D1.3 AGILE's approach to HILPs

Part 2: Strategic foresight, lateral thinking and creativity

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Abstract

This deliverable explores AGILE's approach to managing high-impact, low-probability (HILP) events through a combination of theoretical perspectives, empirical insights, and scenario development guidelines. Building on previous research within the project, it further explores HILPs as the products of systemic, cascading, and compounding risk, necessitating flexible and foresight-driven approaches. The deliverable examines how HILP events interact with critical infrastructure dependencies, social vulnerabilities, and risk perception challenges, highlighting the importance of creative and lateral thinking in scenario planning.

The report is structured around key themes, beginning with a theoretical analysis of cascading effects, compounding hazards, and the systemic challenges they present. It situates HILPs within broader debates on disaster risk reduction (DRR), resilience, and emergency preparedness, showing how traditional models of risk management struggle to address the unpredictability and complexity of these events. Strategic foresight, lateral thinking, and scenario development are identified as essential tools for enhancing preparedness, with a focus on integrating interdisciplinary perspectives. The report also considers risk communication challenges and the role of artificial intelligence in enhancing early warning systems, decision support, and scenario modelling.

Empirical insights are drawn from expert interviews, providing practical perspectives on the use of scenario-based approaches in disaster preparedness. The report outlines existing gaps in HILP scenario-building, noting that such scenarios remain rare despite their potential for improving resilience. It discusses barriers such as institutional resistance, lack of engagement from decision-makers, and the challenge of sustaining interest in low-probability events. Recommendations emphasise the need for structured methodologies that incorporate strategic foresight, counterfactual analysis, and red teaming to stress-test assumptions about future risks.

The deliverable concludes with practical guidelines for developing scenarios that improve planning and preparedness for HILPs. It advocates for a cross-boundary approach that engages multiple stakeholders across sectors, integrates creative thinking to explore non-linear risk pathways, and prioritises learning from past disasters. The findings directly support AGILE's wider objectives, particularly in

scenario-building and training activities under WP3, WP4, and WP5. By addressing both theoretical and practical dimensions of HILP risk management, this report provides a foundation for advancing resilience-oriented strategies that move beyond traditional risk assessment towards more dynamic, adaptive, and systemic approaches.

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R: document, report (excluding periodic and final reports).
DEM: demonstrator, pilot, prototype, plan designs.
DEC: websites, patent filings, press and media actions, videos, etc.
OTHER: software, technical diagrams, etc.

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Abbreviations

AGILE	Agnostic risk management for high Impact Low probability Events
HILP	High-Impact, Low-Probability
HIHP	High Impact High Probability
SOTA	State of the Art
SWOT	Strengths, Weaknesses, Opportunities, and Threats
WP	Work Package

Glossary

Core Disaster Risk Concepts

- **HILP (High-Impact, Low-Probability) events** – High Impact Low Probability (HILP) events are context-dependent shocks that must be assessed in proportion to the specific realities they affect. These events occur infrequently and are marked by high levels of uncertainty in both their predictability and impacts, often bringing an element of surprise or anomaly within their context. Their impact is best understood in terms of disruptions to critical services or essential social functions, where existing vulnerabilities and capacities play a crucial role in shaping the outcome and progression of the crises
- **HIHP (High-Impact, High-Probability) events** – Disasters that occur frequently and have severe consequences, such as seasonal hurricanes or chronic urban flooding.
- **Cascading effects** – A process where an initial disruption triggers a chain reaction, leading to secondary and tertiary impacts, often amplifying the disaster's consequences.
- **Compounding hazards** – Situations where multiple hazards interact, either simultaneously or sequentially, to create more severe impacts than any single hazard alone.
- **Systemic risk** – Risks that arise from interconnected systems, where failure in one component (e.g., energy grid failure) can propagate across multiple sectors (e.g., transport, healthcare).
- **Tipping points** – Critical thresholds in a system, beyond which irreversible changes occur, such as the collapse of ecosystems or the breakdown of governance structures during a crisis.

- **Existential risk** – Risks that threaten the survival of human civilisation or cause irreversible societal collapse, such as nuclear war or global pandemics.
- **Multi-hazard risk models** – Analytical tools used to assess risks from multiple hazards occurring in parallel or sequentially, considering their interactions and potential amplifications.
- **Cascading disasters** – Disasters in which secondary impacts exceed the original hazard in severity, such as the Fukushima nuclear meltdown following the 2011 Tōhoku earthquake and tsunami.
- **Compound risk** – The combination of multiple risk factors, such as climate change exacerbating social inequalities, increasing vulnerability to extreme weather events.
- **Interconnected risk** – Risks that arise from interdependencies between systems, such as how a financial crisis might weaken disaster preparedness and response capacity.
- **Networked vulnerabilities** – Weaknesses in a system that increase the risk of cascading failures, such as a cyberattack disrupting emergency communication networks.
- **Critical infrastructure dependencies** – The reliance of key societal functions (e.g., healthcare, transport, finance) on interconnected systems such as power grids, water supplies, and telecommunications.
- **Trigger points** – Specific conditions or thresholds that, once reached, initiate a significant shift in a system, such as the failure of a financial institution triggering an economic crisis or a specific temperature rise leading to ice sheet collapse.

Risk Management and Governance

- **Risk perception** – The way individuals and societies interpret and respond to risks, influenced by factors such as culture, experience, and trust in authorities.
- **Risk communication** – Strategies for conveying risk-related information to stakeholders, including the public, policymakers, and emergency responders, to improve preparedness and response.
- **Strategic foresight** – A structured approach to anticipating and preparing for future risks by analysing trends, weak signals, and potential future scenarios.
- **Scenario-based planning** – A method for preparing for future disasters by developing and analysing different hypothetical scenarios to improve decision-making.
- **Red teaming** – A structured technique where an independent group critically evaluates plans, assumptions, or risk management strategies to identify vulnerabilities and improve resilience.
- **Counterfactual analysis** – The systematic exploration of "what if" scenarios to understand how different decisions or interventions could have altered the course of past disasters or could shape future outcomes.
- **Panarchy** – A framework for understanding how systems (ecological, social, or economic) operate at different scales and how they can adapt, collapse, or transform following a disaster.
- **Stress testing (in resilience and disaster management)** – Simulated exercises to evaluate the robustness of systems, policies, or organisations under extreme conditions.
- **Adaptive risk governance** – A flexible and iterative approach to managing risks in uncertain environments, integrating learning and stakeholder collaboration.
- **Resilience (in disaster risk management context)** – The ability of a community, system, or society to withstand, adapt to, and recover from shocks while maintaining essential functions.
- **Transformative adaptation** – Adaptation strategies that go beyond incremental changes and instead lead to fundamental shifts in systems, policies, or behaviours to reduce disaster risk.
- **Vulnerability-led approach** – A focus on addressing underlying social, economic, and institutional vulnerabilities rather than just mitigating hazards, ensuring disaster risk reduction is inclusive and equitable.

- **Risk tolerance** – The level of risk an organisation, government, or community is willing to accept before taking action, balancing preparedness investments with the likelihood and impact of potential threats.
- **Feedback loops** – Processes in which an event's consequences reinforce (positive feedback) or counteract (negative feedback) the original cause, such as warming oceans leading to increased ice melt, which further accelerates climate change.

Decision-Making, AI, and Advanced Analytics

- **Explainable AI** – Artificial intelligence systems designed to provide transparent and understandable outputs, increasing trust and usability in disaster risk management applications.
- **Digital twins** – Virtual models of real-world systems (e.g., cities, infrastructure) used to simulate disaster scenarios and improve risk management planning.
- **Contagion effects (in disaster and risk science)** – The spread of risk across interconnected systems, such as how financial instability in one country can trigger economic crises elsewhere.
- **Thresholds (in climate and disaster risk context)** – The points at which gradual changes in environmental or social conditions result in sudden, often irreversible shifts, such as the collapse of ice sheets or widespread migration due to climate change.

1. Introduction

This deliverable aims to deepen the theoretical understanding of resilience to high-impact, low-probability (HILP) events, with a focus on HILP management and governance. Its ultimate goal is to facilitate the operational transition from traditional risk management to resilience management. This deliverable builds on the findings of Task 1.1 (published in Deliverable 1.1), which conceptualised and defined HILP as compound, cascading and systemic risk, developed a taxonomy, and identified common conditions between HILP and high impact high probability (HIHP) events. It also builds on the initial findings of Task 1.2 (published in Deliverable 1.2) which provided an overview of the state of the art (SOTA) in HILP research as well as an empirical analysis of the strengths, weaknesses, opportunities, and threats (SWOT) of HILP management, as a consistent approach for assessing drivers of escalation and common point of failure. This deliverable completes task 1.2 by further theorizing HILPS and defining the possible use of creative/lateral thinking for systematising an approach to tabletop exercises and scenario building. It does so on the basis of a series of theoretical perspectives on HILPs as well as an empirical analysis of expert interviews. It concludes with a set of guidelines on scenario development. The results of Deliverable 1.3 will directly inform other work packages, particularly WP3, WP4, and WP5, in areas such as scenario building and training.

2. Theoretical Perspectives on HILPs

Introduction

Theoretical perspectives on high-impact, low-probability (HILP) events highlight how cascading effects, compounding hazards, and interconnected systems increase the complexity of disasters. Originating from studies in the mid-20th century, research has expanded to explore the dynamic role of societal vulnerability, with scholars noting that natural, human-made, or hybrid categories of disasters often fall short in capturing this complexity. As systems and dependencies grow more intricate, understanding how one event can trigger cascading failures—like infrastructure disruptions or supply chain breakdowns—becomes essential. Recent theoretical models call for adaptive risk governance and scenario-based planning to address these interdependencies and anticipate "tipping points," where accumulated stressors may irreversibly alter system stability, shifting disaster management toward resilience across multiple domains. The sections below discuss resilience to HILPs, each taking a different angle. In order, they focus on cascading effects, compounding events, and system challenges; cascading social impacts; emergency preparedness and management, foresight and the role of scenario building; HILPS and climate change; the use of AI; risk perception and communication; existential risk; panarchies, systems, and resilience; and a contribution by Tohoku University (tbc).

Cascading effects, compounding, and system challenges

by Gianluca Pescaroli

The exploration of the interplay among different types of hazards got underway during the 1960s and 1970s and defined how the root causes of disasters may lie in the societal and organizational domains of vulnerability (Hewitt, 1983). Scholars noted that consideration of each impact needs

to be contextualized in terms of its root causes as these could create feedback in the disaster management and recovery process (Alexander, 2000). Thus, categorizing disasters as merely natural, human-made, or hybrid appears to be reductive and requires a broader understanding of what could be the common elements that could interact together (Shaluf, 2007). On one hand, it is known that crises and events develop in the physical domain and have complex physical interactions. For example, a single major earthquake could trigger many landslides. Rock avalanches could obstruct rivers, resulting in catastrophic outburst floods (Gill & Malamud, 2014; Ward et al., 2020). On the other hand, a paradigm shift in global dynamics has led many researchers to acknowledge that the relationship between the magnitude and frequency of hazards is characterized by developing patterns, entailing the dynamic role of vulnerability as a premise for understanding the nature of disasters (Birkmann et al., 2014). This materializes across various dimensions, encompassing physical, structural, environmental, social, psychological, and institutional aspects across diverse temporal and spatial scales. While climate change might amplify the occurrence of natural hazards, a similar concern arises from a dependency on interconnected networks and the consequences that might arise if they malfunction while an emergency is in progress (Linkov et al., 2014).

In the 1st decades of the 21st century, the idea of cascading effects has been used in different fields and has become relatively widely diffused. It was first used significantly in the mid-20th century in the chemical industry and was part of the idea that accidents could trigger a "domino effect" based on the reactions of different components (Reniers & Cozzani, 2013). The concept of cascading effects as "uncontrolled chain losses" emerged in the 1980s, alluding to the vulnerability of information flows in networked systems (Millen & Schwartz, 1988). Simultaneously, the theory of "normal accidents" incorporated cascading failures in the way that it described major mishaps in intricate technological systems (Perrow, 1999).

A research field that increased significatively in its relevance is the one of cascading disasters that can be regarded as those events that are distinguished by the non-linear escalation of secondary emergencies, in which the progression of the crisis creates new challenges for emergency management (Pescaroli & Alexander, 2016). A key factor that amplifies the effects of an initial triggering event is the disruption of critical infrastructure and the vital assets and systems that are essential to the functioning of society, from system failures to situations that require the activation of continuity protocols designed to foster recovery and restoration. The interlinked series of adaptation cycles triggered by the vulnerabilities is termed "panarchy," largely because it acts at different geographical scales (Pescaroli & Alexander, 2016). Complete adaptation of the system is unlikely to occur. Hence, the interplay of vulnerabilities can escalate to the point of "panarchical collapse," culminating in disaster. Convergence and the overlap of vulnerabilities create escalation points (Pescaroli & Alexander, 2016). In cascading disasters, secondary effects frequently become new sources of impact. They may have the potential to surpass the gravity of the original trigger.

The Tōhoku triple disaster in Japan exemplifies a comprehensive cascading event (Pescaroli & Alexander, 2016, 2018). A magnitude 9 earthquake struck northeastern Honshu on March 11, 2011. While the earthquake caused approximately 100 casualties, the ensuing tsunami resulted in the deaths of at least 19,360 individuals, with an additional 2,569 listed as missing. Among other effects, it created a massive debris field in the Pacific Ocean, disrupted automotive production in European factories, and triggered enduring radioactive contamination and social challenges. The

uncontrolled release of radiation from the meltdown at the Fukushima Daiichi power plant might eventually stand as the disaster's most enduring legacy, and the cleanup process is expected to last for up to 50 years.

A second case that will be remembered for the escalation of the secondary events is the eruption of the Eyjafjallajökull volcano in April 2010, which led to the suspension of flights to and from 70% of Europe's airports for almost a week (Alexander, 2013). While the primary impact of the event was limited, approximately 8.5 million passengers were stranded. There were disruptions of critical supply such as the delivery of bone marrow for transplant. Industrial, cultural, and business activities were thwarted. In the mid-1820s, Eyjafjallajökull erupted continuously for 13 months. Moreover, it is not one of the largest, most dangerous, or most active of the Icelandic volcanoes. Despite the risk, there is still no detailed planning to cope with extended periods without air travel and evaluate the potential consequences of such a situation (Alexander, 2013).

The disruption of forms of infrastructure such as the energy sector can have wider consequences than others. In 2017, Hurricane Maria in Puerto Rico triggered power failures that left millions of customers without electricity and affected all forms of social and organizational situations, causing profound losses in the availability of services (Kwasinski et al., 2019). Finally, an example, with multiple dynamics can be derived from Texas in the United States in early February 2021 (Kemabonta, 2021). During the novel coronavirus pandemic, winter storm Uri struck the region.2 A peak in electricity consumption showed the inadequate measures undertaken for preparing the electricity grid for cold weather and winter. Millions of households and businesses were without essential utilities while a second storm struck the area. Hospitals operated on emergency generators, causing disruptions, including delays in vaccination and difficulties in managing the response to the novel coronavirus pandemic. Moving forward, most disasters are expected to be cascading events to varying degrees. This arises from the substantial reliance of modern society on intricate networks, as well as the combination of different patterns in the anthropogenic and natural domains (Felsenstein et al., 2020). Diverse hazards, ranging from storms to cyberattacks, have the potential to interact together. Beyond their domains lies the uncharted territory of the socioeconomic consequences arising from such failures.

A broader view was proposed by the International Risk Governance Council, which suggested an approach to risk governance that integrated the evaluation of cascading risk into resilience-driven strategies that were able to support the development of well-thought-out management actions (Florin & Linkov, 2018). Cascading disasters were increasingly recognized in terms of the overlap between different patterns of activity. They required a better understanding of how their characteristics could interact with other mechanisms of the human socioeconomic system (Pescaroli & Alexander, 2018). Pescaroli and Alexander (2018) suggest the existence of differences and complementarities between four categories of risks: (a) compound risk, involving the interaction or concurrency of different extreme events, such as climate change, drought, and wildfires; (b) interacting or consecutive risk that involves environmental drivers, such as seismically induced landslides; (c) interconnected risk, which covers the interaction of natural and human systems, such as various forms of networked interaction; and (d) cascading risk, distinguished by the disruption of critical infrastructure, or disruptions in closely linked organizational systems that cause the escalation of the crisis (e.g., electrical power blackouts). Complex crises may involve elements of any or all four previous categories and may require close collaboration between academic disciplines if they are to be understood in terms of their various components. The concept of "cascading disasters" implies that what is known as "business as

usual" in crisis management may have changed radically. A few months before the novel coronavirus pandemic, the first lines of the UN GAR stated that "surprise is the new normal" and "threats that were once considered inconceivable, no longer are" (UNDRR, 2019, p. iv).

It is commonly accepted that climate change implies a new uncharted territory in the patterns of compound and interacting hazards, but it must be understood that this will impact society increasingly through its dependency upon networks, with ever greater consequences if they fail. In other words, the evolution of the operational environment implies that the magnitude–frequency relationship is regarded as dynamic. Not only does the geographical manifestation of hazards become more intricate due to changing patterns of impact, but the complexities of vulnerability also increase. The dynamic nature of vulnerability becomes evident when a triggering event reveals the changes that have occurred since the last disaster. Society's dependency on critical infrastructure is nothing new. Historical assets such as aqueducts have been significant since the Roman era and have undergone shifts in prominence during various historical periods. At the other end of the timescale, during the Cold War, there was an emphasis on safeguarding power plants (Setola et al., 2016). The potential consequences of disturbances of critical infrastructure have been amplified by the increasing influence of information technology, the privatization of utilities, rapid urbanization, and ever more intricate interdependencies among services. In the United States in the late 1990s, the Clinton administration acknowledged this paradigm shift through Presidential Decision Directive PDD-63, which fostered collaboration with countries such as Canada (Setola et al., 2016). Failures of infrastructure can propagate across sectors and domains such as food storage, banking, water and sewage systems, fuel supply, telecommunications, and transportation (Luiijf et al., 2009; Peters et al., 2008; Rinaldi et al., 2001). This is not just a question of technical problems but is also a matter of human and organizational factors that are manifested in points of vulnerability that encompass hardware, software, and services and are influenced by management decisions as they are made (Little, 2002). Technical disturbances can magnify the repercussions of localized disasters on wider crises due to the intricate interplay within networks, such as the interaction between lifelines, supply chains, and emergency responses (Egan, 2007). For example, the amplification of demands on response systems caused by failures of critical infrastructure can be reduced by better coordination and communication (Ansell et al., 2010). As mentioned in the sections "Distinguishing Patterns of Cascading Disasters" and "From Cascading Effects to Cascading Disasters," critical infrastructure disruptions can spiral into escalated crises with both direct implications, such as service interruptions, and indirect ones, such as the possibility that new emergencies will be triggered by damage to vulnerable equipment in industrial settings (Pescaroli & Alexander, 2016; Pescaroli et al., 2018).

