacts

How can the scenario benefit stakeholders?

Improve Understanding of Risks	Explore Emerging Futures	Address Uncertainty	Systems Thinking
To understand the various dimensions of a specified risk that cause negative impacts	To imagine and comprehend new, evolving, and novel combinations of risks	To expand understanding and define a range of plausible future outcomes	To capture the controlling interconnections between complex systems
Support Decision Making	**Aid Communication**	**Allocate Resources**	**Identify Biases**
To inform and enhance effective disaster risk management strategies	To contextualise complex risks and facilitate stakeholder engagement	To plan what and where the effectively distribute resources	To ensure viewpoints and decisions remain objective

On what timescale does the risk materialise?

Trend Risk Scenario	Shock Risk Scenario
Slow-onset, trend phenomena that emerge gradually over time	Sudden-onset, shock events that occur quickly or unexpectedly

Which is the more important scenario outcome?

Exploratory - To ask 'what if?'	**Normative** - To ask 'what for?'
To stimulate imaginative thinking about the future and widen understanding of available options	To better understand the path to desirable futures and evaluate the impact of decisions

Who owns and contributes to the scenario process?

Participatory - Bottom-up, co-production of knowledge	**Expert-Driven** - Top-down, analytical
To incorporate stakeholder culture, knowledge, and experience in the process and end product	To deliver rigorous scientific descriptions of plausible futures to decision makers

Is the scenario required to define the likelihood of an outcome?

Probabilistic	Deterministic
To estimate the likelihood of occurrence based on the variance of quantified causal parameters	To speculatively explore phenomena that involve a high degree of uncertainty

Figure 6: Framing a scenario – scenario typologies and applications

Step 4: Develop Candidate Scenarios

Developing candidate scenarios typically occurs in tandem with the research process and involves imagining the distinct features and narratives of potential scenarios. This should be a free-thinking exercise and includes qualitatively exploring scenario parameters and outlining a narrative sequence of events. For each of the candidate scenarios, consider what risks are measured, and what types of consequences they may lead to. From this, multiple candidate scenarios should emerge to be formalised. Once a series of potential scenarios have been listed, they will be ranked and selected for further development.

There are several methods to rank and select scenarios, which are largely based on user preference and the intended application of analysis. Two such methods are to use an impact uncertainty matrix and the uncertainty breadth approach. In the impact-uncertainty matrix (Figure 7), outcomes are projected upon a matrix which gages both impact and uncertainty. Scenarios which have high impact and high uncertainty are thought to benefit the most from further research. This is followed by scenarios which have either a high impact or high uncertainty

The uncertainty breadth approach is an alternative method which selects scenarios that cover the greatest range of outcomes. In this case, multiple scenario variants would be selected that are the most different from each other and had the least amount of overlap. The uncertainty breadth approach is especially valuable for emerging risks which typically have more unknowns.

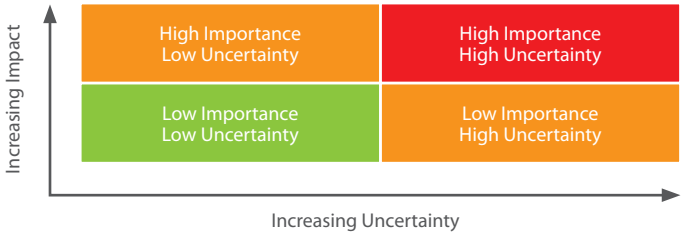


Figure 7: Impact-uncertainty risk matrix

Determining a severity

It is helpful to estimate the frequency and severity of impacts to a rough first order. A probabilistic assessment is demanded in domains such as engineering, to specify the function or longevity of physical infrastructure, or insurance, to price the risk and cost a premium. Event likelihood and magnitude is measured in return periods, or recurrence intervals, i.e. the estimated time interval between the occurrence of similar events. Note that return periods are commonly misunderstood among non-expert stakeholders.

When determining the event severity it is helpful to consider the event trigger. Often, a cascading set of incidents amplify an initial triggering incident. In this perspective, the trigger event may be common, yet the response may be very uncommon, which results in an overall extreme and unusual event. In most cases, it is advised to not make the scenario too extreme, as 'game-over' severities are not actionable.

Step 5: Develop a Narrative

A detailed narrative expands the scenario description to provide the required detail on which to build the analysis. The narrative should include a variety of dimensions of a future event, including context, triggers, timelines, geography, responses, and implications. When determining these factors, it is helpful to once again refer to the intent of the exercise expressed when scoping the scenario (Step 1). Geography and distribution of impacts or needs, and timelines, are particularly relevant to disaster risk management

It can be helpful to consider scenarios as stories which have a beginning, middle, and end, and the narrative guides the reader through the events and their implications. The narrative is imperative for providing logic and reasoning to the proposed events and assists in making the scenario more applicable and relatable. An effective narrative can also create broader interest and relevancy, increasing the scenario's utility. Research conducted in the previous steps should be applied to help guide the narrative based on historical precedence. In providing rich descriptive details and elaborating on the cause-and-effect processes, a more holistic impression of the hypothetical event can be drawn, which assists when determining its direct and indirect impacts.