In this complex web of threats, concepts such as "black swans" (unforeseen high-impact, low-probability events) have been proposed (Taleb, 2007). However, they have limitations because unforeseen events are not without precursors, they may have been simply not foreseen. Sornette (2009) suggested that extreme scenarios might be more frequent than initially thought and may have common underlying factors. The foundation of common probabilistic risk assessment methods, the power-law model, could overlook a set of occurrences known as "dragon kings." These events have distinct amplifying mechanisms, which, although they are variable, can nevertheless be analysed. While it is challenging to predict the initial triggers, it has been shown that chain reactions often emerge in vulnerable areas of the system in which inflexibilities have built up. Despite the limited ability to predict the triggering events, cascades tend to manifest

themselves in a system's weak points, often through the accumulation of vulnerability over time. Consequently, amelioration strategies should target these weak points, especially within interconnected parts of critical infrastructure, rather than merely endeavouring to control primary hazards (Hynes et al., 2020; Linkov et al., 2014; Pescaroli & Alexander, 2016, 2018; Pescaroli et al., 2023).

An illustrative example to understand this process is that of space weather. In 2012, an event akin to the huge coronal mass ejection of 1859 (the "Carrington event") narrowly missed Earth (Russel et al., 2013). Had it impacted Earth it could have triggered widespread disruptions of global positioning systems, satellites, telecommunications, and power supplies. An event of such magnitude would carry an energy content 150 billion times greater than that of the Hiroshima nuclear bomb (Smart et al., 2006). This could result in a serious disruption of common technology by geomagnetic-induced currents and ionizing radiation. Unfortunately, the extent of dependence on the affected technologies is inadequately mapped, and this could lead to unexpected complications. Since the 2010s, countries have increasingly embraced cashless transactions via contactless cards and web apps, all of which depend on having a robust information technology foundation (Krausmann et al., 2016). Digital banking, including ATMs and payment gateways, hinges on the presence of stable internet and satellite systems for synchronization. These systems also govern critical tasks such as supply chain management and deliveries. This transforms simple actions such as grocery shopping into intricate processes that rely on space-based infrastructure and technological links. Multiple stakeholders are involved, and they demand additional services, such as a steady energy supply. Crisis management also depends on the constant presence of such services.

The Carrington event, named after Richard Carrington, the amateur astronomer who observed it, serves as an example of the catalyst of a chain-reaction disaster. It must be noted that events as varied as space weather and cyberattacks can potentially induce similar complications (Giannopoulos et al., 2012; Pescaroli et al., 2018). The intricate structure of a networked society, combined with uncertainties from threats such as geomagnetic storms, demands that approaches to crisis management be reconceived. For example, when considering the lessons to be learned from the novel coronavirus pandemic, it could be argued that some common challenges exist in addressing pandemics and seemingly disparate issues such as climate change. Instances include earthquakes in countries like Spain, drought in California, forest fires in China, flash flooding in cities such as Milan and Palermo (Italy), and widespread heatwaves. Europe, in particular, identified shortcomings in preparedness and the effectiveness of response, prompting calls for the development of a more interconnected capacity to measure up to future contingencies. All these scenarios are characterized by abrupt shifts in operational contexts. They occur swiftly across diverse geographical and ecological scales, and they bring nonlinear alterations to the intensity and frequency of hazards (Pescaroli et al., 2023; UNDRR, 2019, 2022). These challenges fall within the domain of systemic and complex risk. Relying solely on precursor events and traditional risk assessment methodologies is increasingly proving to be inadequate because of the evolving patterns of hazards and vulnerabilities, including new patterns of exposure to the former (UNDRR, 2019). Alterations to one system have impacts on the others, creating distinctive trajectories that go beyond what could be learned merely on the basis of precursors (Hynes et al., 2020). In 2020 alone, emergency responders around the world found themselves confronted by the convergence of COVID-19 and other natural hazards, with the added challenge of elevated levels of uncertainty and unpredictability (Pescaroli et al., 2023). New approaches are needed in

order to consider how to develop operational continuity and achieve resilience and how to go beyond traditional forms of risk assessment to find ground for better collaboration.

As society grapples with abrupt changes and transitions, it becomes more and more clear that maintaining the status quo in critical infrastructure systems is not only hazardous but also unacceptable. Policymakers and infrastructure planners must therefore find ways of enhancing the robustness and service delivery of both existing and future infrastructure against multifarious threats, so as to ensure that losses are minimized regardless of when a crisis hits (Woods, 2018). Traditional forms of analysis conducted at the level of individual components of the system might be ineffective for complex critical infrastructure systems, especially when confronted with interrelated threats that may lead to chain reactions (Florin & Linkov, 2018). In industries such as automotive manufacturing, contingency plans for recovering from disruption have routinely sought to predispose recovery from low-likelihood, high-impact events (Simchi-Levi et al., 2018). However, the interlinkages between infrastructures during concurrent events, such as those that happened during the coronavirus pandemic revealed that this may be inadequate (Clark-Ginsberg et al., 2020). It is paramount to understand how systems with compromised functionality can recover and adapt in the face of multiple stressors. One must adopt a "threat- agnostic approach" that addresses the ways in which multiple disruptions develop regardless of what their origins are (Hynes et al., 2020). An important gap to consider is that systems-wide approaches to "resilience" are often mentioned in scholarly studies, but their applications in understanding system recovery and adaptability at a cross-domain level are often overlooked. It has been suggested that "stress testing" could be a possible tool to adopt more consistently to break disciplinary silos and support decision-makers the interplay between systemic risk and cascading disasters is revealing (Linkov, Trump, Trump, Pescaroli, Mavrodieva, et al., 2022).

Stress testing could be used to understand single and multiple points of failure, producing new standardizations and involving grey areas such as those associated with third-party providers. It could be used to merge the different aspects of scenario modelling, risk estimation, and vulnerability assessment with the practical needs of stakeholders (Linkov, Trump, Trump, Pescaroli, Hynes, et al., 2022). The existing approaches to risk assessment, scenario planning, and modelling could be brought together to evaluate the development of potential impacts and thus orient planning for cascading disasters by prompting a better understanding of system-wide resilience (Pescaroli et al., 2023). Stress testing can play hereby a critical role, by helping identify vulnerabilities and interdependencies within critical infrastructure and organisational systems, highlighting coordination or capacity gaps that could undermine resilience. This approach goes beyond traditional risk registers and hazard-oriented assessments by considering "threat- agnostic" or "hazard-agnostic" perspectives. This means focusing on system-wide resilience rather than predicting specific threats. Stress tests systematically analyse crisis scenarios and evaluate mitigation measures to reduce societal risk exposure. They complement computational modelling and network science by offering practical tools for decision-makers who may not have the resources for highly sophisticated analyses. By integrating stress testing into planning processes, decision-makers can visualise potential secondary emergencies, identify common points of failure, and improve cross-sectoral coordination. This contributes to a shift towards operational continuity, ensuring that resilience planning is flexible and responsive to emerging risks rather than being confined to static risk assessments.

In conclusion, promoting a structured approach to stress testing for cascading disasters could also foster collaborative training among organizations. Short-term responses could be aligned with longer term planning, and new ground for collaboration between the social and physical sciences could be opened up.

Challenges for the community: cascading social impacts

by Maureen Fordham and Femke Mulder

The root causes of any disaster (Blaikie et al 1994; Wisner et al 2004) lie in the social, economic and political inequities experienced by residents before a disaster which permeate all actions and stages following (Finch et al 2010). This establishes the conditions for a social cascade of impacts, illustrated here by the example of Hurricane Katrina which hit the Gulf Coast of the United States in August 2005.

Powers (2024), referencing Brinkley (2006), points to weak infrastructure as the disaster agent which led to the cascading impacts that unfolded in Hurricane Katrina:

> 'Hurricane Katrina, like many other disasters, began long before the rain and wind. Its failures began in the weak infrastructure and in the city, state, and federal government agencies that each played a vital role in the city's emergency preparedness for an immediate response to the storm' (Powers 2024: 90).

However, weak infrastructure impacted some social groups more than others. Data in Pastor et al (2006) showed damaged areas were 45.8 percent African American, compared to undamaged areas which were only 26.4 percent (in the city of New Orleans it was 75 percent and 46.2 percent, respectively) and the ratio of households living below the federal poverty line was 20.9 compared to 15.3%; access to cars among poorer Blacks was less than even poor Whites (53% compared to 17% (Pastor et al 2006: 23).[2]

Short case study

Failures in government efforts at various levels to adequately prepare for, respond to, and assist in the aftermath of Katrina exacerbated the hurricane's impact on communities. Research indicates that specific social groups (e.g., based on income, minority status, gender, age, disability, and tenancy) were disproportionately affected (Laska & Morrow, 2006). The recurrent neglect of these groups in disaster management constitutes a common point of failure. It creates *and deepens* the systemic risk these groups face. As a result, a breakdown of one system (e.g., housing) can have a cascading effect on another system (e.g., social support network), with one adverse event leading to another. This case study focuses on income, but it is important to note that social identities intersect. As Finch et al (2010: 181) argue, it was the interaction of multiple vulnerability dimensions (income, race/ethnicity, family structure, housing, amongst others) which created the foundation of whether your preparedness, response and recovery abilities would be sufficient. Due to the legacy of segregation and discriminatory practices, such as redlining, in New

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[2] See LSU Libraries, Hurricane Katrina Impact on Communities
https://guides.lib.lsu.edu/Hurricanes/KatrinaCommunities#:~:text=Large%20percentages%20of%20children%20and,higher%20among%20more%20vulnerable%20populations for a very succinct overview (in just two paragraphs) of the impacts and with suggested further reading from the Library's collections.

Orleans, poverty is concentrated in certain neighbourhoods, particularly those predominantly inhabited by African Americans (DeSalvo et al., 2005).

Low-income groups

The US Government's failure (at all levels) to adequately prepare for, respond to, and assist in the aftermath of Hurricane Katrina led to cascading impacts for poor households, where one adverse situation compounded another, creating a vicious cycle of worsening conditions:

1. **Inadequate Preparation Leading to Increased Vulnerability**: The lack of investment in infrastructure and emergency planning for poor communities meant that these neighbourhoods were more susceptible to severe damage (Comfort, 2005). When the storm hit, poorly maintained homes in flood-prone areas were destroyed or severely damaged, leaving many low-income families homeless.
2. **Inadequate Response Leading to Injury, Illness, or Death:** Many poor families lacked access to reliable transportation and/or the financial resources needed to evacuate (Bakker & McCarthy, 2005). They were therefore forced to stay behind during the storm. In addition, risk communication with these groups was not adequate and evacuation was not well planned or executed. This left them stranded, exposed to life-threatening conditions, including rising floodwaters, lack of electricity, and limited access to food and clean water. This increased their chances of injury, illness, and death.
3. **Inadequate Recovery Assistance Leading to Disrupted Social Networks**: After the storm, the bureaucratic challenges and lack of targeted information or support from the government made it difficult for poor families to access aid (Tobin-Gurnley & Loomis, 2010) and begin the rebuilding process. 'Disasters tend to disproportionately damage rental and low income housing, which also tend to be rebuilt more slowly, if at all, while owner-occupied housing is typically repaired and rebuilt' quickly (Fussell 2015: 1215; Finch et al 2010). Many were unable to repair their homes or find affordable housing, leading to prolonged displacement. This displacement disrupted community networks, increased financial instability, and made it even harder for these families to recover. This resulted in depression, stress, and psychosocial impacts which were greater in African Americans, older adults, women, singles, lower educated, and those with less social capital (Adeola and Picou 2014).

Emergency managers (EM) often fail to understand the differing conditions of different groups in the community and the mechanisms by which these limit people's options. For just one example, if they had a social worker as part of the EM team, they would probably have realised that a significant minority in New Orléans would be unable to self-evacuate because it was near the end of the month before they received their social benefits, including disability benefits. Extra or different resources could have been provided to support them in making a more timely and effective evacuation.

HILPS, emergency preparedness and management: context, foresight, and the role of scenario building

by David Alexander

Introduction

In relation to disasters, this section examines three fundamental concepts: context, foresight and resilience. We live in an epoch of profound change. Some of this is the result of the development of powerful new technologies that human societies are struggling to assimilate. In the human ecological model of disasters (Barrows, 1923; White, 1974) there is a strong emphasis on adaptation to adversity in the social, economic and cultural functions of society. Seldom in human history has there been as great a need for adaptation as there is at present, but the pace of change continues to accelerate. The main purpose of this section is to investigate how general processes of change in the world affect disaster risk reduction and cause a need for change in the way it is practised. This section seeks to specify some of the ways in which that change must occur.

Context

With few, but notable, exceptions, early studies of the human impact of disasters tended to assume the primacy of hazard (or threat) over vulnerability. Indeed, for many years, 'natural hazards' were by far the dominant paradigm (White, 1974). In a linear model of causality, hazards materialised as impacts. To understand disasters, it seemed to be enough to study hazards. The human element of their impacts would take care of itself or be dismissed as a mere consequence of living with hazards. There were exceptions (Prince, 1920), but for decades they gained less traction than did the hazards field. Despite this, in 1923 a very prominent authority made a plea to work towards a 'human ecology' of hazards (Barrows, 1923), according to which people and their communities had to adapt to the threats and constraints posed by hazards. They had to understand natural phenomena and react to them in such a way as to boost safety and security. However, rather than throwing the emphasis onto vulnerability, this had the effect of increasing the primacy of hazards because natural phenomena were seen to dictate the way that people adjust their lives and their risk-taking propensies.

A full 60 years later a major attempt was made to reverse the order of influences. Hazards trigger impacts, but these should be measured in terms of how they reveal human vulnerabilities: lives, well-being, livelihoods, property and environment. This was the 'radical critique' of Hewitt and his colleagues (1983). By introducing feedback and treating hazard impacts merely as the trigger of disaster the power to explain extreme events in terms of what they did to individuals and communities was increased. Nevertheless, the hazards paradigm survived the critique and has persisted in many quarters ever since. Its basis was the weak and very American model of man as rationalist, or to be more precise as 'optimiser' or 'satisficer' (Simon 1956) - and it was man, in a very unmodern view of gender. This also left no room for cultural differences and offered little opportunity to explore other ways of thinking about how people viewed the threat and impact of disaster (Butzer, 2012). Despite the proposition that vulnerability is the essence of disaster risk, for half a century, disaster studies went ahead with a theoretical framework that was largely derived during the heyday of the natural hazards' paradigm, the 1960s and 1970s. By the second decade of the 21st century, it risked being completely out of step with a world in which profound changes were taking place. The very least that had to happen was that complexity needed to be introduced into the model. In a society that is dependent on networks for the dissemination of information, commerce and social relations, the disruption of those networks would cause effects

to proliferate in the form of cascades of impact (Alexander and Pescaroli, 2019). Notwithstanding the huge strides that have been made in modelling cascading disasters, systemic risks, coincident impacts and other such mechanisms, there is still a missing element, and that is context (Paul, 2011). We can define 'context' as the social, economic, cultural, psychological and environmental milieu that surrounds disaster risk and to some degree interacts with it. If necessary, we can disaggregate different types of context. However, overall, it should be considered as the sum of elements that have no direct causal relationship with disaster but, paradoxically, are (or should be) essential to any attempt to explain it. Thus, context governs or channels the decision making and the actions or reactions that occur in response to disasters or disaster risk (Lavel, 2012).

Unfortunately, it is rare to see context taken fully into account in investigations of disasters. One of the most persistent attitudes is that all we need is to supply decision makers with information on how to reduce disaster risk and it will be reduced. On the contrary, despite enormous increases in the availability of know-how over the years, there has been a failure to bring disaster risk under control. Knowledge may be an essential ingredient of disaster risk reduction but evidently it is not the key. Despite this, there are few studies of why knowledge is not utilised when it is there and ready to provide the solutions to problems. Some of the existing research deals with corruption and its effects (e.g., Escaleras et al., 2007). In fact, corruption is one of the most powerful forms of context because it is insidious and occult, and it debilitates any attempt to make progress in promoting safety against major hazards (Sanderson et al., 2022). Having briefly considered the theoretical basis of context in disaster studies, let us now address some of the realities in the modern world.

Disasters and the End of the Second Age of Enlightenment

We live in the New Baroque Age. This is the result of remarkable parallels between the culture that gave rise to the original Baroque period and present-day society. My understanding of the Baroque comes from the work of a Spanish historian (Maravall, 1986) who was one of the few people to analyse Baroque culture. The Baroque, which lasted from the early 1600s to the mid-1700s and ended with the Rócoco phase, was fuelled by the tension of opposites. Perhaps the greatest contrast, and the source of much tension and change, is that between extreme wealth and extreme poverty (Allegre, 2007). It was therefore a culture of great contrasts but also great creativity that stemmed, at least in part, from those contrasts (Topazio, 1977). There are parallels in the 21st century (Gray, 2007). I am not arguing that history repeats itself. Clearly it does not, but it does seem to have its own Circadian rhythms. The idea of a New Baroque Age was intended to be a key to the interpretation of what is going on in our world, including in disaster studies. However, in the middle of the 2010s, things began to change. The old Baroque partially coincided with the Age of Enlightenment (Whatmore 2023). What we are now seeing is the end of the Second Age of Enlightenment.

As argued above, we cannot understand disasters without understanding their context (Meyer 2008). The degree of influence of context is often fundamental and sometimes overwhelming. For long, we have underestimated or ignored the role of context. For instance, it does not appear in any direct form in the pressure and-release (PAR) model (Wisner et al., 2004), which is the popular theoretical framework for understanding disasters. To understand disasters, we need to look wider than root causes, dynamic pressures and unsafe conditions. We need to look at how society functions. We need to do so because disaster is a social phenomenon, and we must try to understand why decisions are made in certain ways. The connection with the ingredients of the

PAR model is at first analysis tenuous, but in reality it is profound as we cannot separate decisions and their consequences from the context in which they are made. To do so would be to interpret them as irrational (Slovic et al., 2000).

Foresight

Because we are dealing, not merely with the present, but with the future, we need to exercise foresight. That is not a question of predicting the future but of identifying and evaluating trends and weak signals which could become important. I recall that in the 1960s, when I was finishing school, society's preoccupations were radically different to those that prevail now. Issues that are taken for granted as important now were then unconsidered. To have raised them would have led to ridicule--and in fact in some cases it did. The lesson here is that what concerns us now may not exactly coincide with the main preoccupations in a future moment. Over time, society's priorities shift.

The end of the Second Age of Enlightenment involves rising tension, proliferating authoritarianism (erroneously supposed to be a remedy to the tension but instead fuelling it) and something called anomie (Marks, 1974). Long ago, the French sociologist Emile Durkheim resurrected this ancient word in his investigation into labour (Durkheim 1893). With respect to disasters, we can regard anomie as a loss of the faculty of governance as a result of the abandonment of standards and principles. It is a route to anarchy and incapacity. Governance, a word that in the 14th century simply meant 'government', has accumulated overtones of the public or private corporate control of events and processes. Anomie can be regarded as lack or failure of governance, the system by which our lives are directed (whether democratically or not). It is a consequence of the abandonment of moral purpose. Consider the current state of society. The birth of social media in the late 2000s was heralded with great optimism (Alexander, 2014). Some still regard the present day as a "golden age of communication", given the ease with which one can achieve interaction with other people--at least for those with free access to the technological means of communicating. Since the mid-2010s social media have been generating 'parallel realities'. A simple mechanism is at work. If enough people espouse an idea, it may not become true in any objective sense, but the idea may acquire a life of its own that invites people to believe it. These 'alternative realities' have begun to proliferate, and their "realness" is a function of their ability to disrupt. Hence, simply because something is clearly untrue does not mean that it should not be taken seriously. The power of misinformation is compounded enormously by the ability of modern networks to spread it, and by their relative or absolute lack of governance. There is a robust positive feedback mechanism (i.e., one which is self-reinforcing) by which misinformation or disinformation consolidates itself by inculcating belief among ever more of the credulous. Meanwhile, conditions deteriorate (Venegas-Vera et al., 2020).

Let us start with the United Kingdom. The journalist Rafael Behr (2023) commented rather ironically that British culture is noted for its stoical indifference to suffering--especially the suffering of other people. For decades in Britain there has been a process of transferring wealth from the poor to the rich. There are now 14.4 million people who are poor, including many children. They are often hungry, cold and diseased. Forty per cent of them, including a million children, are destitute, defined as being unable to purchase all the basic necessities of civilised life. This situation has been repeatedly denounced by the United Nations (Alston 2019), but it has continued to worsen. Meanwhile the number of billionaires domiciled in Britain continues to rise. In 2023 there were 177, 24 more than in 2020. Moving to continental Europe, it is probable that Hungary's

espousal of fascism merits ejecting the country from the European Union. The main argument against doing so is that this would be a victory for Russia and would enable the dictatorship of Vladimir Putin to gain a bridgehead in central Europe. A lack of unity between neighbouring countries not only points to a dangerous growth of opposing purposes but also to a failure to govern to the same standards, or in some cases any positive standards at all. It also weakens the collective effort to bring the problem of disasters under control (Dhungana and Curato 2021).

A possible consequence of the deterioration of standards is the growth of an economy that would exploit such a situation. At the global scale, the virtually limitless demand for narcotic drugs has led to a parallel economy of exceptional ruthlessness. Cocaine, for example, devastates tropical environments, especially species-rich rainforests. It kills and impoverishes farmers, starts and propagates wars, and leads to phenomenally high murder rates. Cocaine itself is a highly persistent toxin that contaminates aquatic environments. Hence it is not unreasonable to argue that unregulated cocaine use is, among other things, murder by proxy (Arias and Grisaffi 2021). About one fifth of the global economy is illicit, and the drug trade represents slightly less than half of that. However, wealth acquired illegitimately is cycled back into the regular global economy by laundering it. With its lax controls, London is the money laundering capital of the world and is further enhanced in this role by its connection to the 12 British territories that are tax havens, including some of the most successful of the 87 such places. In London, 4,629 mafia groups have been identified, and the total annual throughput of laundered money is about £90 billion (NCA 2020). The mafias of organised crime thrive by the parallel activities of unfettered criminal activity and apparently legitimate investment in 'clean' activities.

Democracy is in serious retreat around the world. In fact, the bases of organised crime are now more powerful and more stable than those of democratic institutions. In Britain, for example, the country lacks a constitution and an elected upper house. Politics are riddled with corruption and as a result there is very little public trust in politicians. In other countries, a leader can dominate by providing governance (of a sort) for criminal syndicates, corrupt government and the owners of extreme wealth, sometimes labelled oligarchs. These three pillars may be sufficient to rule and run a vast piece of territory autocratically. Meanwhile, the number of fully democratic countries has diminished from 27 to 23, less than 12 per cent of the world's nations. This is important because the governance of disasters depends on human rights, which guarantee access to knowledge and ability to act in favour of disaster risk reduction. Too often the forces that combat disasters are seen as rival forces to those of repressive regimes. During the Covid pandemic, billionaires enriched themselves at the rate of 24 per cent per year. We are now on the way to the first trillionaire. The imbalance in the global distribution of wealth has not only increased continuously since 1970-1973, in doing so it has accelerated the wealth differential between the extremely rich and the rest of us (Konings et al., 2021). In a decade the number of fully democratic countries in the world has declined from 29 (14.9%) to 23 (11.7%) (Shenkkan and Repucci, 2019). Moreover, COVID-19 was responsible for a significant increase in authoritarianism, repression and human rights violations in 88 countries (45.1%) ((Clay et al., 2022; Chiozza and King, 2022; Elshobake, 2022)). Democracy is important to disaster risk reduction because it allows access to information on disasters and the ability to act in order to reduce their impacts. Lack of democracy reduces a population's resilience.

In 2023 the UK House of Lords set up a select committee to look into British assessment of risk and planning to manage it (House of Lords 2021). In the gathering of knowledge and opinion for

the committee's report, 94 witnesses were interviewed. Most of them were public administrators, risk managers, heads of industry and politicians. Four were novelists. Herein is a lesson. The novelist Frederick Forsyth (who was not one of those interviewed) wrote a spy thriller called Icon. This lengthy peroration detailed with surprising accuracy what would happen in Russia over the period 2022-2024: a failed coup d'etat, political incarcerations and assassinations, massive corruption, autocracy and kleptocracy, private armies, and so on. The surprising thing is that it was written and published in 1996 (Forsyth 1996). Forsyth's foresight was the result of encyclopaedic knowledge of strategic factors at the world scale, very diligent research and absolute precision in writing the story. As with the testimony of the novelists interviewed by the parliamentary committee, it demonstrates that even fiction has a role in seriously assessing the future. In the context of future disasters, foresight involves the creation (more or less rigorously) of scenarios of future events for the purposes of planning risk reduction and disaster response, as well, perhaps, as recovery processes. There are at least 35 methodologies that can be employed to deliver foresight. They include, for example, counter-factual analysis (Woo, 2018), a structured way of asking "what if?". We need to develop scenarios for possible future events, in suites that vary from 'best case' to worst case'. The scenarios should use systems theory as a means of ensuring formal rigour and should include response as well as the impact of extreme events (Alexander, 2016, Ch. 6).

The process of feeding scenarios into emergency plans provokes some difficult decisions, for example, regarding the size of event for which one can plan[3]. The tendency in emergency planning is to make provision for the sort of event that occurs about once in a decade, or at most, once or twice in a century. It is time to revisit this strategy in the light of the increasing frequency and magnitude of adverse events. Although preparing for enormous events is neither practicable nor affordable, something more can be done, and the benefits are bound to outweigh the costs. Such is the velocity of change in threats and hazards that the demonstration of this is likely to occur sooner rather than later. Rapid change is creating a situation in which there are no longer fixed points on which to base our analysis. Hence, major concepts need to be re-evaluated. One of these is resilience.

Resilience

Resilience is an ancient concept; one in fact whose history extends over at least 2090 years (Alexander 2013). It was first used in a scientific manner in the English language in 1625 (Bacon 1624, p. 245). It became popular in disaster risk reduction between 1981 and 2003. Now there are resilience officers in many organisations, and it is the official goal of numerous bodies, entire countries even. The problem is that resilience is an illusion. Here, I am not trying to discredit attempts to protect people and things against disaster. They are usually perfectly legitimate and justified. However, resilience is a concept that on several levels does not work. Many studies of resilience in disaster risk reduction use the formulation provided by the Canadian-US ecologist Crawford Stanley Holling (Holling 1973). Indeed, not a few authors have credited Holling with having invented the concept of resilience (which at the time was at least 2030 years old). Holling wrote his seminal paper at a time when two developments were causing much debate in the field of ecology. One was James Lovelock's Gaia hypothesis. Although Lovelock did not publish his full manifesto until 1979 (Lovelock 1979), he did produce papers on aspects of the theory from the

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[3] A key focus of WP5 on Evidence-Based Planning is determining how foresight thinking should be integrated into emergency plans for HILP events.

beginning of the 1970s. The essence of Gaia is that the earth's natural living systems tend towards equilibrium. They invoke homeostasis. In the early 1970s this idea was much tested on small tropical islands. These have the advantage of rapid vegetative growth and the fact that they are open systems for energy, but not for mass. Holling evoked homeostasis in his formulation. However, once the concept was transferred to social science it met a situation in which systems do not tend towards equilibrium. They suffer constant shocks, and they trend. The concept of resilience has been widely misused in disaster studies. Hence its interpretative power is severely limited. That is one way in which resilience is illusory. Consider a very simple example of another. In the late 2020s a large undersea earthquake occurs off the eastern coast of Honshu roughly at the latitude of Tokyo. A six metre tsunami is generated. Warning, evacuation and systems of robust sea walls substantially limit the damage and toll of casualties. in fact, the damage and casualties are mainly the result of the shower of long-range missiles launched by North Korea, and the fallout of the Chinese reconquest of Taiwan and some peripheral Japanese islands. The ability to counter the effect of disasters is a function of the tension of opposites: factors that create vulnerability and those that reduce it (hence the New Baroque Age). The wild card in this process is perception, which can go either way. Gentle reader, you may imagine where it is going during a period of history in which anomie looms. Confirmation of this can be found in the introduction to the midterm review of the Sendai Framework for Disaster Risk Reduction. The head of UNDRR, Ms Mami Mizutori, wrote that in parts of the world progress has stalled and in some cases gone backwards (Mizutori, 2023, p. 5). I would argue that, in disaster risk reduction, resilience needs a homeostatic mechanism in order to function. If the determinants of stability keep changing (i.e., things trend upwards or downwards) that mechanism is easily lost. For a start 'bounce back' becomes impossible. 'Bounce forward' may be attainable, but only if it is based on highly successful foresight (Manyena et al., 2011). Dealing with disaster then becomes a matter of constant adaptation, coupled with some 'hardening' in order to resist impacts. The creation of high sea walls along the east coast of Honshu is 'hardening' on an impressive scale that few other countries can or would support with adequate resources (Haphuriwat and Bier 2011). Resilience should be dispensed with because it gives an illusory sense that safety and security are within our grasp.

What, then, is the alternative? The answer is to return to a concept that was paramount for three quarters of the last 40 years: vulnerability. Those of us who have a vested interest in keeping disasters neutral and apolitical tend to cleave to the study of hazards, which in Hewitt's seminal work of 1983 was shown to be the trigger but not the essence of disaster (Hewitt 1983).

Over the years, vulnerability as a concept has had a rougher ride than have hazard and threat. In part this is because much more has been invested in hazard control, while at the same time the factors that create vulnerability have prospered and proliferated. In part it is because we have taken far too narrow a view of vulnerability. What we need to do is to distinguish specific vulnerability (e.g., to floods) from general vulnerability (to all other negative threats) and then conjoin them. General vulnerability becomes a context for specific vulnerability. In other words, it is of relatively little use to make a person safe against floods if the person is homeless, unemployed and in poor health. The exercise is likely to fail on the grounds that the safety provided is outweighed by the other threats and hazards that the person undergoes.

Conclusions

In 1953, when I was born, the population of the world was 2.6 billion people. This means that the global total has increased more than threefold during the seven decades that I have been alive.

This alone is a major driver of change. It also is a force that impels conflict, competition for resources and exploitation. There is no doubt that the world is becoming more unstable. Hence, as we study disasters or try to reduce their impact we need to think very carefully along two parallel lines. One concerns the role of stability (or more likely instability) in the process of providing safety. The other relates to how we may visualise the future, conceived as the environment in which we will have to operate. What constraints and opportunities will it provide, especially in the light of the changing salience of hazards and threats? There is commonly a tendency "to plan for the disasters of the past rather than those of the future". We need to accept that the former will not be a reliable guide to the latter. This means that we will need to employ all possible means to create the scenarios that enable emergency planning to make us ready to respond to the challenges and disaster impacts that have yet to come.

A View on HILPs from Climate Change Impacts and Adaptation

by Mark Pelling

Climate change is a threat multiplier (Goodman and Bandu, 2023). Increased energy in the global atmosphere and oceans impacts circulatory systems, sea-level, bio-chemical and physical systems with complex feedback mechanisms. Instability and extremes in weather are felt simultaneously across multi-annual rhythms, seasonal cycles, hourly and in the moment. The direct impacts of climate change on biophysical systems include human and non-human health. Heat related health impacts are a priority concern; cold shock is also locally important. Arguably more damaging are the secondary impacts of climate change on health, ecology and economy caused by storms, floods, wildfire and drought (Myers and Bernstein 2011). These in-turn have cascading consequences.

This note offers four lessons for HILP event research arising from work on climate change. These include consideration of the interacting hazards of climate change, the political economy of risk management, limits of adaptation and transformation and proposes greater attention to human vulnerability and generic resilience in any action to manage risk from HILPs.

Lesson 1: Thresholds and contagion shape impacts from climate change
Climate change research on impacts has drawn heavily from disaster risk management science. A risk approach entered the climate change cannon explicitly with the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) in 2012. Two concepts in particular help understanding of high impact events: thresholds and contagion. Thresholds describe those limits beyond which adaptation is impossible and impacts inevitable (McKay et al 2022). Contagion describes the relationship between connected systems and the possibility of cascading impacts multiplying or redistributing harms (with priorities for pro-active adaptation) (Laurence et al 2020).

Threshold breaching events take place in natural systems, e.g. ecosystem collapse, in human-made systems, e.g. overtopping of river defences, and in hybrid social-ecological systems, e.g. crop failure. Threshold breaching events are especially important where they are irreversible, such as in place destruction or species extinction (Song et al 2012). These are described as having hit the hard limits of adaptation. There are soft limits too, where the institutional or political

arrangements in society limit access to finance, technology or will to act, e.g. where there is a decision not to protect eroding coastlines. Soft limits are more immediate as a challenge for risk management, and deeply political.

HILP events will include those arising from the crossing of thresholds in global bio-physical systems provoked by climate change, e.g., the slowing or reversal of the thermohaline circulation in the North Atlantic; accelerated Greenland ice-melt and sea-level rise or collapse of the Amazon forest bioregion. These are well studied physical phenomena but have attracted little consideration of human consequences. There is still less consideration (in the public realm) of human or hybrid systems failure at this scale. Multiple crop failures and geopolitical conflict are examples. Limits in the insurance sector to cope with payouts for multiple global catastrophes and so itself face collapse is one exception. Questions of human mobility, geopolitical tensions or even of economic perturbations are less well studied. The impacts of adaptation and mitigation efforts also need consideration. How might geotechnical responses to climate change impact on life on earth? What might the more local consequences of adaptation, e.g. sea-defences or changes in land-use, be for ecological health or the distribution of asset ownership and poverty? Understanding HILP events will need to consider such risk management interventions.

Today, the precursors of climate change associated global threshold breaching events are already measurable. Some systems are perceptibly close to tipping into irreversible cycles of collapse. This limits the time available to prevent catastrophe and means more urgent and comprehensive action is required to mitigate and adapt - raising the economic and political stakes and making managed change more difficult just as the need for it increases. Figure 1 highlights this temporal effect for five global key risks reported by the IPCC Fifth Assessment (2014) and Sixth Assessment (2023) Reports. Comparing these two reports, at 2.0 degree warning relative to pre-industrial levels, risks for unique and threatened ecological systems, extreme weather events have progressed from high to very high, the distribution of impacts, global aggregate impact and large scale singular events continue to be moderate risk – all with moderate to high certainty, based on contemporaneous scientific literature.
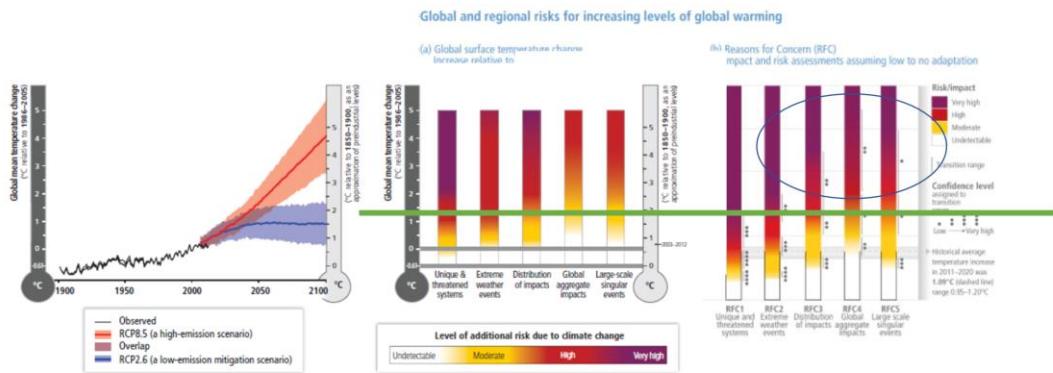
FIGURE 1: GLOBAL KEY RISKS FROM CLIMATE CHANGE

As climate change unfolds it does so in relation to other processes, many that also confer risk. Risk itself is changed by these interactions, and dynamic over time. Figure 2 presents multiple risk drivers and their interactions from the perspectives of global economics and global life support processes. Dynamism arises from the consequences direct interaction but is also mediated by human response to perceived risk and its impacts. Thus, impacts or responses to climate change can have consequences for other risk domains while patterns of risk elsewhere also mediate the impacts of climate change and human capacity to management risk. This includes opportunities to learn across risk domains and raises the possibility of systemic resilience – where targeted acts can reduce risk beyond a single risk domain. There may be lessons here for strategic interventions in the management of potential HILP events.