Scenario variants

Once the scenario narrative is completed, its variants can be considered. Variants are different versions of the scenario where variables are adjusted to account for uncertainty. Examples of adjustments can include the magnitude, duration, or social reaction to the event. By adjusting a variable, losses will increase or decrease.

Scenario variants are frequently used to show a potential range of outcomes and their severity. The number of scenario variants is dependent on time and resources, but typically ranges from three to seven. When considering the number of scenarios, the centre stage effect[83] dictates that users are more prone to select the middle scenario.[84] As a result, there is benefit in presenting an even number of scenarios, to dissuade the tendency to select the centre as default.

Designing a Scenario Narrative

The scenario narrative provides the context for a scenario and is needed when determining the direct and indirect impacts of an event. When creating a scenario narrative, several variables should be considered.

Event Trigger: The narrative should specify the trigger of a hazard event, for example the occurrence of an earthquake. Further, it should specify any amplifying factors which might exacerbate the event, or whether cascading events may be triggered by an initial shock.

Location: Consider where the event trigger occurs and how far reaching the impact is felt. Indirect impacts should also be considered in addition to primary impacts. With increasing global networks, event impacts are not limited to the surrounding geographic footprint and can quickly expand to a global scale.

Timing: The timing of an event occurrence, or a timeline of events, should be outlined within the scenario narrative. Variables such as the length of an occurrence or the speed and effectiveness of a response is critical for assessing the criticality of decisions.

Impact: The narrative should highlight who and what is impacted by the occurrence, both directly and indirectly, and how the severity of impacts is distributed. Impacts, such as the effects on human lives and livelihoods, business disruption, physical damage and destruction, are unlikely to occur uniformly across space and time. The narrative should also consider individuals who face delayed impacts, especially for occurrences which have a longer timeline.

Recovery: Just as important as understanding the cause and effect of the occurrence, the narrative should also consider the recovery process. Specifically, the narrative should identify who is involved, the types of resources recovered, and how long the recovery takes. This directly influences the impacts that the occurrence has, and the scale of the event.

83. The centre stage effect refers the tendency for people to select the middle item when presented with a list of options (Valenzuela and Raghubir 2009a)
84. (Valenzuela and Raghubir 2009a)

Step 6: Assess Impacts

Once the scenario event has been developed, the next step is understanding what the potential impacts are to a specified community, and/or systemic impacts to wider social, environmental, or economic systems. Consideration of dependencies and interconnectivities between shocked systems with a 'multi-threat' approach is critical to understand the hidden and cascading impacts beyond the expected (see Section 3.1 on 'systems thinking'). For example, the 2011 Tohoku earthquake triggered a tsunami that caused the meltdown of the Fukushima Daiichi nuclear reactor[85]. A common demand of scenarios in DRM is to prioritise the needs that must be addressed most urgently, to minimise risk or alleviate impacts with the given resources in the most efficient manner. This prioritisation is a required step towards structuring effective decisions. Often, the interest is in identifying what variables will 'tip' the balance beyond a threshold which is considered manageable.

Step 7: Communicate and Act

Effective communication of realised scenarios controls the efficacy of the process. Although it may appear trivial, a catchy name that provokes interest is an often-overlooked scenario element that can aid its successful uptake and communication. Then, meaningful, comprehendible, and interesting outputs are essential, and are likely to include both qualitative and quantitative components addressing the scenario impacts and materiality. It is important for the narrative to explain and contextualise the results, and it may often be helpful where multiple scenarios are explored to focus on the most probable and use this as a reference to explore others. The scenario outcomes can inform and prompt decisions and actions where this is the intended purpose. Consider how and to whom the scenario is delivered; this may include internal and or external stakeholders, with individual intentions, expertise, and constraints. Importantly, it must be made clear what the scenario is intending to accomplish, and how the findings should be interpreted. The scenario is not a prediction of future events, but instead a thought exercise into plausible futures.

Shaping a Scenario to the User

Distribution audience

With whom will the scenario be shared? Is the scenario an internal resource for an individual team, or to be shared within a wider organisation with a variety of interests, or for public consumption? Public scenarios typically require significant explanation, often via supportive documentation and reference material, to mitigate potential ambiguity. Critically, a scenario must be attractive and accessible to prospective users; they must understand that it is there to be used and appropriate for their purpose. Branding a scenario appropriately with a catchy name is helpful in this respect.