As climate change adaptation and mitigation become more normalised into development so development paths, processes and outcomes will be shaped by responses to climate change. So called Climate Resilient Development (Schipper et al 2020) captures this and established the ambition for responses to climate change to address or at least take account of and limit negative consequences for adaptation, mitigation and sustainable development.
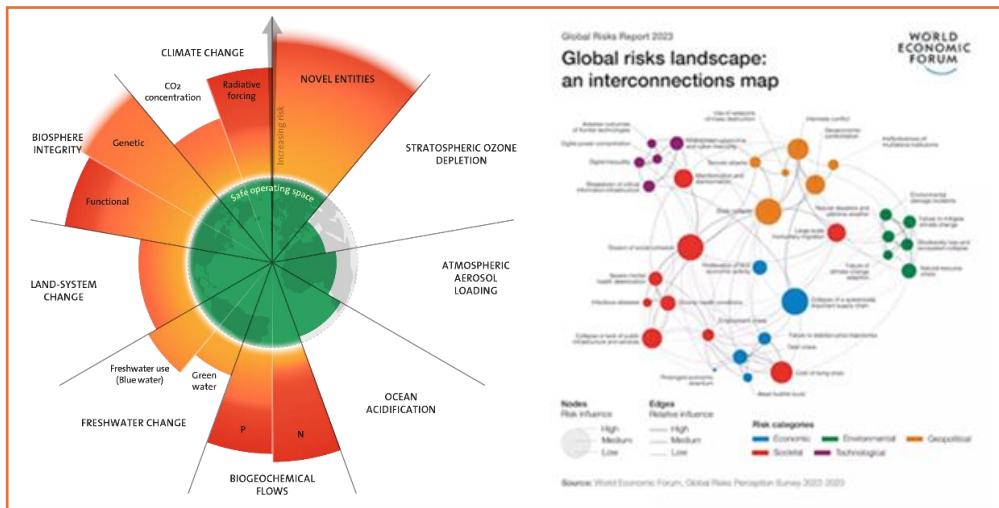
FIGURE 2: CLIMATE CHANGE IN CONTEXT

Sources: World Trade Organisation (2023) Global Risks Report; The Earthbound Report 2023, https://earthbound.report/2023/09/14/the-planetary-boundaries-in-2023/

Lesson 2: Risk management is all about political economy

Moving beyond mid- to end-century, run-away, globally irreversible effects of climate change become increasingly more likely without deep climate mitigation. The alternative is run-away climate change. Both have profound consequences for all forms of life on Earth and open unknowable cascading consequences for life sustaining systems. Managing such massively disruptive and potentially HILP event triggering risks requires proactive action. The alternative, responsive risk management (insurance, humanitarianism, recovery), accepts the high costs of loss and damages, will carry exceptionally high adaptation costs and its own risks for humanity. Proactive mitigation and preparatory adaptation in turn rest on scientific foresight, technological innovation, finance and governance frameworks and incentives for those with power to act and bare costs today to avoid harms in the future (Pelling et al 2011).

Even where scientific evidence is clear, technological solutions exist and finance and governance frameworks are conceivable or operating locally, still there is inaction. Where the distribution of costs and harms are not easy to measure or communicate or are weakly aligned with power this constrains incentives and limits action, as we observe (Barnett 2022).

The same geopolitical considerations and selfish-state behaviour that inhibit nation states from adequate leadership on climate change mitigation also supress coordinated and committed action on climate change adaptation (Savacool et al 2015). Both the Global Goal on Adaptation and agreement on payment for Loss and Damages have been slow and are orders of magnitude below financial targets necessary for addressing risk already being felt.

Nation states are important because they set the rules of the game for private sector and sub-state, or trans-national actors, for example through the UNFCCC. But these other actors can also show leadership and go beyond existing national and international agreements. In larger, richer countries with decentralised decision-making, regional and city administrations can show leadership and in aggregate produce national footprints of action even when state governments are unable. The US under Trump and George Bush presidencies continued to show city-level

action despite state-level failures. Economic capacity and administrative centralisation make impactful sub-state leadership difficult elsewhere.

The interaction of large-scale private capital interests and nation states is arguably more important but receives less prominence in research. Where private capital has grown relative to state capacity, effective regulatory oversight has withdrawn and the distinction between private interest and public authority has diminished understanding the behaviour of private actors becomes more important. This is a significant gap in knowledge with which to hold such actors to account as well as determine appropriate public policy.

Lesson 3: The limits to adaptation and transformation
The distinction between hard and soft limits to adaptation is critical – because soft limits can be addressed (Thomas et al 2021). However, once limits are reached the only option is to prepare for collapse, instability and progression towards a new point of equilibrium. This may have cascading consequences for associated systems so that the overall impact of a single system reaching its limits of adaptation can be very far reaching.

Reaching the limits of adaptation and tipping a system beyond its threshold of resilience is one pathway for transformation. For fundamental change in a system's functioning. But transformation can also be chosen (Pelling 2011). Transformative adaptation unfolds when the process of adaptation leads to fundamental change. There is no essential orientation in transformative adaptation but there is the possibility that this can bring progressive political/social change, e.g., more informed and inclusive decision-making processes or a more equitable resource, capacity and life chance distribution. In this way transformative adaptation points to a way of living with climate change that can bring social (and potentially also no-human) benefit.
To date there are few examples of intentional, progressive, transformative adaptation being attempted (Wilson et al 2020). The default position across polities and economies is to double down on the protection of existing systems through adaptation. There may be some egalitarian policy, but this tends to be at the margins. Recent work has identified the importance of future visioning as a mechanism that can bring together political, technical and local actors to collectively map out desired adaptation pathways at neighbourhood and even city scale (Comelli et al 2024). With this as a guide progressive options are less threatening for predominant interests. There is a gap in understanding how transformative adaptation might be considered at national or international scale, or in diverse decision-making contexts such as businesses.

Lesson 4: Generic resilience and vulnerability reduction
HILP events include those where triggers are known and unknown. Even where triggers are known, e.g. mega-volcano or massive solar-magnetic storm, cascading consequences jumping from one system to another make risk assessment and so risk management difficult. It is likely that high impact events have arisen from cascading failures across connected systems. Indeed, initial trigger (or triggers) might not be considered high impact events – producing only modest direct loss and damage but leading to high net impact through cascading consequences. Climate change research has begun to consider cascading risk but there are few empirical studies that HIPL event research can draw on. Most studied is supply chain contagion (Ghadge et al 2019). National exposure to food insecurity can change fundamentally when considering exposure to direct and cascading impacts of climate change on food production. Food import dependent countries become exposed to impacts in food producing countries. At a local level businesses

and livelihoods within supply and value chain networks mediate exposure and capacity to cope for other connected actors so that resilience sits at the level of the system, its component actors and their connections. There is some initial work that considerers which kinds of infrastructure might be most fundamental for cascades (Dodman et al 2022). Transport, energy and communications infrastructure are highlighted, but these are studies in urban systems. More rural and less technologically dependent societies may have other infrastructural vulnerabilities which could include failures in natural services. Following the analogy of infrastructure failure, zoonotic disease could be seen as a consequence of failure in the institutional infrastructure that is in place to manage wild-life hunting and poultry or livestock rearing.

HILP events force a reconsideration of the balance of effort on knowledge for risk reduction. Figure 3 maps out the established knowledge landscape for risk. Here knowledge is separated between hazard and human vulnerability. Hazard includes exposure and human vulnerability includes social and physical vulnerability and capacity. The predominant domine for risk management is built on hazard science. This works well for managing risk arising from single or simple, coupled hazards. Where the progression from hazard to impact is more complex, and where knowledge exists, a vulnerability led approach is more useful. The problem is that knowledge on human and especially social vulnerability is far behind that of hazards. There is not even any globally agreed protocol for collecting social information and loss data to enable a statistical basis for human vulnerability studies which remain localised or driven by theory. For those cases where there is knowledge of hazard and vulnerability risk can be internalised into development, for example by standard operating procedures. The inverse, where there is lack of knowledge on both the hazard and vulnerability drivers of impact, risk can only be managed through generic (i.e.., hazard agnostic) resilience. This aims to build capacity, avoid depths of inequality, asset poverty, political exclusion and social fragmentation and enhance population, rule of law and access to information and education. There may be investment in redundant capacities and in decentralised decision-making as well as clear lines for emergency decision-making.

The distribution of effort across these domains means that generic resilience and vulnerability led risk management are under-developed. This is a problem for any HILP event that cannot be managed by direct hazard mitigation or is so well understood that it can be embraced by everyday development. Because of cascading impacts, few HILPs fall into either category.
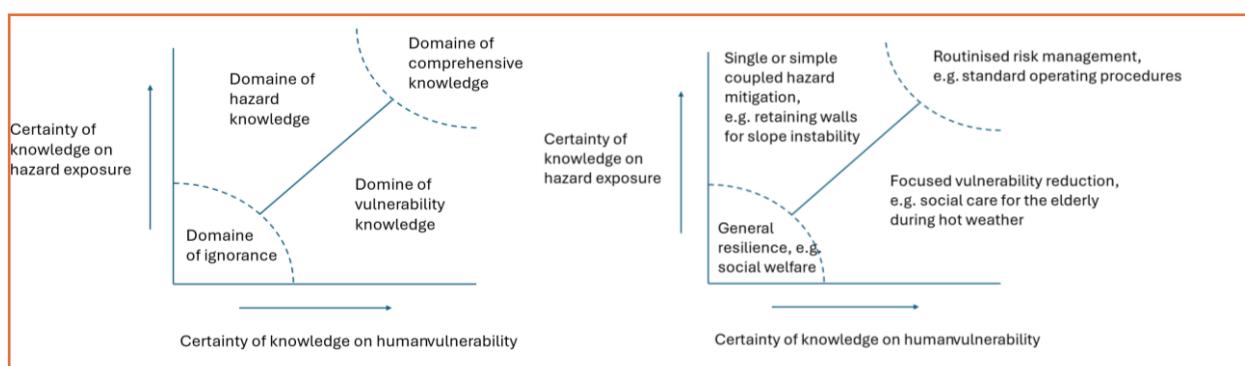
FIGURE 3: KNOWLEDGE DOMINES FOR RISK MANAGEMENT

A good starting point for improved vulnerability knowledge could be a Vulnerability Profile agenda. This could be a parallel effort to the UNDRR Hazard Information Profiles that seek to provide global agreement on the features of specific hazard types. Motivating such work requires a paradigm shift in risk management from a hazard centric perspective to one that also fully embraces vulnerability. This is especially relevant to HILP events given the defining focus on impacts.

Conclusion

If climate related risks are represented as a normal distribution of impacts against frequency, then climate change increases the possibility of HILP events. In a changing climate, historically low probability events may now be increasing in probability and previously unimaginable events – or series of events – not only now possible but even observed. Do we not consider high impact, historically low but now increasing probability events as HILP? Where do we draw the line? The speed of climate change and rising interconnectedness in human life-supporting infrastructures suggests any study of contemporary HILPs may quickly be overtaken! Given how poorly humanity has adapted to cope with, let alone live well or thrive with, existing risks to leave these behind is questionable.

If climate change makes us think about the temporality of probability in describing HILPs it also brings lessons from the ways in which climate change science has engaged with risk. Here we have focussed on climate change represented as a set of thresholds in single and more often connected systems with cascading risks and impacts. This also raises the possibility of cascading resilience. At the heart of all challenges for risk management is political economy. The tension between vested interest in the status quo – which produces the geography of risk we observe – and alternatives. If political economy is the context for understanding risk and how it is managed then transformative adaptation offers a theoretical pathway through which to live well even in the face of increasing risk and loss. Hard choices are needed but these can be based on inclusion, science and rule of law. That this can be done is not born out by historical president – large scale threats tend to bring centralised, and interest led government, though not always. Finally, HILP events will unfold across a range of knowledge contexts. For those, perhaps the majority HILPs, where there is limited understanding of the nature of hazard or vulnerability, generic resilience is a risk management default. For other events where multiple cascading pathways lead to impact and vulnerability led approach may be more useful than trying to second guess hazard. These are all debates within the climate change community that can gain strength from HILP events thinking.

Risk perception and communication of HILPS

by Sarah Dryhurst, Lauren Mc Millan, Beatrix Rosa, Jose Palma, Edited by Gianluca Pescaroli

Building on the previous section of the review of the state of art and section 1.1 of the deliverable, a holistic approach to effective risk communication for High Impact Low Probability (HILP) events requires collaboration between emergency managers and the public, bridging gaps in perception and enabling stakeholders to co-create meaningful communication strategies. Such collaboration fosters mutual understanding of perceived risks, barriers to action, and what constitutes relevant information for the public. This co-creation process goes beyond just delivering information; it iteratively involves communities to validate the clarity and effectiveness of risk messages, leading to greater trust and engagement (Slovic, 1992; Paton, 2007; Morss et al., 2016). Studies show

that risk communications co-created with audiences are significantly more impactful, as they meet real needs and perspectives (Dilling & Lemos, 2011; Vaughan et al., 2016).

The calculation of probabilities for HILP events is essential yet complex, as it requires incorporating uncertainties and adjusting assumptions as data evolves. Probabilities for HILPs can vary depending on time frames, geographical context, and cyclic patterns, as certain events, like tsunamis in Japan, have periodicities that affect recurrence intervals and perceived risks (Higaki et al., 2021). As probabilities are recalculated, distribution curves can shift, reflecting new insights or conditions. This dynamic nature of probabilities underscores the importance of making such contextual factors explicit in risk communications.

Some researchers argue that traditional probabilistic models may underestimate the occurrence of extreme events. Sornette's (2009) theory of "dragon kings" posits that certain extreme events follow different mechanisms from regular outliers and may reveal self-organizing patterns not typically observed in smaller incidents. This view contrasts with conventional power-law distributions, suggesting that some HILP events might be predictable within certain parameters, despite their rarity. Such insights underscore the need for dynamic, flexible approaches in risk assessment, where rare events are anticipated as part of complex systems (Taleb, 2013). Geographic and contextual factors are also critical to defining HILP events. For example, a flash flood may be rare in one area but frequent in another, altering its classification from a HILP to a High Impact High Probability (HIHP) event. Consequently, communities often develop adaptive responses, reducing an event's impact and shifting it out of the HILP category. This adaptability highlights the fluidity in how HILP events are perceived and classified and emphasizes the need for context-specific risk assessments that consider both spatial and temporal variables.

From a social science perspective, risk perception differs significantly between experts and the public. Laypeople often incorporate broader factors, such as catastrophic potential and intergenerational impacts, beyond the quantitative risk assessments typically used by experts (Fischhoff et al., 1978). In particular, low probabilities often amplify feelings of uncertainty and uncontrollability, affecting how the public perceives rare but severe risks (Slovic, 2000). These differences underscore the importance of addressing both technical assessments and public concerns in risk communications. Ultimately, incorporating insights from both probability modelling and social science can improve the communication and understanding of HILP risks. Psychometric analysis positions HILP events along a gradient of familiarity and control, helping distinguish them from more frequent, predictable HIHP events. This model reflects the fluid nature of risk perception, as an event considered HILP in one context may shift to HIHP as systems adapt or public familiarity increases (Slovic, 1987). In summary, effective risk communication for HILPs demands both a robust understanding of probabilistic modelling and a commitment to inclusive, adaptive communication practices that consider the evolving landscape of risk. People often struggle to maintain consistent levels of risk perception over time, as worry about future events naturally declines. After extreme events, memories fade, leading to a false sense of safety and reduced preventive behaviours (Pidot, 2013). This means that, after periods of calm, people may be shocked when disaster strikes again.

The availability heuristic explains how people assess risk based on recent or memorable events. For example, COVID-19 risk perception varied with government responses across cultures, as people estimated risks by recalling experiences from their networks (di Baldassarre et al., 2021; Hertwig et al., 2005). Media also amplifies certain risks: rare catastrophic events often receive more attention, leading people to overestimate their frequency. This dynamic between cognitive

biases and media influence can distort perceptions, prompting people to fear dramatic but infrequent events, like plane crashes, more than common ones like car accidents (Eisenman, 1993; Park and Grow, 2008; Lichtenstein et al., 1978).

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The use of AI: applications for preparedness, prediction, forecast

by Saman Ghaffarian

Introduction

Artificial Intelligence (AI) has emerged as a transformative force in the digital era, continuously revolutionising how we process, analyse, and interpret vast amounts of data. The advent and evolution of digital technologies necessitated the digitisation and digitalisation of information, leading to the development of data science—a field dedicated to extracting meaningful insights from complex datasets. Within this domain, AI has evolved as a pivotal subfield, enabling machines to perform tasks that traditionally required human intelligence, such as learning, reasoning, and problem-solving (Russell & Norvig, 2020). AI's ability to automate data processing optimises workflows, reduces human error, and enhances decision-making across various sectors (Kelleher & Tierney, 2018).

In the context of DRM, AI's application has already led to notable improvements in disaster response, recovery, prediction, and preparedness. Machine learning, for example, enables the analysis of large, complex datasets to detect patterns and make predictions. This has proven effective in areas such as damage assessment, infrastructure monitoring, vulnerability identification, resilience evaluation, recovery tracking, and overall risk management. AI-powered tools, such as predictive analytics and decision support systems, have transformed how disaster risks are evaluated and addressed (Hughes et al., 2023). One notable application is AI models that analyse satellite imagery to predict wildfire spread, helping authorities make timely interventions (Mohajane et al., 2021). AI-driven geospatial data analysis has further facilitated post-disaster damage assessments and supported the design of resilient infrastructure solutions in disaster-prone areas, contributing to the development of sustainable cities (Yousefi et al., 2020). AI's role extends to long-term resilience planning as well, where it helps identify vulnerabilities and suggests sustainable strategies, such as modelling sea-level rise risks informing coastal management plans (Adebisi & Balogun, 2022).

Despite these advancements, the full potential of AI in DRM remains largely untapped. While current applications have yielded significant benefits, there is considerable room for growth, particularly as an emerging and more achievable goal in the integration and adaptability of AI systems across a wider array of disaster scenarios. AI systems tailored to specific events, such as flood prediction or earthquake damage assessment, could be designed—or, if not directly applicable, adapted—to work interchangeably across different types of disasters. Developing more flexible models would enable AI to adapt to various disaster contexts, improving both preparedness and response. Moreover, incorporating reinforcement learning techniques offers substantial promise for using AI-based solutions directly in decision-making. By integrating real-time feedback, AI models can continuously improve their predictions and optimise different DRM applications, such as resource allocation and resilience interventions. The integration of advanced ML techniques, such as deep learning, can further enhance AI's predictive accuracy and its ability to process more complex datasets (Ghaffarian et. Al., 2021). Multi-modal AI, which combines data from various sources such as satellite imagery, sensor networks, social media, and historical records, could provide richer and more comprehensive predictions for DRM. This approach would not only improve forecasting accuracy but also enable more nuanced risk assessments by considering a broader range of variables.

HILP events present unique challenges due to their rarity and the severe consequences they can cause. One such challenge is the scarcity of data available for these events, limiting the historical and experimental data needed to train AI models. However, AI technologies could provide innovative solutions for understanding, preparing for, and responding to such events. By leveraging AI, emergency managers and policymakers can enhance their ability to model scenarios, detect anomalies, and support decision-making processes in the face of such events.

Multi-Hazard Risk Models and Cascading Risks

AI also plays a pivotal role in addressing multi-hazard risks, which are critical for comprehensive DRM. Traditional risk assessments often evaluate disasters in isolation, AI's ability to integrate data from different disaster types—such as earthquakes, floods, wildfires, and storms—could enable more holistic understanding of interconnected risks.

For instance, AI can evaluate how a major earthquake might trigger cascading events such as landslides, tsunamis, or widespread fires, or how a hurricane followed by flooding could exacerbate damage to infrastructure and communities. By accounting for these cascading and compound risks, including HILP events, AI provides a more accurate and thorough understanding of how one disaster can trigger a series of secondary effects—an aspect often overlooked in traditional risk assessments.

The consideration of systemic risks is particularly important in the modern world, where complex infrastructures and interconnected systems mean that disasters can trigger a chain reaction of impacts, including HILP events. AI models allow decision-makers to simulate cascading effects, providing valuable insights into the propagation of risks through systems. Furthermore, by simulating the interrelated risks of cascading events, AI can help urban planners, policymakers, and disaster response teams better anticipate and mitigate potential impacts, leading to more efficient and targeted disaster response efforts (Kelman et al., 2022).

Explainable AI and Trust in DRM

AI systems must also be transparent and interpretable, particularly in high-stakes DRM and HILP scenarios. Explainable AI (XAI) plays a critical role in addressing these concerns by ensuring that

AI predictions and decisions are understandable to human decision-makers (Ghaffarian et al., 2023). This transparency is essential in fostering trust in AI systems, especially among emergency responders, policymakers, and the general public. Trust is a key factor in the successful integration of AI tools into DRM, and increasing the interpretability of AI decisions can facilitate greater acceptance and collaboration across stakeholders.

To build on already said, collaboration between AI experts, DRM professionals, and local authorities is crucial for developing AI solutions tailored to the specific needs of different regions, cultures, and disaster types. Ensuring that AI tools are accessible, effective, and contextually appropriate will be critical to their success in enhancing DRM.

AI-driven Digital Twins

AI is one of the main pillars of digital twins—virtual replicas of physical systems. In DRM context, digital twins create dynamic, real-time models of infrastructure, cities, and systems, offering significant potential for improving disaster preparedness and response, including in the context of HILP events (Lagap and Ghaffarian, 2024). By simulating the impact of various disaster scenarios, such as earthquakes, floods, or storms, before they occur, AI-driven digital twins allow stakeholders to anticipate vulnerabilities and weaknesses in infrastructure, supply chains, and urban environments. This predictive capability enables more effective preventive measures and timely interventions.

For example, AI-powered digital twins can simulate how a city's transportation network would behave during a flood, providing valuable insights into evacuation routes or infrastructure design adjustments. By modelling how specific systems would function under crisis conditions, decision-makers can optimise planning and adapt infrastructure to better withstand future events. Additionally, these digital twins can support long-term resilience efforts by monitoring infrastructure in real time, predicting degradation, and recommending maintenance or upgrades based on different scenarios.

The potential of digital twins extends beyond immediate disaster scenarios, including HILP events. They offer the ability to continuously monitor urban and environmental changes, thus helping cities evolve to meet the challenges of future climate conditions and hazards. By integrating real-time data with AI, digital twins facilitate decision-making in disaster-prone areas, contributing to the development of more resilient infrastructure that can better withstand the impacts of disasters (Guan et al., 2022).

Generative AI

Generative AI is opening up new possibilities for disaster preparedness and training. By creating realistic disaster scenarios for simulation exercises, AI ensures that emergency responders are better prepared for diverse, unpredictable situations like HILP events. These AI-generated scenarios can reflect a wide range of catastrophic events, helping response teams build skills and strategies for managing complex crises.

Generative AI can synthesise data from various sources to create real-time situation reports, assisting decision-makers in understanding rapidly evolving situations. This capability is particularly useful when dealing with crises where accurate, up-to-date information is critical. By integrating generative AI into DRM, response teams are better equipped to handle unexpected developments and adapt to changing circumstances, which is critical for HILP.

Challenges and the Road Ahead

The future of AI in DRM holds immense promise, but several challenges must be addressed to unlock its full potential, especially in managing HILP events. Issues such as data availability, model interpretability, ethical considerations, generalisation of models across different contexts, and integration with existing DRM systems need to be carefully managed.

Research should focus on innovations like hybrid models that combine AI with physical models, integrated learning for real-time (digital twin-based) DRM, and addressing multi-dimensional problems. By addressing these challenges and responsibly integrating AI technologies into DRM practices, the sector can significantly enhance resilience to both frequent and HILP events, ensuring a safer and more resilient future for communities.

From HILPs to existential risk: toward an understanding of tipping points

by Benjamin Trump

Introduction to Tipping Points

Tipping points are critical thresholds within complex systems, where small changes in input can lead to drastic and often irreversible changes in the system's overall state. In the context of high impact, low probability (HILP) events, tipping points represent the moments when a system experiences a significant shift from one state to another due to accumulated stresses or external shocks. These shifts can manifest in various forms, such as environmental changes, economic collapses, or technological disruptions, and they pose substantial risks to systemic stability and resilience (Linkov & Trump 2019).

Mathematical and Network Science Perspectives on Tipping Points

From a mathematical perspective, tipping points are often described through concepts like bifurcation, where a small change in system parameters causes a qualitative change in its behavior. For instance, the transition from a stable to an unstable state can be modeled using differential equations that exhibit multiple equilibria. These equilibria represent different possible states of the system, and a tipping point occurs when the system moves from one equilibrium to another due to a critical change in conditions.

In network science, tipping points are understood through the study of complex networks characterized by nodes and edges representing components and interactions within the system (Barabasi 2002). A tipping point is identified when a perturbation in one part of the network triggers a cascade of failures across interconnected nodes, leading to a large-scale systemic collapse. For example, in a financial network, the default of a single institution can propagate through interbank linkages, causing widespread financial instability (Hynes et al., 2022).

Network science uses metrics such as node centrality, clustering coefficients, and network topology to identify critical points within a network that, if perturbed, can lead to a tipping point (Barabasi 2002). These metrics help in understanding the resilience of a network by identifying which nodes (or components) are most vulnerable to cascading failures and where interventions might be most effective to prevent systemic collapse.

System and Network Understanding of Tipping Points in Disaster Risk Governance

To improve disaster risk governance and response, it is crucial to adopt a system and network-based understanding of tipping points (IRGC 2018). This approach allows for a comprehensive view of how different elements within a system interact and contribute to its overall stability or fragility. By identifying and analyzing potential tipping points, policymakers can develop strategies to enhance the resilience of critical infrastructure and reduce the likelihood of catastrophic outcomes.

1. **Mapping Interdependencies and Feedback Loops**: Understanding tipping points begins with mapping the interdependencies and feedback loops within a system. Complex adaptive systems, such as socio-ecological or socio-technical systems, are characterized by numerous interacting components that may either stabilize or destabilize the system. Positive feedback loops, where an initial change is amplified, can lead to tipping points. Conversely, negative feedback loops may dampen changes and contribute to system stability. By identifying these loops, risk managers can focus on strengthening the negative feedback mechanisms to maintain systemic resilience.

2. **Early Warning Signals and Predictive Models**: The identification of early warning signals is critical for anticipating tipping points, even if the result is an identification of 'weak signals' that suggest, but do not guarantee, that disruption is looming based upon emerging system behavior. These signals may include increased variance in system outputs, slowing recovery rates from small disturbances, or shifts in leading indicators. Predictive models based on statistical early-warning signals (s-EWS) and network science techniques can provide quantifiable metrics for the proximity of a regime shift, allowing for timely interventions.

3. **Scenario Planning and Stress Testing**: Scenario planning, supported by network-based stress testing, can help identify potential tipping points under different conditions. By simulating various HILP scenarios, such as natural disasters, cyber-attacks, or pandemics, decision-makers can assess the robustness of critical infrastructure and identify points of failure. This information enables the development of targeted strategies to reinforce vulnerable areas within the network and to establish contingency plans that reduce the likelihood of reaching a tipping point.

4. **Adaptive and Proactive Risk Management Strategies**: Effective disaster risk governance requires adaptive and proactive management strategies that account for tipping points. Adaptive strategies involve preparing for known risks by building redundancy, flexibility, and modularity into critical infrastructure systems. Proactive strategies aim to prevent the emergence of new tipping points by monitoring systemic risks continuously and making preemptive changes to system design and operations. This dual approach ensures that systems are both robust against anticipated risks and agile in responding to unforeseen events.

Integrating Tipping Points into HILP Risk Governance (IRGC 2018)

Translating systemic risks and tipping points into a resilience risk governance strategy involves recognizing that traditional risk management approaches may be insufficient for dealing with the interconnected, dynamic, and often unpredictable nature of modern complex systems. A

resilience-based strategy focuses on enhancing the capacity of systems to withstand shocks, adapt to changes, and recover from disruptions. This approach goes beyond mere risk mitigation and encompasses a proactive and adaptive framework to manage the potential for tipping points that could trigger systemic failures.

To implement a resilience risk governance strategy, it is essential to first understand the structure and dynamics of the system in question. This includes mapping the interdependencies and feedback loops within the system to identify which components are most vulnerable to disruptions and where tipping points might occur. By recognizing how different elements within a system are connected and how changes in one area can cascade throughout the network, decision-makers can better anticipate where interventions will be most effective in preventing or mitigating systemic risks.

A resilience strategy also requires the development and deployment of early warning systems that monitor for signals of instability. These signals, such as increased variability in performance metrics or slower recovery rates from minor disturbances, can provide crucial insights into the proximity of tipping points. By continuously monitoring these indicators, organizations can detect emerging risks before they escalate into full-blown crises, allowing for timely and targeted interventions to reinforce system stability. Scenario planning on one end and threat-agnostic stress testing are critical components of a resilience-based strategy. For recurring or well-known threats to a given region, organizations can use threat scenarios to explore how different systemic shocks might impact their operations. These exercises help to identify potential points of failure and opportunities for enhancing resilience, such as building redundancy into critical infrastructure, diversifying supply chains, or developing alternative response strategies. Ideally, however, scenario-driven approaches would be complemented by a threat-agnostic understanding of a given system's configuration. This allows an evaluation of system performance and mission execution regardless of situational context, and provides an improved governance strategy against HILPs that, by definition, are historically rare but can be devastating.

Finally, a resilience risk governance strategy emphasizes the importance of adaptability and flexibility. This means designing systems that can adjust dynamically to changing conditions, rather than relying solely on rigid, predetermined responses (which, in turn, are reliant upon a threat-agnostic understanding of system brittleness, resilience, and potential single points of failure). By fostering a culture of continuous learning and innovation, organizations can remain agile in the face of uncertainty, ensuring they are better prepared to cope with unexpected shocks and stresses.

Complex Events, Collapse, and Existential Risk

To translate the concept of systemic risks and tipping points into a resilience risk governance strategy, it is essential to understand how cascading and compound risks can accumulate vulnerabilities within interconnected networks, leading to potentially catastrophic outcomes. Systemic risks, by their nature, can trigger a series of failures across critical services and networks. When these failures reach a tipping point, they can manifest as complex events, civilizational collapses, or even existential risks, depending on the scale and scope of the impact.

At the core of this approach is the recognition that the accumulation of vulnerabilities across interconnected systems can create conditions conducive to cascading failures. For instance, the

interaction of multiple stressors—such as climate change, economic instability, and technological disruptions—can magnify the effects of a single event, transforming it from a localized disruption into a systemic crisis. This process is observed in the compounding risks where each vulnerability interacts with others, creating feedback loops that exacerbate the overall system's fragility.

The concept of tipping points is critical to understanding how these cumulative vulnerabilities manifest in real-world scenarios. A tipping point is reached when the accumulated stress on a system pushes it beyond a critical threshold, leading to a sudden and often irreversible transformation. In the context of systemic risk, these tipping points can be categorized into three levels:

1. **Level 1: Complex Events** – These are high-impact, low-probability events that can trigger multiple cascading effects across interconnected systems (Haldon et al., 2021). An example is the 2011 triple disaster in Japan, where an earthquake triggered a tsunami, which in turn caused the Fukushima nuclear plant meltdown. The compounding effects of these interrelated events highlighted how different types of critical infrastructure are interconnected, creating vulnerabilities that can lead to widespread system failures.
2. **Level 2: Civilizational Collapse** – When systemic failures become widespread, they can lead to the collapse of entire civilizations (Pollock et al., 2023). Drawing on lessons from the Late Bronze Age collapse, where interconnected trade and socio-political networks failed, we see how cumulative risks—such as climate change, social unrest, and external invasions—can reach a tipping point that results in a rapid and comprehensive societal breakdown. The Bronze Age societies were highly interconnected, and the failure of key nodes, like Egypt and the Hittite Empire, caused cascading failures across the region, demonstrating how compounded risks can overwhelm even the most robust systems (Linkov et al., 2024).
3. **Level 3: Existential Risk** – At the highest level, tipping points can threaten the survival of humanity itself (Centeno et al., 2023). Existential risks are those that pose a global threat, potentially leading to the extinction of human civilization. These risks often involve scenarios where cascading failures occur on a planetary scale, such as nuclear war, catastrophic climate change, or advanced artificial intelligence scenarios. The accumulation of vulnerabilities—whether through geopolitical tensions, technological dependencies, or environmental degradation—can bring the global system to a critical tipping point where recovery is no longer feasible.

To address these risks, a resilience risk governance strategy must focus on four main components of resilience: **anticipation, response, recovery, and adaptation** (Pescaroli et al., 2024)**.** This involves developing early warning systems to detect signs of systemic instability, creating robust and flexible networks that can absorb shocks and recover quickly, and implementing adaptive measures that reduce the likelihood of reaching critical tipping points. By continuously monitoring, assessing, and adjusting governance strategies based on evolving conditions, we can enhance the resilience of critical systems and reduce the risk of cascading failures that could lead to civilization collapse or existential threats.

The Great East Japan Earthquake: Insights into High-Impact, Low-Probability (HILP) Events

by Miwako Kitamura and Anawat Suppasri

Introduction

The Great East Japan Earthquake (GEJE) of 11 March 2011 stands as a pivotal example of a High-Impact, Low-Probability (HILP) event. This section of the report explores the cascading impacts of this disaster, including the earthquake, tsunami, and the nuclear meltdown at the Fukushima Daiichi Nuclear Power Plant. By analysing community responses to structural measures, such as seawalls, it provides valuable insights into managing future HILP events. The findings underscore the importance of integrating local expertise and global collaboration to enhance disaster resilience. The GEJE triggered a magnitude 9.0 earthquake followed by a massive tsunami that devastated Japan's northeastern coastline, culminating in cascading crises, including the Fukushima nuclear disaster (Miura et al., 2011). These interconnected events highlight the complex interplay of geological, hydrological, and technological risks. This section of the report examines these cascading impacts and the divergent community responses to them.

Cascading Impacts of the Fukushima Nuclear Disaster

The Fukushima Daiichi Nuclear Power Plant meltdown epitomises the cascading effects of HILP events, influencing public health, food safety, political dynamics, and environmental management.

1. **Radiation Contamination and Public Distrust:** The nuclear meltdown released significant radioactive materials into the environment (Koo, et al., 2012) Government efforts to provide data on radiation levels were met with scepticism, as many citizens perceived a lack of transparency and potential manipulation Reconstruction Agency (2024, April 20). This mistrust exacerbated communication gaps between authorities and communities. Tohoku University addressed these challenges through initiatives like the Miharu Project, empowering residents to monitor radiation levels and fostering trust between the government and local communities (Koike, 2014).

2. **Cascading disasters triggered by tsunami hazards:** A proposed cascading magnitude scale (Alexander, 2018) was applied to each tsunami event not only the GEJE but also other historical tsunamis in Japan and Indonesia to determine and categorize causes, effects, and escalation points as results with a few joint publications. Large tsunamis tend to be associated with earthquakes, liquefaction, and landslides that multiply the scale of impact (Suppasri et al., 2021) and recently applied to the 2024 Noto Peninsula earthquake (Suppasri et al., 2024). The main escalation points for tsunami related disasters were found to be failures of tsunami warnings, power plants, medical facilities, educational facilities, and infrastructure. From the perspectives of critical infrastructure resilience and disaster risk reduction, analysis of cascading impacts of multiple recent tsunami events could contribute to greater understanding of economic, political, and social impacts that stem from technical decisions regarding infrastructure management (Suppasri et al., 2022).

3. **Food Safety and Trade Issues:** Contamination fears significantly impacted Japan's agricultural and fisheries sectors. Despite rigorous safety testing, consumer confidence in

products such as mushrooms, rice, and seafood remained low (The Japanese Government 2017). Trade restrictions imposed by countries like China further hindered economic recovery (Nakagawa 2019)

4. **Political and Global Implications:** The disaster reshaped global nuclear energy policies. Countries like Germany accelerated plans to phase out nuclear power, while others emphasised transparent risk communication to maintain public trust (World Nuclear Association 2024).

Seawalls: Community Responses and Environmental Considerations

The construction of seawalls following the GEJE has been a contentious issue, illustrating the complexities of balancing disaster mitigation with environmental and cultural preservation.

Kesennuma, Resistance to High Seawalls: High seawalls in Kesennuma faced opposition due to their economic costs and environmental impacts. Residents expressed concerns that the seawalls obstructed their connection to the ocean, which is integral to their fishing culture. IRIDeS facilitated discussions to explore alternative mitigation measures, such as community-led evacuation plans.

Onagawa, A Model for Integrated Planning: Onagawa adopted a more participatory approach, relocating residential areas to higher ground and preserving coastal areas for non-residential use. This strategy balanced disaster resilience with cultural and environmental priorities (Aoki 2018).

Lessons for Managing HILP Events

The experiences of the GEJE, combined with offer critical lessons for future disaster management:

1. Inclusive Governance: Engaging communities ensures disaster strategies align with local needs.
2. Risk Communication: Transparent, participatory communication rebuilds trust and fosters resilience.
3. Integrated Planning: Combining structural and natural solutions enhances sustainability.
4. Global Collaboration: Sharing knowledge and best practices strengthens resilience worldwide.

By synthesising these lessons, policymakers can build systems capable of addressing the complexities of future HILP events[4].

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[4]Established in the aftermath of the GEJE, Tohoku University's International Research Institute of Disaster Science (IRIDeS) leverages lessons learned from this unprecedented multi-disaster scenario. The Institute's multidisciplinary approach addresses the gaps in traditional disaster management frameworks that were ill-equipped to handle cascading crises involving earthquakes, tsunamis, and nuclear accidents. The institute makes significant contributions to disaster science and resilience-building.

1. Advanced Research on Cascading Disasters: IRIDeS conducts in-depth studies to understand the complex interactions of multi-hazard scenarios with Professor David Alexander and Dr. Gianluca Pescaroli.
2. Innovative Methodologies: The Institute develops forward-thinking disaster risk reduction (DRR) strategies tailored to both local and global contexts.
3. Interdisciplinary Collaboration: IRIDeS integrates engineering, social sciences, and public health to create holistic solutions.

Developing disaster scenarios for HILPs

by Danny Ralph

On disaster scenarios in general

The point of scenarios is to **inspire an interest in managing**, today, the consequences of **multiple futures**. Shoemaker (1991) argues that scenario planning helps organisations manage uncertainty by defining a range of possible futures rather than attempting to predict a single outcome. Effective scenarios go beyond describing end states—they should illustrate the dynamics of change and incorporate diverse perspectives to ensure a broad understanding of possible developments.

Unlike traditional forecasting, which often relies on linear projections, scenario planning helps decision-makers bound uncertainty and explore potential risks in a structured manner. It serves as a conceptual framework that allows organisations to ask the right "what if" questions, avoiding misleading assumptions caused by isolated variable changes.