Background knowledge

How familiar is the user with the subject? This dictates the level of description and type of language (use of subject-specific lexis) used, which should be targeted to the user's expertise. The scenario delivery should include introductory and explanatory information and direction to further resources. As a standard practice, the scenario should include appropriate reference material to be widely accessible to a broad audience.

Resource allowance

The amount of time and human capital that the user can be expected to dedicate to interpret and action the scenario. The resource allowance should dictate the length of content, time demand, and level of detail of a scenario. In the context of disaster risk, urgency and resource pressure are key constraints on a scenario's success. Keeping the exercise simple will maximise value within these constraints, focusing on viable actionable outcomes.

85. (Zastrow 2019)

Step 8: Evaluate and Update

To complete the scenario process, it is encouraged to evaluate whether the objectives of the exercise were achieved. This is likely to involve a consultation with participants and associated stakeholders, to review whether a scenario is plausible and if it can be useful in developing the users' understanding of a risk and informing decisions. Listen to contrary opinions, as a method to overcome groupthink and build on insights from a range of sources. Consider if the stress test scenario answers the initial problem, and if the severity of the event meets the intended targets. This process has been expressed in a linear step-by-step process, but it is critical to use this evaluation process to identify and address any weaknesses in the scenario and applied analytics in an iterative process.

Sometimes, the most interesting and insightful scenarios are those that initially appear to be the least probable. Scenarios have varying lifespans, intended to be discarded after the exercise is finished or to be kept and reused over a period of years.[86] Therefore, it is important to acknowledge that scenarios are dynamic. The possibility and character of a scenario will change over time as controlling factors evolve, as will its impact on society – including social, economic, and environmental characteristics – and so it should be updated periodically to maintain relevance and continued utility.

4.3 Disaster Risk Reduction Scenarios: Recommended Considerations

Effective scenarios play a vital role in informing users of potential risks and reactions. Throughout the consultation process leading to this report, scenarios users were asked to recommend specific actions which could be taken to improve scenario development and application. The following considerations were noted.

Enhance Narratives

Narratives are a staple component of scenarios, bridging between a scenario's story and specification and its technical requirements. If not expressive and comprehensible, narratives may limit scenario efficacy, and so should be carefully designed to make scenarios effective tools for the decision making. This can be done through reflecting the needs of the user in narrative development and providing the appropriate level of depth and detail. The context and message should be enough for users to gain understanding and make sense of what might be. This can aid in building stronger consensus regarding behaviour, thinking or working.[87] Allan, Fairtlough, and Heinzen (2002) suggest that:

"The sensible management response is to create an enabling infrastructure that gives a good chance for self-organisation. You don't design a solution, you design a capacity for solutions to emerge" (p. 129).

Although the criteria that define a successful narrative are personalised and unique, they should broadly strive to be original, memorable, provocative and compelling.[88]

Audience Engagement

A scenario is only effective if it is used, which is intrinsically linked to the engagement of the scenario users. Engagement is often woven into the scenario narrative and its effectiveness; however, a more conscious approach is to try to better understand who the audience is, and adapt a methodology to its users and context. Many scenario resources already consider audience engagement, yet there was consensus that additional resources need to be invested to reflect user needs.

86. (Roxburgh 2009) **87.** (Rasmussen 2005) **88.** (Rasmussen 2005)

Cognitive Biases

When designing and using a scenario, one must consider the effects of cognitive bias on decision making. Cognitive bias is an umbrella term which describes the input of subjectivity onto decision making and our interactions with the environment. These biases can guide what risks we choose to focus upon, and how we interpret given information.

When discussing cognitive bias, it is helpful to provide some perspective as to why it is important, and why it occurs. The world provides the brain with a complex environment with enormous amounts of information to process. This complexity is compounded when decisions need to be made. To reduce the effort and delay until a decision is made, cognitive biases develop based on interactions with the environment. These cognitive simplifications are commonly referred to as 'heuristics' and can be thought of as mental shortcuts or our 'intuition'.

While an individual's cognitive biases and developed heuristics likely developed for adaptive reasons to simplify decision making, these intuitive judgements based on intuitive probability and frequency judgements have the potential to lead to judgement errors. Although many of these errors are unavoidable, we can be mindful of their impact and take precautionary steps if needed.

As a first example of a bias, we pick out overconfidence which describes the tendency to be overly optimistic in ignorance of contrary evidence, often in the context of setting a goal. Nobel laureate Daniel Kahneman identifies overconfidence as "the most significant of the cognitive biases".[89]

Below we discuss two common biases influencing scenario development.

4.3.1.1 Availability Bias

Decisions on probability and judgements are based on the ease with which relevant instances come to mind[90].

Frequent occurrences of an event mean individuals have plenty of relevant experience to draw from when judging the probability of an event, so basing judgments on availability is sensible and people's frequency judgments are often very accurate. However, availability can be biased if our experience of past events does not reflect the true frequency or if an event is easier to recall for a reason other than its frequency.