Scenarios also function as a form of strategic insurance, helping organisations recognise potential pitfalls and dead ends before they materialise. Shoemaker illustrates this with examples from business history, where firms failed to anticipate technological shifts, ultimately leading to their decline. While scenario planning does not guarantee accurate predictions, it raises awareness of uncertainty and provides a structured approach to decision-making, even in fields where empirical evidence is limited (Shoemaker 1991).

In the setting of HILP, our interest in futures is confined to future shocks that have systemic impacts. These are analogous to classical natural-hazard based catastrophes in that we know they are possible but the arrival of the next (systemic) event is both unlikely in any human-scale time period, e.g., a 1-in-100 year event is unpredictable. Shoemaker (1993) highlights that traditional risk models often struggle to capture uncertainties stemming from limited worldviews, particularly epistemic risks such as political or economic disruptions. Scenario planning offers a way to counter these blind spots by broadening decision-makers' perspectives and challenging cognitive biases. However, scenarios must be framed as possibilities rather than deterministic forecasts, ensuring engagement with extreme uncertainties rather than their dismissal (Shoemaker 1993). Wilson (2000) further emphasises that scenario planning must extend beyond constructing scenarios to influencing strategic decisions. Many projects fail not due to weak scenario design,

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4. Global Knowledge Exchange: The Institute collaborates with international organisations to disseminate best practices in disaster preparedness and resilience.

Through its leadership in disaster science, IRIDeS has become a global reference point for integrating local knowledge with international DRR frameworks. Its role is crucial in addressing the multi-layered challenges presented by events such as the GEJE. The GEJE highlighted the limitations of reactive disaster management, emphasising the need for proactive and foresight-based strategies. IRIDeS has spearheaded initiatives that reflect this shift:

1. Interdisciplinary Collaboration: IRIDeS integrates engineering, sociology, and public health to address the multifaceted nature of disasters.
2. Community Engagement: IRIDeS promotes education campaigns and drills, empowering communities to take active roles in disaster preparedness.
3. Global Knowledge Sharing: Platforms like the World Bosai Forum enable IRIDeS to share expertise with international partners, enhancing global resilience.

By fostering collaboration and innovation, IRIDeS has redefined disaster preparedness, ensuring more resilient systems.

but because they do not drive meaningful action. Shifting to scenario-based strategic planning requires a transformation in organisational thinking, where scenarios become embedded in decision-making rather than a one-time exercise. Successful adoption depends on senior leadership commitment, effective communication, ongoing training, and repeated practice. Just as mastering a skill takes time, developing scenario-based insight requires continuous refinement and application (Wilson 2000).

We take the view that "the unexpected nature of catastrophes has more to do with human and organizational perception, specifically the failure to recollect or consider long past events, than to the occurrence of unique or new processes." (Citi GPS & Cambridge Centre for Risk Studies, 2021) Phadnis et al. (2016) highlight that while scenario planning influences strategic decisions, its effectiveness depends on continuous application, Structured scenarios help prevent rigid thinking by providing multiple plausible futures, ensuring that organisations remain agile in changing conditions, and de facto affecting the behaviours of decision making but also being oriented by psychological drivers Hence the word "inspire" is important: How to interest a decision maker, whether their responsibility is more day-to-day operations or involves planning the near-to mid-term future, to pay attention to HILPs given that any particular type of event is both rare and unpredictable?

An observation which supports the effort to inspire is that there are many types of systemic events which here are shocks or, more generically, threats. This is intuitively obvious and also explicit in various **catastrophe taxonomies** (Coburn et al., 2014; Coburn et al, 2019). Hence while the type (e.g. earthquake), origin (e.g., epicentre or ground zero) and timing of the next systemic event are entirely unpredictable, the expectation of some 1-in-100 year event occurring in the next century is perhaps much closer to 1-in-10 than 1-in-100. This leads to another observation which, though fundamental, we won't pursue further here: Resilience of a system or organisation requires flexibility to survive the event and to reconfigure depending on the resources available and state of the post-event environment; the key word is flexibility because everything about the next HILP is unknown other than it coming from very long list of possibilities[5] which we seek to comprehensively cover in a taxonomy.

Returning to scenarios, let us take for granted that they should be engaging, to use a word other than inspiring; the use of **narrative** in scenarios (Schoemaker, 1993) is important in this respect. The intention of scenarios is to be informative, and we would highlight two dimensions of information which AGILE scenarios should embody: **connectivity** and **quantification**. The impacts of a systemic event are often termed as **cascading** impacts or a domino effect, especially contemporaneous or sequential or correlated impacts that are not seen except in extremis. To describe such impacts seems to require a description of **transmission** from one sub-event to another. Transmission is often detailed or delimited in terms of extant networks which could be physical, like rivers, or digital, like telecommunications, or social, such as social acceptance or ranges of behaviours. Traditionally, post-mortems of historical shocks and their cascading impacts reveal critical connectivity issues as limits or blockages in flows through **networks** and in how they interact. A simple example of how a physical network leads to cascading impacts is that a pandemic is spread most rapidly by air travel (Ruffle et al, 2014); a recent two-tier example is the February 2021 power outages in Texas that resulted from a winter storm not because electricity

generators couldn't operate but because their fuel feed, the natural gas network, froze.[6] [7] The second informational dimension of scenarios is quantification. This may not be a barrier to engagement because qualitative descriptions of severity and likelihood of catastrophic events can be very effective (Rasmussen, 2008). However, quantification is important for an organisation to go beyond awareness to consider, e.g., investments in threats mitigations or the capacity to respond to a future shock. For note: A helpful default is to associate a metric or metrics for severity with each type of shock, then to qualitatively describe a probability distribution where higher severity events occur with lower frequency or lower likelihood in a given time period. The severity metric should be natural or canonical to the type of event, e.g., the Richter scale or peak ground acceleration for quakes. The implication is that severities associated with event types are to be distinguished from, and need to be translated to, impacts that an event has on a given system.

Building scenarios and stakeholder engagement

Figure 4 below depicts a framework for scenario development developed by CCRS as part of their report "Scenario Best Practices: Developing Scenarios for the Insurance Industry" (Strong et al, 2020), see also section 4 of that report which explains the 8-step framework in detail. This framework depicts an iterative cycle of 8 methodological steps. Stakeholder engagement is centred in the last 2 out of 8 steps.

The first cycle produces a taxonomy and a long list of potential threats, each tagged to a skeleton scenario description, which is the basis for a stakeholder selection process to reduce the threats/scenarios down to a shortlist of around 6-12 candidates. Scenarios are short-listed based on either their plausible materiality or the lack of formalisation, within the organisation, of knowledge of that type of event; the latter comes under the heading of blind spots. The short list is typically constructed so that represents sufficiently different types of threats, a kind of diversification strategy to acknowledge that we don't know the type of the next event. In a second cycle, the background analysis of each type of event on the short list is refined and deepened, and the corresponding scenarios are correspondingly developed with the aim of understanding the likely cascades within the system of interest and, thus, impacts on the organisation.

To reduce cost and save time, a briefer and qualitatively focussed version of steps 1-8 can be undertaken in two of more cycles of analysis and engagement, as quantification[8] requires a more significant organisational commitment of intent, funding and development time.

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[6] https://www.texastribune.org/2021/02/16/natural-gas-power-storm/

[7] See also the section Beware the Cascades, on page 16, and the cascading risk implications of Covid in Figure 13, page 36, of ref. 1 (Citi GPS and Cambridge Centre for Risk Studies, Systemic Risk: Solutions for an Increasingly Interconnected World, 2021; Citi GPS: Global Perspectives & Solutions and Centre for Risk Studies, University of Cambridge, Judge Business School).

[8] For a brief description of what quantifying the impacts of scenarios might offer, see the discussion on page 42 of CCRS's report Scenario Applications: Stress Testing Companies in the Energy Value Chain, particularly Figure 13 which shows a breakdown of balance sheet impacts of three different types of scenarios on a hypothetical organisation. For an alternative example of balance sheet quantification of risk to an organisation, visit Risilience's website, www.risilience.com; Risilience has built a platform for quantifying risk to an organisation from climate change, covering physical and transition risks, which includes an analysis of cash flow impacts over the next 5 years associated with a variety of climate change scenarios.

Step 1 — Scope the Risk
Identify the risk to be addressed, or, if the risk is uncertain or unknown, define the issues or vulnerabilities that the scenario exercise aims to expose. In the latter case, the risk may be identified later in the process. This contextualises the objectives and resultant decisions of the analysis.

Step 2 — Conduct Background Research
Research the topic defined in Step 1 by consulting relevant sources of (scientific) knowledge and all associated stakeholders within and beyond the insurance industry. If possible, consider each dimension of risk: hazard, exposure, and vulnerability, to recognise how and where impacts occur.

Step 3 — Frame the Scenario(s)
Consider and define the key aims, benefits, and characteristics of a scenario and its process. Figure 2 outlines some of the key questions the developer should ask when framing their scenario. Sections 2 and 3 provide the context to inform these considerations.

Step 4 — Develop Candidate Scenarios
Compose a series of candidate scenarios that capture a range of plausible futures. Summarise scenarios with brief outlines and key variables, and explore contrasting characteristics. Select scenarios to progress that will challenge and achieve the desired objectives.

Step 5 — Develop a Narrative
Expand the selected scenarios with descriptions that are interesting, challenging, and plausible for all stakeholders. Account for all dimensions of a future event, including context, triggers, timelines, geography, responses, and implications.

Step 6 — Assess Impacts and Materiality
Assess the impacts within the insurance industry and in wider macro systems. Consider complexities and interconnectivities that may cause cascading impacts beyond the expected. Define what constitutes a material impact in order to focus the analysis on materially affected assets and areas of business.

Step 7 — Communicate and Act
Communicate the key findings to stakeholders via meaningful qualitative and quantitative outputs. The content and complexity should be tailored to the audience. Include a clear indication of the extent to which the results can be relied on to inform decisions and actions to address the risk.

Step 8 — Evaluate and Update
Evaluate whether the objectives of the exercise have been achieved and iterate the process with stakeholder input to ensure or enhance efficacy. Be aware that the possibility and character of a scenario will change as controlling factors evolve, as will its impact as the industry advances, and so it should be updated to maintain relevance and utility.

Figure 4: a framework for scenario development for the insurance industry.

Conclusion of the theoretical section

HILP events are generally marked by cascading impacts that unfold across physical, social, and technological systems. As societies grow more interconnected, shocks like earthquakes, tsunamis, pandemics, and cyberattacks are increasingly capable of setting off chain reactions due to vulnerabilities within infrastructure networks, supply chains, and community resources. Understanding these compounding forces requires looking beyond traditional approaches looking at risks in isolation —and recognising how critical interdependencies function under stress. Modern risk strategies therefore must embrace a broader perspective that integrates hazard anticipation, scenario-building, and dynamic monitoring of weak points. Preparing for these HILPs calls for understanding interconnections within infrastructure systems, developing adaptive capacity in communities, and promoting interdisciplinary approaches to identify systemic pressure points before they fail.

In parallel, new technologies such as AI and digital twins offer tools for early warning and real-time analysis, boosting the speed and accuracy of disaster response. Yet no technological breakthrough alone can substitute for effective governance, targeted resource allocation, and tailored risk communication. True resilience emerges from sustained collaboration—between public authorities, private industry, scientists, and community members—to ensure that preparedness measures address social inequities and protect those most exposed to harm. Through continual stress testing, scenario planning, and inclusive decision-making, societies can transform episodic vulnerability into a foundation for long-term resilience, enabling them not only to withstand unexpected shocks but also to adapt and thrive in their aftermath.

3. Methodology

This section outlines the data collection process used to capture the empirical data from experts on HILPs to support the theory-building process and to address the WP1, task 1.2. It is presented in three main parts: Design, Method, and Data.

Design

Semi-structured interviews, including a short questionnaire, were used to discuss with experts in the field about HILPs and HIHPs. The data collection aimed to address the following research questions, leading to elaborate a conceptualisation of HILP to promote a holistic perspective:

1. How do HILPs interact at the societal level, organisation level, political level, influencing decision making under conditions of higher uncertainties?
2. What could be the commonalities and differences between HILP and HIHP?
3. Which elements could be used for exploiting existing technologies and tools that could be affected by limited datasets and a lack of precursors (i.e., scenario building and machine learning)?

Interview Design and Content

The predominate method for the data collection was semi-structured interviews. The interviews were structured into three main parts: feedback on the definition; participant's experience of preparing for and responding to HILPs; and Likert-scale questionnaire. The content of the interview questions was largely derived from the preliminary findings of the State-of-the-Art (which commenced a few months prior to the interviews). Using semi-structed interviews for this type of data collection is common.

The table below explains the inclusion of content for the interview guide (in Appendix A):

Section	Content	Reasons/justification for inclusion
Definition	Definition feedback	Validation of AGILE's HILP definition
	Commonality in understanding	Perceptions of sector's knowledge and understanding of HILPs
Expertise and Experience	Strengths and weaknesses	Perceptions on where the sectors are currently at in terms of prevention and response
	Common point of failures	How and why HILPs have occurred
	Commonalities of HILPs and HIHPs	Similarities and differences for prevention and response to high impacts events

	Different sectors and size of organisations	Similarities and differences across sectors
	Leverage HILPs in scenario planning	Development of planning materials and tools for HILPs
	Strategic foresight, lateral thinking, and counterfactual analysis	Understand sectors' views on future of risks and uncertainty, specifically around HILPs
Likert-scale questions	All sections from expertise and experience	Obtain quantitative answers to questions to support mixed-methods approach
Open	Extra comments	Opportunity to share extra relevant information, examples, and comments

TABLE 1 THE INCLUSION OF CONTENT FOR THE INTERVIEW GUIDE

The interviews were expected to last between 30-45 minutes; however, interview slots were scheduled for 60 minutes to ensure that sufficient time was allocated for further explaining of the project—if needed—and for additional questions, comments, or conversation/discussion at the end of the interviews. The participants were interviewed on a voluntary basis; therefore, it was important that the questions were engaging, relevant and time efficient. Technical terminology was used during the interviews; however, they were largely understood by the participants due to their level of expertise. In some instance, terms or phrases had to be explained, primarily due to some participants not being fluent English speakers.

Participant profile and recruitment sample

The target group for potential participants were emergency planners, business continuity managers, and a broader category of crisis and resilience managers. The participants are decision makers, academics, emergency planners, and resilience officers who have at least 10 years of relevant work experience. Their work is principally involved with preparedness and coordination of emergency response and training. The participants were recruited from the Private, Public (local, national, and regional level), International Non-governmental Organisations (INGOs), and Academia sectors to capture a diversity in experience, knowledge, and perspectives on HILPs. The target sample size was between 20-40 participants.

Pre-testing and Pilot Interviews

The interview question guide was pre-tested by review from the AGILE consortium partners, some members of the project advisory board, and the UCL team. The feedback from the reviewers was that the questions were clear, however, only for individuals who had the right level of experience and 'mindset' (i.e., 'outside-of-the-box' thinking). Based on this feedback, we decided to increase the number of years of professional experience from a minimum of 5 years to 10 years.

The interview question guide was piloted with four participants, one from each sector (Private, Public, INGO, and Academia). One comment from a participant was that it would be good to have

some examples or lay-person explanation of some technical terms used during the interviews, especially for non-native English speakers, therefore a glossary was produced to support the interview question guide. As the interview questions largely remained the same, the four interviews were included for the data coding and analysis.

Ethical Considerations

This research is based on a strict ethical protocol that was approved in three phases by the UCL IRDR Ethic Committee (ID Number: 23120801), in in compliance with the Data Protection Act (DPA) and General Data Protection Regulation (GDPR) 2018). It was further approved by the UCL IRDR fieldwork safety officer (RA086964/1); and data management by UCL Data Protection Team (Reference Number: Z6364106/2024/01/28 social research).

The nature of HILPs

This project's aim is to be leading in the understanding of HILP events. Due to the nature of such events, these can have significant societal and environmental impacts. Thereby, it is of utmost importance that the research conducted, and findings are framed appropriately, sensitively, and valid. This work is hoped to change the understanding of dealing with large uncertainties around, therefore, the information being provided to decision makers needs to be correct (to the best of current knowledge) as decision which could impact thousands of people could be made on these. This research may evaluate some downfalls, failures, or weak points in current projects and operational process which may lead to HILPs, such as nuclear power plant failures. In doing so, there is a burden in knowing that there potentially could be a large-scale disaster due to this and leads to the following considerations during the interview. The participants may refer directly to existing issues in policy making or directly associated to senior management failures. In this case, the standard procedure is asking to confirm about privacy, agreement to proceed with the interviews, the permission to report the names in the transcripts or if the interviewee would like to have the direct reference removed. All participants received their transcripts to review and edit if necessary.

Informed consent

All participants were well informed of the project and their expected participation so that they could make an informed decision whether to accept being interviewed. A short brief was given at the start of the meetings to check that participants understood the topic and participation—this was also an opportunity to clarify any questions—before commencing the interview. The participants were asked if they wished to be identified (either by name, position, and/or organisation) or anonymised. Participants either returned a signed consent form before or after the interview, or after their review of the interview transcript. In some instances, we accepted an email confirmation as some individuals preferred to not sign the form.

Participants were sent their transcripts within a few weeks of their interviews (before the anonymisation process) so that they had to option to remove or add sections. This process was deemed appropriate as these were content-based interviews, therefore we wished to maximise the quality of information included in our data collection, as well as build trust and professional relationships with our participants. About half of the participants informed us that they reviewed their transcripts, and some sent back modifications.

Benefits and Risks to Participants

Benefits to the participants include being able to share their expertise with a wider audience as well as share their thoughts (including concerns) outside of their place of employment (i.e.,

institution, organisation, etc), and potentially improving their own operational capacity and quality of training.

Potential risks to the participants include that they may be identifiable due to their expertise. The participants were asked if they wish to be identified or not, as well as being informed in the participant information sheet, consent form, and reminded before commencing the interview that their identify may not be able to remain fully confidential due to elements of traceability (likes of sector-specific work experience). All precautions were taken to minimise the identifiability of participants, unless specified otherwise. There is a remote possibility that participants appear to be negatively affected (including stressed or upset) during the interview, then the researcher(s) would have asked the participant if they would like to take a break, terminate the interview, or contact someone (it would be suggested either a colleague, friend, or family member). This is standard practice for conducting interviews. Furthermore, it can be seen in the interview question guide that the nature of the interviews are not about personal life experiences (of HILPs), however, they are about the general knowledge, understanding, and theory of HILPs.

Research Team and roles

The UCL Research team comprised of 5 members, including Dr Gianluca Pescaroli (AGILE Scientific Research Lead), Dr Lauren McMillan (Research Fellow), Ms Femke Mulder (Research Fellow), Ms Mhari Gordon (Research Assistant), and Mr Krisno Nugroho (Research Assistant). The data collection process was led by Ms Gordon, from inception to completion, who took the lead on the interview design, ethical and data management procedures, interviews, and data coding and analysis. Dr Pescaroli contacted all potential interview participants, was present in all interviews, and led on deriving two AGILE HILP definitions and the theory building. Dr McMillan supported the interview design and structure based on her lead in the State-of-the-Art process and was present during the pilot interviews. Ms Mulder carried out parallel data coding and analysis and merged these to derive wider findings. Mr Nugroho assisted with the cleaning and anonymisation of interview transcripts as well as the quantitative analysis from part 3 of the interview data.