These biases can be introduced by the environment or the individual. Rare events are often given disproportionate publicity and are correspondingly more mentally available than their true frequency would merit. Similarly, events that individuals have experienced personally with an emotional response are much more readily available.

The availability bias is helpful to consider when evaluating risks, as we generally underrepresent common risks which do not receive as much attention while we over represent recent heavily reported risks, or risks which we have experienced ourselves. When applying the availability bias to scenario development, one should attempt to understand the viewpoint users of the scenario have, to create scenarios that make the risk accessible and personal.

4.3.1.2 Anchoring Bias

Final estimates or judgements are often reached by adjusting away from an initial "anchor" value, but these adjustments are often insufficient.[91]

Anchoring bias occurs when we focus decision making on an initial piece of information. An initial value is used as a reference when evaluating and comparing additional information. The outcome may be skewed or influenced by the initial, possibly arbitrary, anchor. An example of this may be seen when estimating catastrophic events.

89. (Kahneman 2011) **90.** (Tversky and Kahneman 1974) **91.** (Tversky and Kahneman 1974)

Assigning Probabilities

Assigning probabilities in scenario exercises has historically been valuable for resource allocation and policy decisions.[92] Some feel that information on likelihoods is required to make judgement, and that results cannot be properly interpreted and acted upon without them. Comparably, others feel that assigning probabilities to a hypothetical event is misleading, as it may dilute the credibility of a proposed scenario. Assigning an accurate probability itself can often be a difficult exercise; for example, it is notoriously difficult to assign regional probabilities to technological and political risks. These risks are often difficult to define manageable boundaries for, thus exploring the impact can be difficult. The inclusion of probabilities can also make involvement of diverse participants difficult, as they may hold different opinions on the likelihood of an event. Within the DRM community, the need for probabilities is variable, with some applications benefiting from their inclusion, while others may not be impacted, or hindered, by their involvement. We recommend scenario developers consider their current scenario applications and review their relation to probabilities. Whether this will be beneficial relates heavily to the scale and scope being considered, the types of risks in question, and the type of scenario being developed.

Invest in Data, Evidence, and Collaboration

There are cases of both insufficient data and data overload in the context of scenarios. As a result, this report does not simply suggest that more information needs to be made available. Instead, the report advocates for investment in usable and effective datasets with a focus on collaboration.

The ease of achieving this has improved with the expansion of technologies that facilitate participatory data gathering and sharing methods, which support information integration at unprecedented levels and promoted non-conventional data generation.[93] This is providing previously data scarce areas with novel resources, and a democratisation of decision support materials.[94] This is aiding in shifting the power and responsibility to citizens and the public and increasing the community investment in risk research. The importance lies in ensuring this wealth of information is used effectively, and that it is effectively prioritised and organised to make it accessible to potential users. This may also result in removing excess data which can get in the way of decision making.[95]

92. (Groves and Lempert 2007) **93.** (Zulkafli et al. 2017) **94.** (Zulkafli et al. 2017) **95.** (Bastardi and Shafir 1998)

Main ghat at Varanasi on the Ganges River, India

5. Definitions

Back-casting: A scenario technique which identifies a future state, and then works backwards to determine possible paths from the present state.

Baseline Scenario: An assumed future with no explicit deviations, used for outcome comparisons.

Cascading Events: An event which directly or indirectly triggers another event.

Counterfactual Scenarios: An alternative outcome of a historical event had a specific intervention not occurred.

Decision Making Under Deep Uncertainty: An emerging paradigm comprising a variety of approaches to cope with uncertainty with robust decisions.

Deep Uncertainty: Exists when various parties to a decision do not know, or cannot agree on, how a complex system works, the probability of possible future states, and how important the various consequences of interest are.[96]

Deterministic Approach: An examination of the impacts to a singular event, defined by the scenario developer.

Disaster: A hazard event which seriously impacts the functioning of a community or a society due to its interaction with conditions of exposure, vulnerability, and capacity, leading to human, material, economic, and environmental losses and impacts".[97]

Disaster Risk: "The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity".[98]

Disaster Risk Reduction: "Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development".[99]

Disaster Risk Management: "The application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses".[100]

Forecast: The most probable prediction that something will happen in the future.

Hazard: A natural or anthropogenic process or phenomenon that may result in negative social, economic, or environmental consequences. A hazard event is the manifestation of a hazard in a particular time and place.[101]

Intervention Scenarios: A scenario which demonstrates the consequence of mediating action.

Mitigation: Reducing the severity or intensity of the negative impacts of a hazard.

Narrative: A descriptive summary of the events occurring within the scenario. Also known as a storyline.

Prediction: A subjective (probabilistic) statement that something will happen in the future.[102]

Preparedness: The knowledge and capabilities enacted to effectively anticipate and alleviate the impacts of a disaster.[103]

Probabilistic Approach: An examination of all potential outcomes, and their estimated likelihood (Probability)

Projection: A probabilistic statement that something will happen under certain conditions, allowing for significant changes in the boundary conditions that might influence a prediction.[104]

Resilience: "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management".[105]

Resource Allowance: The amount of resources which can be spent on a specific task. Examples of resources can include time, money or persons.

Scenario: "Plausible descriptions of how the future might develop, as based on a coherent and internally consistent set of assumptions ("scenario logic") about the key relationships and driving forces".[106]

Vulnerability: "The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards".[107]

96. (Kwakkel 2017) **97.** (UNISDR 2017) **98.** (UNISDR 2017) **99.** (UNISDR 2017) **100.** (UNISDR 2017) **101.** (UNISDR 2017) **102.** (MacCracken 2001) **103.** (UNISDR 2017) **104.** (MacCracken 2001) **105.** (UNISDR 2017) **106.** (Van Vuuren et al. 2012) **107.** (UNISDR 2017)

6. References

Alexander, David. 2013. 'Resilience and Disaster Risk Reduction: An Etymological Journey'. *Natural Hazards and Earth System Sciences* 13 (11): 2707–16. https://doi.org/10.5194/nhess-13-2707-2013.

———. 2015. 'Disaster and Emergency Planning for Preparedness, Response, and Recovery'. *Oxford Research Encyclopedia of Natural Hazard Science*, September. https://doi.org/10.1093/acrefore/9780199389407.013.12.

Allan, Julie, Gerard Fairtlough, and Barbara Heinzen. 2002. *The Power of the Tale: Using Narratives for Organisational Success*. Chichester ; New York: Wiley.

Bastardi, A., and E. Shafir. 1998. 'On the Pursuit and Misuse of Useless Information'. *Journal of Personality and Social Psychology* 75 (1): 19–32.

Beven, Keith J., and Ruth E. Alcock. 2012. 'Modelling Everything Everywhere: A New Approach to Decision-Making for Water Management under Uncertainty'. *Freshwater Biology* 57 (s1): 124–32. https://doi.org/10.1111/j.1365-2427.2011.02592.x.

Birkmann, Joern, Susan L. Cutter, Dale S. Rothman, Torsten Welle, Matthias Garschagen, Bas van Ruijven, Brian O'Neill, et al. 2015. 'Scenarios for Vulnerability: Opportunities and Constraints in the Context of Climate Change and Disaster Risk'. *Climatic Change* 133 (1): 53–68. https://doi.org/10.1007/s10584-013-0913-2.

Birnbaum, Marvin L. 2008. 'Response and Recovery'. *Prehospital and Disaster Medicine* 23 (01): 1–2. https://doi.org/10.1017/S1049023X0000546X.

Cambridge Centre for Risk Studies, in collaboration with Lighthill Risk Network. 2020. 'Scenario Best Practices: Developing Scenarios for the Insurance Industry'. Scenario Best Practices. Cambridge Centre for Risk Studies at the University of Cambridge Judge Business School.

Carbon Brief. 2019. 'Mapped: How Climate Change Affects Extreme Weather around the World'. Carbon Brief. 11 March 2019. https://www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world.

Chang, Stephanie E. 2010. 'Urban Disaster Recovery: A Measurement Framework and Its Application to the 1995 Kobe Earthquake'. *Disasters* 34 (2): 303–27. https://doi.org/10.1111/j.1467-7717.2009.01130.x.

Coetzee, Christo, Dewald Van Niekerk, and Emmanuel Raju. 2016. 'Disaster Resilience and Complex Adaptive Systems Theory'. *Disaster Prevention and Management; Bradford* 25 (2): 196–211. http://dx.doi.org/10.1108/DPM-07-2015-0153.

Davies, Tim R. H., and Alistair J. Davies. 2018. 'Increasing Communities' Resilience to Disasters: An Impact-Based Approach'. *International Journal of Disaster Risk Reduction* 31 (October): 742–49. https://doi.org/10.1016/j.ijdrr.2018.07.026.

Dieu-Nalio, Chery. 2018. 'Eight Years Later, Haiti Still Recovering from Devastating Earthquake'. *CTV News*, 1 December 2018. https://montreal.ctvnews.ca/eight-years-later-haiti-still-recovering-from-devastating-earthquake-1.3758154.

Dreborg, Karl H. 1996. 'Essence of Backcasting'. *Futures* 28 (9): 813–28. https://doi.org/10.1016/S0016-3287(96)00044-4.