Data collection

Interviews

Participant were contacted via email by Dr Pescaroli with an introductory email which gave a high-level overview of the project and the aim of the interview, as well as attached the participant information sheet (Appendix B). When participants positively responded, consent forms (Appendix C) and the interview question guide (Appendix A) were shared with them. This allowed them to prepare beforehand and for time-efficiency when interviewing. The 41 interviews were conducted online, predominately using MS Teams via UCL credentials, between April to September 2024. A slide deck was used during the interview by sharing the interviewers' screen which included AGILE's (academic) working definition of HILPs and was shared again to show the Likert-scale questionnaire (Appendix D).

Before commencing interviews, an introduction was given to participants, including information about the project, consent matters and terminology clarification. Audio-recording was optional in case individuals were concerned about confidentiality. All but two interviews were recorded via MS Teams with automatic transcripts. Hand-written notes were taken by Ms Gordon for the two interviews without recordings, which were written up timely. The interview times ranged from 30-90 minutes, post-introductory pitch, with a mode average time of about 45 minutes. Some

participants had less than one hour available for the interview (i.e., 30 minutes only), so they were emailed part 3 of the interview questions.

The questions from the guide were asked depending upon the nature of conversation flow and were tailored to the individual, incorporating or making reference to previously shared content. This was to create a more reflexive exchange between both parties. The same probes were used during the interviews to guide answers, as well as attempting to restrain distinguishing content between participants' answers.

Method limitations

There are methodological limitations and challenges. Primarily, interviews can produce a substantial amount of data which can be time consuming to process. This type of data is needed for the depth, critical reflection, and nuanced expertise from the participants to understand a complex matter such as HILPs. There are also public and private domain limitations—many of the participants could only share so much based on their experiences 'on the record', even if they were participating in the interview as an individual and not a representative of their institution or organisation. Despite this, the larger themes and commonalities could be shared, not necessarily specific examples, which supported this project's overall aim. The interviews were conducted with senior experts in business, academia, and government. The views of operational, frontline professionals are absent from this dataset, as are the views of DRR stakeholders at grassroots initiatives, civil society organisations, and the general public. Furthermore, the focus on individuals capable of 'forward' or 'outside-of-the-box' thinking about HILPs may introduce some bias, as these criteria emphasised their capacity to engage with innovative perspectives.

Data

Participant sample

The participant recruitment process was highly successful, with 41 out of 44 individuals contacted agreeing to participate. The recruitment process was very selective, targeting individuals within AGILE stakeholder networks who held senior-level positions and had at least 10 years of experience in leadership roles within their organisations. Job titles included roles such as "Director," "President," "Vice President XXX," "Chief of XXX," "Secretary XXX," "Head of XXX," "Deputy Head of," "Senior Advisor," or similar positions. Participants were required to have the expertise to answer questions about HILPs. Most participants were identified through the existing stakeholder networks of AGILE consortium members, with additional support from some of the interviewees who facilitated connections. The exceptionally high recruitment rate is attributed to the thorough identification process and the specificity of the selection criteria. Additionally, this success may reflect the strong interest in the research topic among experts and a recognised need for further research and improved training in this area.
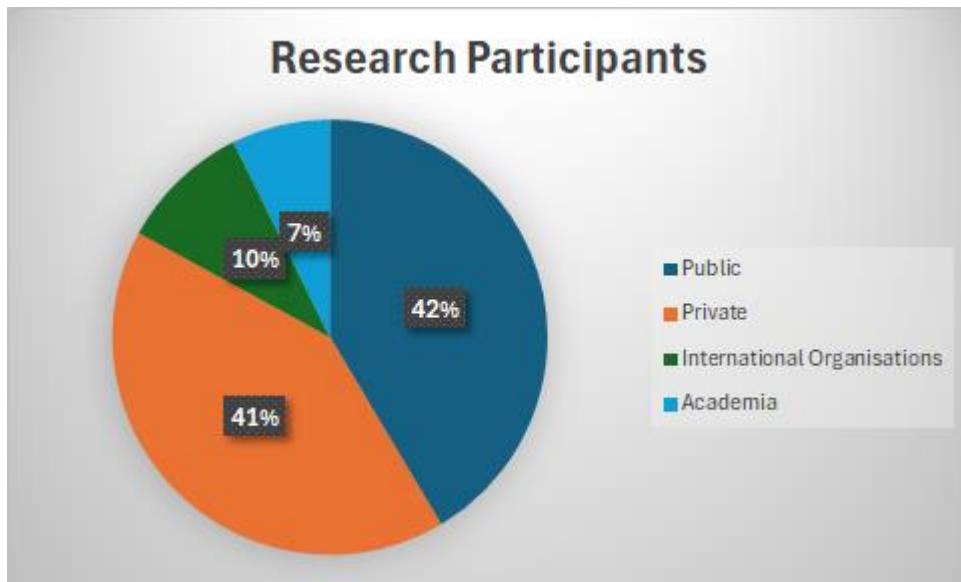
FIGURE 5: COMPOSITION OF SECTORS FROM THE 41 PARTICIPANTS

The above shows the breakdown of the sectors of where the participants are currently working in, summing 41 participants (Public—including local, national, and regional, 17; Private, 17; International Organisations (IO), 4; Academia, 3. It should be noted, however, that at least ten of the forty participants have worked in other sectors before their current positions, such as experience in the Public sector prior to current position in Private, or in the Public sector with affiliations to or experience in Academia. The participants' experiences largely varied from local, mainly European focus to broader multi-national or international focus, dependent on their job experience and/or company or organisation's role. They included multinational companies, international organisations such as branches of the United Nations or European Commission. The high sensitivity of the target group required the development of a strict ethical protocol, described above under "Ethical Considerations".

Data Management

The high sensitivity of the target group required the development of a strict ethical protocol, which was approved in three phases by UCL IRDR Ethic Committee (ID Number: 23120801), in compliance with the Data Protection Act (DPA) and General Data Protection Regulation (GDPR) 2018). Similarly, the dataset was subject to a strict data sharing agreement. Most of the participants required a full anonymization of the transcripts and they required "not to be identified", The anonymization process will include a double-anonymizing process with ID numbers, to minimize the possibility of traceability. See Annex C. According to this protocol and the limited target group involved, any specific reporting of the company names, organizations, or specific geographical locations could result in a breach of the privacy agreement. All files were securely stored on a shared OneDrive folder. The folders and data were all managed by Ms Gordon. All members of the immediate team had complete access to the files, expect for Mr Nugroho who could only access the transcripts (including only first names) and audio-recordings of the interviews. Participants had been given the option of remain anonymous. Therefore, the participants' information and consent forms were stored in separate folders to reduce the risk of their information being associated with the data. Ms Gordon organised auto-recordings to be limitedly available for the purpose of checking the auto-generated transcript. These were promptly

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removed from the folder with the transcripts once checked. Ms Gordon would send the participants their transcripts, in case they wanted to add or remove any content, allowing them about 10 days to do so. After this point, the transcripts were anonymised by Mr Nugroho, unless the participants stated otherwise. The data types from interviews include consent forms (pdf files), interview transcripts (word files), data coding (word and excel files), as well as data analysis and wider findings (word files).

Data Analysis

The interview transcripts were coded to break down the transcripts and extract relevant information. This process used two approaches, deductive and inductive coding, to ensure that the interviews were thoroughly reviewed. This allowed for building a comprehensive data set to view the data in wider themes, setting up for later data analysis. The deductive approach was done by Ms Gordon, who carried out the interviews. A deductive coding tree was created by reviewing all interviews and sharing this with Dr Pescaroli who was present during the interviews. The coding tree was also shared with both Research Fellows, to assure consistency with the State-of-the-Art and other parts of the project. The inductive approach was done by Ms Mulder, who joined the project during the later stages of data collection. This provided the unique situation of having a fresh perspective on data coding and analysis. Qualitative inductive interview coding is a method used to analyse interview data by identifying patterns, themes, or categories that emerge directly from the data. Unlike deductive coding, where researchers apply pre-established codes, inductive coding allows the data to guide the analysis. The process typically begins with reading through transcripts to gain a broad understanding. Researchers then identify recurring ideas, labelling these as codes. As the coding process continues, they refine and group codes into broader themes or categories. This method is flexible, allowing for new insights to emerge as patterns in the data become clearer, and helps capture the complexity of participants' experiences in a grounded, data-driven way. The coded data from both the deductive and indicative approach were merged to the final analysis, provided in Annex E. Bringing both approaches allowed for drawing out the wider and significant themes and research findings which has created a rigorous foundation to the theory building process.

4. Insight on disaster management scenarios and training in general - not HILP specific

This section starts with a discussion of the insights experts provided that apply to disaster management scenarios and training in general. The next section will specifically focus on scenarios and training for high impact low probability events (HILPs).

On disaster scenarios in general

Scenarios should support planning and preparedness	The main purpose of scenarios is to support planning
	Scenarios can support the mainstreaming of preparedness in all sectors
	Scenarios can highlight what capacity / resources organisations have to improvise

Scenarios can build understanding of the best, worst, and catastrophic	There is a rush to solve problems without understanding them first
	Scenarios can highlight what capacity / resources organisations have to improvise

TABLE 2 ON DISASTER SCENARIOS IN GENERAL

Scenarios should support planning and preparedness

Scenarios are essential tools for effective planning and preparedness, providing critical context and insights that help organisations anticipate and respond to disasters. Their primary purpose is to inform planners about the specific conditions under which they might operate. As one expert explains, "A scenario is useful only as much as it provides planners with the context they need to understand the needs, constraints, limitations, and assumptions" [R20]. By clarifying these factors, scenarios enable more targeted and practical planning, ensuring that decision-makers are prepared for the challenges they are likely to face.

In addition to enhancing individual planning efforts, scenarios play a crucial role in mainstreaming preparedness across all sectors. Disaster risk management (DRM) should not function as an isolated activity but be embedded into broader systems such as infrastructure, education, and social protection. As an expert notes, "I think a lot of focus is now like what we as a DRM community have been advocating for is preparedness before things happen. And trying to integrate that into planning. So not just thinking about disaster risk management as a separate kind of sector but making sure that risk-informed decisions are kind of mainstreamed into every sector, into infrastructure planning, education, social protection systems, and so on. And I think to do that, you need to have a bit of an idea or modelling, building the scenarios of how disasters play out. What are the likely impacts? And thinking of it about the climatology in terms of frequency and projections in the future and the climate change so all of that I think is happening, these kinds of scenario modelling exercises are being integrated into actual planning" [R26].

Scenarios also help organisations strike a balance between detailed planning and the flexibility to adapt during crises. By highlighting available resources and support networks, they provide insights into the capacity for improvisation. As one practitioner explains, "It's a little bit of planning but not too much planning, not too much detail. We make a trade-off between planning and capacity to improvise. Before the incident happens, we need to be aware of the capacity we have on-site or we can deploy or project, and the ecosystem of assistance we can benefit from" [R14]. This balance ensures that preparedness efforts remain adaptable and responsive to the realities of a rapidly changing world. By integrating scenarios into planning, organisations can better anticipate risks, mainstream preparedness across sectors, and identify the resources and capacities needed to respond effectively. This proactive approach strengthens resilience and ensures a more coordinated and agile response when disasters strike.

Scenarios can build understanding of the best, worst, and catastrophic

Scenarios are critical for building a deeper understanding of complex problems, particularly in high-stakes situations. One common pitfall in disaster management is the tendency to rush into problem-solving without first grasping the root causes of the issue. As one expert notes, "I think sometimes there's a rush to problem solve... there's a rush to solve the problem without understanding why we have the problem... I think it adds to confusion or misunderstanding or management of those events" [R11]. Scenarios help mitigate this by encouraging a deliberate exploration of why problems arise, enabling more effective and informed responses.

Tools designed to examine the best, worst, and catastrophic outcomes are especially valuable in this process. They provide a structured framework for understanding different possibilities and the actions required at each stage. As one practitioner explains, "Putting in place tools that enable you to look at best case, worst case, catastrophic case, and to have escalating measures based on the outcome is a very powerful tool to have […] These tools are used in everything from disease through to social unrest... You have a barometer where you've predetermined what the indicators of each alert level are, and as you move into each alert level... you start carrying out the next set of actions" [R13]. By predetermining indicators and corresponding actions, these tools allow organisations to respond proactively and escalate measures as situations evolve. By incorporating these approaches, scenarios enhance understanding of a wide range of potential outcomes, enabling decision-makers to anticipate challenges, allocate resources effectively, and respond in a measured and strategic way. This structured understanding ensures that responses are rooted in a comprehensive awareness of the situation.

On disaster management training in general

Training is an integral part of effective disaster management	Need the right people, right equipment, right training, right monitoring, and right performance management
	The combination of planning, training, and exercising is key
	People will remember 80% of what they learned and adlib the other 20%
Challenges related to training in general	Too many trainings – business continuity training gets short changed
	Even people who will never be operational due to their function are trained – (but that's good)
	SOPs and training for different types of events are sometimes missing
	It's rare to have a post-event analysis – so training isn't updated
Developing and delivering disaster management training effectively (in general)	Support of senior leadership is key
	Involve all staff - not just primary people
	Use past experience
	Involve local actors
	Adapt training to the local culture
	Interconnect training, lessons learned, and preparation
	Train across strategic, tactical, and operational levels
	Use communication specialists to deliver training for the general public
	Create a training "diet" that gives everyone exposure to a particular type of problem, operation, or subsystem.

TABLE 3 ON DISASTER MANAGEMENT TRAINING IN GENERAL

Training is an integral part of effective disaster management

Training is a cornerstone of effective disaster management, ensuring that personnel are equipped to respond confidently and competently during crises. Success relies on having "the right people at the right place with the right equipment and the right training. And then you can add with the right monitoring and performance management" [R7]. Without proper training, even well-prepared plans can fall short, as the people implementing them may lack the necessary experience to act effectively. The interplay of planning, training, and exercising forms the foundation of disaster preparedness. As one expert emphasises, "The combination of planning, training, and exercising is crucial. The triangle is not complete without all three elements... You've gotta do them all" [R13]. Training brings plans to life, allowing personnel to practice their roles and understand how to execute strategies, while exercises simulate real-world conditions to test and refine these skills. Together, these elements ensure that disaster management is not just theoretical but operationally sound.

Training also prepares individuals to adapt in dynamic and unpredictable situations. While no simulation can perfectly replicate a real disaster, it equips participants with core knowledge and skills that they can draw upon when events unfold differently than expected. As one practitioner explains, "The more you prepare people the better off they are responding. And even though again, statistics will show they're not gonna execute the plan accordingly, because what you simulate is going to be different than how things unfold. But people are going to remember 80% of what they learned in the exercise. And remember that going forward and then the other 20% will be adlib just because of the way the event is unfolding" [R16]. This combination of structured training and adaptive thinking ensures that responders can remain effective even in unexpected circumstances.

Challenges related to training

Training for disaster management comes with significant challenges. One issue is the overwhelming volume of training courses, which can lead to prioritisation issues and diluted focus. "We just, we have challenges that there are too many training courses, everybody has to attend. So even just to prioritise, you know who's now allowed to go and watch which training and what's the impact in the end and who benefits is something that's greatly discussed. There's only so much time you have in a year. To deploy and train and do your day. That it becomes quite critical that every day is effective of the training and that you can adjust the training on a daily basis" [R37].

Given the overwhelming number of training courses, a failure to streamline training efforts can result in essential training, such as business continuity, being neglected. One expert notes, "I do think that oftentimes the business continuity training gets shortchanged, like, oh, we've got enough training that the staff needs to do. Therefore, we only do this every other year… but we've got to figure out ways that we can continue to say that the staff is trained because again, if not… you get on an airplane. We've all been on an airplane. You know what the drill is gonna be. But they always say now, no matter how often you fly, this aircraft might not be the same type that you've flown on before, so please pay attention to the emergency note" [R16]. This highlights the importance of consistent, high-quality training that addresses both routine and exceptional circumstances.

Despite the overload of training courses, it is beneficial to expose a wide range of participants to disaster management principles, even if they will not be directly operational. As one practitioner

observes, "It's good that people are trained, even if in some courses I have the feeling that people are there, but they will never be operational at the end due to the function, whatever. But it's good that they get an understanding on this about situation and how to handle situations afterwards" [R28]. This broader engagement helps to build general awareness and understanding, which can enhance organisational resilience.

A further issue that undermines the effectiveness of training is the lack of thorough post-event analyses. "It is relatively unusual to have a post-event investigation, because people are glad that it has passed and that the procedures worked, to a degree. There is an under-analysis on what worked and what didn't" [R22]. This gap in feedback limits opportunities for improvement to trainings and prevents organisations from fully learning from their experiences. Another challenge is the lack of standard operating procedures (SOPs) and event-specific training, even when plans are in place. As one expert explains, "Failures… in the preparation phase, I think, what is needed is especially kind of standing operating procedures and trainings. This is what very often is missing. Even if people have their plans, often I see the problem in all those comments, say in all those different types of events that they are not prepared accordingly" [R28]. Without SOPs and tailored training, preparedness efforts risk being superficial, leaving personnel ill-equipped to respond effectively during emergencies. Addressing these challenges requires a focus on creating effective, prioritised, and context-specific training while ensuring lessons from real-world events are systematically captured and integrated into future preparedness efforts.

Developing and delivering training effectively

Effective training requires thoughtful design and delivery to ensure maximum impact. Support from senior leadership is essential to create a culture of engagement and accountability. As one expert explains, "The only reason why it works, and we have that type of engagement and they come back and we monitor we track all of that is because the CEO mandated that" [R10]. Leadership involvement ensures that training is prioritised, properly resourced, and taken seriously at all organisational levels. Training should build on past experiences, using historical events as valuable benchmarks for planning and preparedness. Experts emphasise that "Anything that's happened in the past can be used to go forward and planning of things" [R16] and "the past is the only benchmark you have. And we need to use it" [R21]. By integrating lessons learned from previous incidents, training remains relevant and grounded in real-world scenarios.

To ensure comprehensive preparedness, all staff—not just primary responders—should be involved. As one expert noted, "Don't always use… the primary people who do it, make sure you're rotating everybody through on the team so that they know what to do" [R16]. This approach ensures broader organisational readiness and prevents over-reliance on key individuals. Similarly, local actors must be engaged in training efforts, as their proximity to affected areas enhances preparedness and response. "Local authorities can have a tremendous role in this process… institutions and dimensions closer to the territories are better able to prepare, better able to respond to events when they actually happen" [R33]. Cultural adaptability is another key aspect of effective training. Trainers must adjust their methods to suit the cultural contexts of their audience. One practitioner recalls, "After the first course... I was nearly shocked because it's also different to teach people there or to train them... I had immediately to adapt... you immediately have to adapt to the different cultures" [R28]. Tailoring training to cultural nuances ensures it resonates and is effectively absorbed.