Dwiningrum, Siti Irene Astuti. 2017. 'Developing School Resilience for Disaster Mitigation: A Confirmatory Factor Analysis'. *Disaster Prevention and Management; Bradford* 26 (4): 437–51. http://dx.doi.org/10.1108/DPM-02-2017-0042.

Filmer, Leighton B., and Jamie Ranse. 2013. 'Who Is My Leader? A Case Study from a Hospital Disaster Scenario in a Less Developed Country'. *Australasian Emergency Nursing Journal* 16 (4): 170–74. https://doi.org/10.1016/j.aenj.2013.08.004.

FitzGerald, Gerard J., Peter Aitken, Elinor R. Davis, and Elaine Daily. 2010. 'Disaster Recovery'. In *International Disaster Nursing*, edited by Robert Powers and Elaine Daily, 495–512. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511841415.031.

Groves, David G., and Robert J. Lempert. 2007. 'A New Analytic Method for Finding Policy-Relevant Scenarios'. Product Page. 2007. https://www.rand.org/pubs/reprints/RP1244.html.

Haasnoot, Marjolijn, Jan H. Kwakkel, Warren E. Walker, and Judith ter Maat. 2013. 'Dynamic Adaptive Policy Pathways: A Method for Crafting Robust Decisions for a Deeply Uncertain World'. *Global Environmental Change* 23 (2): 485–98. https://doi.org/10.1016/j.gloenvcha.2012.12.006.

Hallegatte, Stéphane, Ankur Shah, Robert Lempert, Casey Brown, and Stuart Gill. 2012. 'Investment Decision Making under Deep Uncertainty'. *World Bank Group*, Policy Research Working Papers, 6193. https://doi.org/10.1596/1813-9450-6193.

Harvard Law School. 2019. 'Intergovernmental Organizations (IGOs)'. Harvard Law School. 2019. https://hls.harvard.edu/dept/opia/what-is-public-interest-law/public-service-practice-settings/public-international-law/intergovernmental-organizations-igos/.

Henrichs, Thomas, Monika Zurek, Bas Eickhout, Kasper Kok, Ciara Raudsepp-Hearne, Teresa Ribeiro, Detlef van Vuuren, and Axel Volkery. 2010. 'Scenario Development and Analysis for Forward-Looking Ecosystem Assessments'. *Ecosystems and Human Well-Being: A Manual for Assessment Practitioners*, 151–219.

Kauffman, Draper L. 1980. *Systems One: An Introduction to Systems Thinking*. Pegasus Communications.

Kopinak, Janice. 2013. 'Humanitarian Aid: Are Effectiveness and Sustainability Impossible Dreams?' *The Journal of Humanitarian Assistance* (blog). 3 October 2013. https://sites.tufts.edu/jha/archives/1935.

Kwakkel, Jan H. 2017. 'Managing Deep Uncertainty: Exploratory Modeling, Adaptive Plans and Joint Sense Making'. *Integration and Implementation Insights* (blog). 14 August 2017. https://i2insights.org/2017/08/15/managing-deep-uncertainty/.

Kwakkel, Jan H., Warren E. Walker, and Marjolijn Haasnoot. 2016. 'Coping with the Wickedness of Public Policy Problems: Approaches for Decision Making under Deep Uncertainty'. *Journal of Water Resources Planning and Management* 142 (3): 01816001. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000626.

Lempert, Robert. 2011. 'Managing Climate Risks in Developing Countries with Robust Decision Making'. In *Washington DC, World Resources Institute*. Citeseer.

Lempert, Robert J., Steven W. Popper, and Steven C. Bankes. 2003. *Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis*. https://www.rand.org/pubs/monograph_reports/MR1626.html.

Lempert, Robert J., Steven W. Popper, David G. Groves, Nidhi Kalra, Jordan R. Fischbach, Steven C. Bankes, Benjamin P. Bryant, et al. 2013. 'Making Good Decisions Without Predictions: Robust Decision Making for Planning Under Deep Uncertainty'. Product Page. RAND Corporation. https://www.rand.org/pubs/research_briefs/RB9701.html.

Linkov, Igor, Benjamin D. Trump, and Jeffrey Keisler. 2018. 'Risk and Resilience Must Be Independently Managed'. *Nature* 555 (February): 30. https://doi.org/10.1038/d41586-018-02567-0.

Lloyd's of London. 2015. 'Food System Shock'. Emerging Risk Report. London: Lloyd's of London. https://www.lloyds.com/news-and-risk-insight/risk-reports/library/society-and-security/food-system-shock.

Lorenz, Edward N. 1963. 'Deterministic Nonperiodic Flow'. *Journal of the Atmospheric Sciences* 20 (2): 130–41. https://doi.org/10.1175/1520-0469(1963)020<0130:DNF>2.0.CO;2.

MacCracken, Mike. 2001. 'Prediction versus Projection - Forecast versus Possibility'. *WeatherZine*, 26 February 2001, 26 edition. https://sciencepolicy.colorado.edu/zine/archives/1-29/26/guest.html.

Martin, Eric, Isabelle Nolte, and Emma Vitolo. 2016. 'The Four Cs of Disaster Partnering: Communication, Cooperation, Coordination and Collaboration'. *Disasters* 40 (4): 621–43. https://doi.org/10.1111/disa.12173.

Mens, Marjolein. 2017. 'A Practical Approach to Resilience'. *DMDU Society* (blog). 8 May 2017. http://www.deepuncertainty.org/2017/05/08/a-practical-approach-to-resilience/.

Mietzner, Dana, and Guido Reger. 2005. 'Advantages and Disadvantages of Scenario Approaches for Strategic Foresight'. *International Journal of Technology Intelligence and Planning* 1 (2): 220. https://doi.org/10.1504/IJTIP.2005.006516.

Olabisi, Laura Schmitt. 2017. 'Dealing with Deep Uncertainty: Scenarios'. *Integration and Implementation Insights* (blog). 5 January 2017. https://i2insights.org/2017/01/05/deep-uncertainty-and-scenarios/.

Platt, Stephen, and Emily So. 2017. 'Speed or Deliberation: A Comparison of Post-Disaster Recovery in Japan, Turkey, and Chile'. *Disasters* 41 (4): 696–727. https://doi.org/10.1111/disa.12219.

Popper, Steven W., James Griffin, Claude Berrebi, Thomas Light, and Endy M. Daehner. 2009. 'Natural Gas and Israel's Energy Future'. Product Page. 2009. https://www.rand.org/pubs/technical_reports/TR747.html.

RAND Corporation. 2019. 'Robust Decision Making'. Robust Decision Making. 2019. https://www.rand.org/topics/robust-decision-making.html.

Rasmussen, Lauge Baungaard. 2005. 'The Narrative Aspect of Scenario Building - How Story Telling May Give People a Memory of the Future'. *AI & Society* 19 (3): 229–49. https://doi.org/10.1007/s00146-005-0337-2.

Red Cross Red Crescent Climate Centre. n.d. 'Games'. Games. Accessed 25 June 2019a. https://climatecentre.org/resources-games/games.

———. n.d. 'Race for Risk Reduction'. Games. Accessed 26 November 2019b. https://climatecentre.org/resources-games/games/15/race-for-risk-reduction.

———. n.d. 'Social Protection Shuffle'. Games. Accessed 26 November 2019c. https://climatecentre.org/resources-games/games/26/social-protection-shuffle.

Renard, Philippe, Andres Alcolea, and David Ginsbourger. 2013. 'Stochastic versus Deterministic Approaches'. In *Environmental Modelling*, 133–49. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118351475.ch8.

Riddell, Graeme A., Hedwig van Delden, Graeme C. Dandy, Aaron C. Zecchin, and Holger R. Maier. 2018. 'Enhancing the Policy Relevance of Exploratory Scenarios: Generic Approach and Application to Disaster Risk Reduction'. *Futures* 99 (May): 1–15. https://doi.org/10.1016/j.futures.2018.03.006.

Robinson, John B. 1990. 'Futures under Glass: A Recipe for People Who Hate to Predict'. *Futures* 22 (8): 820–42. https://doi.org/10.1016/0016-3287(90)90018-D.

Roxburgh, Charles. 2009. 'The Use and Abuse of Scenarios'. McKinsey & Company. November 2009. https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/the-use-and-abuse-of-scenarios.

Rozenberg, Julie, Cecilia M. Briceno-Garmendia, Xijie Lu, Laura Bonzanigo, and Harry Edmund Moroz. 2017. 'Improving the Resilience of Peru's Road Network to Climate Events'. WPS8013. The World Bank. http://documents.worldbank.org/curated/en/691821490628878185/Improving-the-resilience-of-Perus-road-network-to-climate-events.

Sayers, Paul B., Gerald E. Galloway, and Jim W. Hall. 2012. 'Robust Decision-Making under Uncertainty ? Towards Adaptive and Resilient Flood Risk Management Infrastructure'. In *Flood Risk*, 281–302. ICE Publishing. https://doi.org/10.1680/fr.41561.281.

Schwartz, Peter. 2012. *The Art of the Long View: Planning for the Future in an Uncertain World*. Crown Business.

Serinaldi, Francesco. 2015. 'Dismissing Return Periods!' *Stochastic Environmental Research and Risk Assessment* 29 (4): 1179–89. https://doi.org/10.1007/s00477-014-0916-1.

Speiser, Joshua. 2018. 'Eight Years After the Haiti Earthquake, Progress and Challenges'. *From The Prow* (blog). 12 January 2018. https://fromtheprow.agu.org/eight-years-haiti-earthquake-progress-challenges/.

Star, Jonathan, Erika L. Rowland, Mary E. Black, Carolyn A. F. Enquist, Gregg Garfin, Catherine Hawkins Hoffman, Holly Hartmann, Katharine L. Jacobs, Richard H. Moss, and Anne M. Waple. 2016. 'Supporting Adaptation Decisions through Scenario Planning: Enabling the Effective Use of Multiple Methods'. *Climate Risk Management* 13 (January): 88–94. https://doi.org/10.1016/j.crm.2016.08.001.

Suarez, Pablo. 2017. 'It's Time to Rethink the Future of Global Governance through Games'. Thomson Reuters Foundation. 28 November 2017. http://news.trust.org/item/20171128151141-dmc36/.

Tourki, Yousra, Jeffrey Keisler, and Igor Linkov. 2013. 'Scenario Analysis: A Review of Methods and Applications for Engineering and Environmental Systems'. *Environment Systems & Decisions* 33 (1): 3–20. https://doi.org/10.1007/s10669-013-9437-6.

Tuck, Laura. 2016. 'Embracing Uncertainty for Better Decision-Making'. Text. Ppps. 3 October 2016. http://blogs.worldbank.org/ppps/embracing-uncertainty-better-decision-making.

UNISDR. 2015. 'Sendai Framework for Disaster Risk Reduction'. 2015. https://www.unisdr.org/we/coordinate/sendai-framework.

———. 2017. 'Terminology on Disaster Risk Reduction'. UN Office for Disaster Risk Reduction. 2 February 2017. https://www.unisdr.org/we/inform/terminology.

———. 2018. 'Strategic Approach to Capacity Development for Implementation of the Sendai Framework for Disaster RIsk Reduction'. https://www.unisdr.org/files/58211_section4.pdf.

———. n.d. 'What Is Disaster Risk Reduction?' https://www.unisdr.org/who-we-are/what-is-drr.

Van der Helm, Ruud. 2006. 'Towards a Clarification of Probability, Possibility and Plausibility: How Semantics Could Help Futures Practice to Improve'. *Foresight* 8 (3): 17–27. https://doi.org/10.1108/14636680610668045.

Van der Merwe, Louis. 2008. 'Scenario-Based Strategy in Practice: A Framework'. *Advances in Developing Human Resources* 10 (2): 216–39. https://doi.org/10.1177/1523422307313321.

Van Notten, Philip W. F, Jan Rotmans, Marjolein B. A van Asselt, and Dale S Rothman. 2003. 'An Updated Scenario Typology'. *Futures* 35 (5): 423–43. https://doi.org/10.1016/S0016-3287(02)00090-3.

Van Vuuren, Detlef P., Marcel TJ Kok, Bastien Girod, Paul L. Lucas, and Bert de Vries. 2012. 'Scenarios in Global Environmental Assessments: Key Characteristics and Lessons for Future Use'. *Global Environmental Change* 22 (4): 884–95.

Warner, Koko, Laurens M. Bouwer, and Walter Ammann. 2007. 'Financial Services and Disaster Risk Finance: Examples from the Community Level'. *Environmental Hazards* 7 (1): 32–39. https://doi.org/10.1016/j.envhaz.2007.04.006.

Wilson, Elisabeth. 2018. 'EVD - Rwanda Conducts a Full Scale Simulation Exercise'. World Health Organization: Rwanda. 2018. https://www.afro.who.int/news/evd-rwanda-conducts-full-scale-simulation-exercise.

Wood, Lisa, Bryan Boruff, and Helen Smith. 2013. 'When Disaster Strikes ... How Communities Cope and Adapt: A Social Capital Perspective'. In . Nova Science Publishers. https://trove.nla.gov.au/version/259023801.

Zack, Naomi. 2010. *Ethics for Disaster*. Rowman & Littlefield Publishers, Inc., Plymouth, UK. https://books.google.co.uk/books?hl=en&lr=&id=JjBOYQHYVhoC&oi=fnd&pg=PR9&dq=ethics+for+disaster&ots=ny6-PDxydg&sig=r5-SFc8SbNby-LQ1eXf6AtwJMBg#v=onepage&q=ethics for disaster&f=false.

Zastrow, Mark. 2019. 'Fukushima Bosses Cleared over Nuclear Disaster'. *Nature*. https://doi.org/10.1038/d41586-019-02822-y.

Zulkafli, Zed, Katya Perez, Claudia Vitolo, Wouter Buytaert, Timothy Karpouzoglou, Art Dewulf, Bert De Bièvre, Julian Clark, David M. Hannah, and Simrita Shaheed. 2017. 'User-Driven Design of Decision Support Systems for Polycentric Environmental Resources Management'. *Environmental Modelling & Software* 88 (February): 58–73. https://doi.org/10.1016/j.envsoft.2016.10.012.

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