Training should also be interconnected with lessons learned and preparation. It is vital to continually update training materials to reflect new insights. As one expert notes, "You have not only the training but… use the lessons learned to include them in the training so that you are really up to date… also rethink your guidelines or plans" [R28]. This ensures that training remains current and aligned with evolving challenges. For training aimed at the general public, communication specialists are invaluable. Traditional methods of public awareness are becoming less effective, especially for younger generations. As one expert highlights, "We need professional communication specialists… to understand whether a two-minute video or even a 20-second clip on social media would be the best way to get the message across" [R24]. These specialists can design engaging and impactful campaigns to ensure key messages reach diverse audiences.

Given the constraints on time and resources, a "training diet" can help optimise the balance between depth and coverage. This approach exposes participants to specific problems or operations, providing foundational knowledge that enables them to handle unforeseen challenges. "There's only so much training time you can deliver… so you had to come up with a training diet where everybody had exposure to a particular type of problem or operation" [R22]. Finally, training must address all levels—strategic, tactical, and operational—while prioritising the operational level. Operational personnel are often the ones executing plans in real-time, making targeted and specialised training for them critical. As one expert notes, "The main part, I think, lies on the operational part… they should be specially trained" [R28]. Strategic and tactical training should provide broader understanding and context, while operational training equips individuals for hands-on, decisive action during crises.

The gap between a disaster management plan and its activation (in general)

Plans are often created without mechanisms to enforce their implementation	There are no repercussions for failing to follow processes, leading to plans being effectively useless in practice
	From a legal perspective, organisations may feel they have met their obligations by creating plans and training, but the lack of follow-through undermines their effectiveness
Insights from planning exercises are not always used	Results of preparatory exercises are sometimes ignored
	Planning does not always translate into actionable preparedness
Plans are sometimes unrealistic or impractical	Plans are sometimes based on unrealistic assumptions, such as requiring resources that are unavailable
	"Fantasy" plans are ineffective when real crises occur

TABLE 4 ON THE DISCONNECT BETWEEN PLANS AND THEIR IMPLEMENTATION

A significant challenge in disaster management lies in bridging the gap between planning and activation. Having a well-documented plan is insufficient if it cannot be effectively implemented during a crisis. As one expert notes, "There's one thing we're very good at is creating processes, and then one thing we're really good at is having nobody follow them and there's no repercussions

for that. And I don't mean like fire people or whatever, but there's no enforceability. And so, you're kind of in this situation where from a legal perspective, you've done everything. You've created a program, you've trained… but if it's not followed then you're not going to have an impact to either prevent or minimize… a high impact" [R05]. This highlights the critical need for enforceability and accountability mechanisms to ensure plans are acted upon when required.

Planning exercises often generate valuable insights, but these are frequently ignored, leaving organisations unprepared when disasters occur. For example, in the UK, "there were eight or nine pandemic exercises, which produced results that weren't taken into account… When the pandemic surfaced in February 2020… were we ready for it? Short answer, of course, there's no… We had a plan, but there was an abyss between the plan and its activation. The ability to use it. Planning is pointless if you can't do anything with the plan. If the plan says send 500 ambulances, and you've only got 3, then obviously the plan is sheer fantasy" [R04]. Disaster management plans must be both actionable and grounded in the realities of available resources and capacities, ensuring critical resources are available when needed. "The UK… had sold off its stocks of personal protective equipment… the alternative is to have accelerated manufacturing agreements…Perhaps a UK factory can drop what it's doing and be ready to churn out masks and gowns and visors, or ventilators or whatever is needed" [R04]. Unrealistic assumptions in planning render plans useless in real-world scenarios. During the COVID-19 pandemic, many organisations found their business continuity plans to be irrelevant or unused. One practitioner explained, "I asked every function across my organisation since COVID kicked off, did you reference your business continuity plan… not one of them actually picked it up, looked at it or opened it… it didn't align with what they had documented" [R19]. In sum, effective disaster management needs to minimise the gap between the plan and its implementation. This requires enforceable plans, the integration of insights from exercises, realistic assumptions about resources, and mechanisms to ensure plans are actionable.

Engaging stakeholders in scenario building and training (in general)

Importance of a safe environment and trust	Role-playing exercises can make participants feel exposed, so trust and a safe environment are essential
	Creating an environment where participants feel comfortable fosters engagement and creativity
Structure exercises around a sandbox approach	Use tabletop exercises to simulate stakeholder interactions, media scenarios, and operational response procedures
	Use a "sandbox" approach to let teams explore systems and their dependencies (e.g., simulating restarting systems that are down)
Use skilled moderators	Skilled moderators can encourage participants to use creativity when exploring worst-case scenarios
	Taking individual perceptions and personalities into account, along with a well-structured and managed tabletop exercise, can foster creativity

Value of cross-sectoral and multidisciplinary collaboration	Cross-sectoral and multidisciplinary teams generate the best results as diverse perspectives lead to innovative ideas
	Including unconventional participants (e.g., students, businesspeople) disrupts conventional thinking and adds fresh viewpoints
Exercises must be adapted to the cultural and linguistic context of participants	Intercultural competence is critical for success
	Missteps, such as inappropriate examples or group dynamics, can alienate participants and reduce effectiveness
Training can facilitate relationship building and networking	Training fosters a shared understanding and can sometimes influence values
	In operational contexts, training also builds personal connections, which are valuable during collaborative work

TABLE 5 ON ENGAGING STAKEHOLDERS IN SCENARIO BUILDING AND TRAINING

Effective stakeholder engagement in scenario building and training requires careful planning and implementation to foster creativity, collaboration, and trust. Establishing a safe and supportive environment is critical, as some participants, including senior personnel, may feel vulnerable or resistant to certain activities, such as role-playing. "You have to be very respectful in how you do it... creating trust. You have to have a safe environment that you create for everybody" [R37]. Building trust and mutual respect encourages participants to engage fully in the process. A structured approach, such as tabletop exercises, helps guide participants through scenario building and rehearsals. These exercises can simulate complex situations and are invaluable for team readiness. As one expert explains, "You still have table exercises with more elaborate environments… and the orchestration that you restart in order to have the sequence to enable the systems cascade… Rehearsing that sequence is instrumental for the readiness of the teams, and in order to rehearse that sequence, you need a playground. You need a sandbox" [R14]. These controlled environments enable teams to analyse scenarios, evaluate, and refine their responses without real-world consequences.

Creativity can be harnessed through well-moderated workshops and brainstorming sessions. Experienced facilitators can encourage participants to explore the most extreme and unexpected scenarios, fostering out-of-the-box thinking. "Structured, workshop ideation or brainstorming process as part of tabletop exercise… actually works pretty well… They were given the task to come up with the worst type of things that might happen and consequences, and that worked very, very well" [R32]. This approach helps participants to contribute meaningfully and expand the range of possible scenarios.

Cross-sectoral and multidisciplinary teams yield the most innovative ideas. Including diverse perspectives, such as students, business professionals, and bureaucrats, can disrupt entrenched thinking and generate fresh insights. "The best ideas come up when people are truly cross-sectoral… Students work like crazy because they are still young. They are not cemented in their way of thinking, not constrained by the budget" [R32]. Such diversity enhances creativity and ensures a broader understanding of challenges and solutions.

Cultural competence is crucial in engaging stakeholders effectively. Trainers must be aware of and sensitive to cultural differences, which can affect participation and outcomes. Missteps, such

as using culturally inappropriate examples, can alienate participants. "We had some examples with UK training in Sri Lanka where you had different ethnic groups… who were utterly affronted by some of the examples… intercultural competence is really key here" [R37]. Understanding the audience and adapting language, examples, and group dynamics to cultural contexts ensures inclusivity and participation. Training and scenario-building activities also create opportunities for relationship-building and shared understanding. "Training creates common understanding and also… connections, like we do also in the EU scheme… that the EU civil protection training programme is really like creating networks" [R39]. These networks enhance operational collaboration and foster trust among stakeholders, which can prove invaluable during real-world crises.

Using generic versus hazard specific approaches (in general)

Generic versus hazard specific approaches	It's more effective to provide generic training than hazard specific
	Many disaster management needs, constraints, limitations, and assumptions apply across multiple scenarios
	Need agnostic incident response capability
	You can extrapolate and generalise from all sorts of different and unexpected events
	It's hard for people to understand how to prepare for a generic event – they want specifics

TABLE 6 ON GENERIC VERSUS HAZARD SPECIFIC SCENARIOS APPROACHES

Respondents discussed the merits of generic (risk agnostic) versus hazard-specific approaches to scenario development and training. Focusing on the latter, one expert observed that generic approaches offer foundational knowledge and flexibility that can be applied to any type of disaster. They reflected, "I did for many years in West Africa a training course for humanitarian assistance… I trained people in general, what they have to do if such an event happens, be it an earthquake, whatever, or floods or whatever. So, they are able to handle the situation by themselves… The main part should be to have this overview to know how it will work, how the international community will come in and support you, and so on" [R28]. This approach ensured that responders were equipped with universal principles regardless of the specific hazard. Generic approaches work well for widely applicable skills. For example, "We have generic induction trainings and… there's some common modules that you can run no matter what emergency you're talking about. So, for instance, public speaking or speaking to the media has some generic pointers that you can teach everybody… and they can then adapt that to the emergency they're dealing with" [R37]. Focusing on universally relevant competencies ensures preparedness for a broad spectrum of hazards. "You need an agnostic incident response capability. So, you need to train people on how to take command, to brief people, to share information, and you need leadership training" [R12].

This generalised preparation is especially useful in the context of HILP events, which are highly unpredictable. As one expert explains, "You'll look at 100 HILPs… Doesn't matter if you get them right. The important thing is to figure out that… your needs, constraint, limitation, and assumptions will be roughly the same, and these are the ones you should be planning for" [R20]. Planning for commonalities across scenarios provides a robust foundation for handling even unforeseen

disasters. However, some argue that generic approaches may be less intuitive for those without experience, who often prefer specific scenarios. "It's very difficult sometimes for people to understand how to prepare for an event that you don't know what it is… They want to know an exact sort of scenario" [R41]. To address this, multiple hazard specific scenarios can be used to identify general principles that apply across the board and develop flexible response strategies. By combining both approaches, disaster management professionals are better equipped to handle a wide range of events, whether anticipated or completely unexpected. This balance ensures preparedness remains both practical and adaptable.

Cross boundary approaches to disaster management scenario building and training (in general)

Use a multi-level approach	A multi-level approach (regional, national, local) enhances preparedness and response
	Involving stakeholders at various levels ensures comprehensive scenario-building
	Coordination across sectors and boundaries is vital for large-scale events
The subsidiarity principle - decisions and actions should be taken at the most local level	Aim for decentralisation
	Local actors lead on risk assessment, planning, and preparedness
	Local levels respond first; upper levels intervene only when necessary
	National and regional support ensures preparedness for large-scale hazards
	Organising responsibilities in the shape of a pyramid ensures national coverage with tailored local plans
A multi-level approach in business	Global leadership can mandate specific scenarios (e.g., cyber risks) for testing when deemed necessary.
	Cascading global frameworks and tools for local implementation
	Regular checks ensure plans are tested, and local adaptation occurs
Cross-industry and cross-domain collaboration	Regular cross-industry exercises improve coordination across industries
	Integrate disaster management into broader planning (e.g., around infrastructure) and build scenarios to assess cascading effects.
	Multidisciplinary teams combine diverse perspectives, improving scenarios and preparedness.
	Use cross-sectoral multidisciplinary teams and ensure that people actually listen to each other (this is rare).

TABLE 7 ON CROSS-BOUNDARY APPROACHES TO SCENARIO BUILDING AND TRAINING

Involve relevant stakeholders at regional, national, and local levels

Effective disaster management requires the active engagement of stakeholders across regional, national, and local levels, ensuring that planning, preparation, and response efforts are cohesive and comprehensive. This multi-tiered approach allows responsibilities to be distributed and tailored to the specific needs and capabilities of each level.

Government Stakeholders

Involving government stakeholders at all levels is critical to building a resilient and responsive system. In Portugal, for example, a national civil protection law established clear roles for local authorities, making mayors the civil protection political authority within their territories. As one expert explains, "There's a principle of subsidiarity, so the upper level only gets activated if the lower level does not manage or is not capable… They are responsible for their own planning, for their own risk assessment, for their own preparation, of course, with the support from the different regions and also from the national level. But our concept is that institutions and the dimensions which are closer to the territories, they are better able to prepare, better able to respond to events when they actually happen" [R33]. This approach ensures that local authorities take ownership of planning for specific risks within their jurisdictions, such as earthquakes in Lisbon or the Algarve, while receiving necessary support from higher levels of government. The engagement of local and regional authorities has resulted in comprehensive emergency plans that cover the entire territory. This system balances daily civil protection responsibilities with preparedness for HILP events, creating a layered and responsive framework.

Business Stakeholders

In the private sector, engaging businesses in scenario development and training ensures that organisations are prepared for risks relevant to their operations. Businesses must not only identify critical risks but also adapt and test their plans to address those risks effectively. As one practitioner explains, "Every year, you have to test a crisis, and you have to use the scenario… If we identify a risk that we are certain is going to happen to us and we want all of the markets to practice, then we use our authority from the global level, from the CEO, and the CEO mandates every market… to adapt [the plans] locally" [R10]. This involves creating playbooks, mitigation plans, and response procedures that can be tailored to local contexts, ensuring plans are relevant and actionable. For example, companies may mandate local markets to practice scenarios such as cyberattacks or product recalls, addressing both mitigation and response. "We have done that with proper recall as well… We mandated, we made sure that the CEO mandated the markets to practice… and make sure it works" [R10]. This rigorous process, supported by cross-checks against a standard business continuity management framework, ensures accountability and effectiveness.

The Importance of Integration

The key to successful stakeholder engagement lies in integration and collaboration across levels. Local stakeholders provide granular insights and ensure that plans are grounded in the realities of their communities. National and regional levels provide the resources, guidance, and oversight needed to support these efforts. Businesses, as part of the broader ecosystem, contribute expertise, operational capabilities, and risk mitigation strategies. By involving stakeholders at all levels and ensuring that responsibilities are clearly defined and supported, disaster management efforts become more inclusive and effective. This layered approach not only strengthens preparedness but also ensures a coordinated response when crises occur.

Working across industries and professional domains

Developing scenarios and training benefits from collaboration across industries, domains, and professional disciplines. This approach helps organisations better understand interdependencies, prepare for cascading effects, and strengthen their capacity to respond effectively to complex disasters. One participant explained, "There are scenarios which are run as cross-industry events and then you look at where you fit within that and how you could/would be impacted" [R36]. These events provide an opportunity to examine roles within broader systems and assess vulnerabilities. Integrating DRM into wider planning frameworks is useful to achieving this cross-sectoral collaboration. One respondent highlighted this, stating, "What we as a DRM community have been advocating for is preparedness before things happen - and trying to integrate that into planning. So not just thinking about disaster risk management as a separate kind of sector but making sure that risk-informed decisions are kind of mainstreamed into every sector, into infrastructure planning, education, social protection systems and so on. And I think to do that you need to have […] ideas or modelling, building the scenarios of how disasters play out" [R26].

Joint exercises that involve multiple sectors, agencies, and even nations are helpful in building preparedness. As one participant explained, "Those civil protection agencies that have regular cross-agency exercises with carefully plotted scenarios, especially with those that take into account cascading effects… they seem to be more prepared for including the high-impact low-probability events […] It seems to be that this is the more modern way of dealing with the capacity building. I would take a step further. I could see that cross-country, cross-agency exercises could be extremely important because, as my colleagues say, usually the hazards do not know any borders. If something happens between countries […] the common command and control should be at least set up once as a board game or as a tabletop exercise. So yes, cross-sectorial, cross-country exercises with well-done scenarios with cascading effects seem to be something that those the best in the industry think is the answer" [R32].

Ensuring that different perspectives are present – and listened to – can encourage creativity and challenge conventional thinking. Another respondent noted, "I do a lot of workshops with my people because it's very difficult to just put people around the table, come up with the best idea. So, we are trying different things and when the best ideas come up is when people are truly cross-sectoral. It's such a common space right now, is the cross-sectoral multidisciplinary teams yield the best results. However, […] in most of the industries, in fields through cross-sectorality and true multidisciplinary teams, where people actually listen to each other, do not happen. So, each time I disrupt my usual self-education circle with an inclusion of a simple businessperson or working in the same industry or a bureaucrat or a student, even students work like crazy because they are still young. They everything is open for them. They not cemented in their way of thinking, not constrained by the budget. They say things that practitioners say, well, that's interesting" [R32].

Achieving meaningful collaboration across levels of governance and sectors requires careful coordination. One participant explained, "Important that we get as many views as possible and we look in all levels and try to come maybe confine them in a kind of a brainstorming… The more that you have of different people with different approaches on different levels… If you get all these people in the same room to think about those kinds of events, I think the resource will be more fruitful than if you just talk about it on different levels with different approach" [R40]. Collaboration across strategic, operational, and regional levels creates a more comprehensive understanding

of risks and potential responses. By leveraging diverse perspectives and ensuring communication and coordination across sectors, organisations and governments can better address the complexities of modern disaster risks.

Effective disaster management also relies heavily on coordination and joint planning, particularly for large-scale events that exceed the capacity of any single organisation or country to manage independently. This includes collaboration at regional, European, and even broader levels to ensure that systems and resources can be pooled effectively when required. One respondent noted, "we need to have a joint planning in regional level or in the in the whole European level […] the scenario can be that the really the whole Europe needs to support you somehow" [R30]. Cross-sectoral / cross-national preparedness is challenging. As another participant noted, "I think the main challenge here is the preparedness. I'm very much involved with preparedness and when it comes to different kinds of disasters […] the question is how you prepare for the normal expected disaster – […] that's already a challenge to identify standards and to have harmonized training schemes [..] throughout countries, […] that's already a challenge. So, when it comes to these events [HILPs], then the prepared method [is] even more challenging because how can you standardise your response if you if you don't know how or what you are preparing for?" [R24].

The scale and unpredictability of large disasters further complicate coordination efforts. One respondent highlighted how such events strain existing systems and standards, saying, "[The earthquake] was a large event and unexpected event, in my terms at least. And that required extra support and extra capacities, and it didn't require anything which we do not train for, like earthquake response, […] search and rescue. That's a standardized and very well-developed system we have internationally for that. However, the scale again challenged those standards which we have, and even it challenged it in a way that, at a level that, even at the highest level, now they are reconsidering how to adjust the coordination standards, for instance, to these large-scale events, as no one really expected that would be required because no one really. So, that earthquake can hit that large area, requiring not only one but nine to ten coordination sites for you." [R24].

Cross-sectoral and multidisciplinary teams can play a critical role in improving coordination, provided people actually listen to each other. Another participant observed, "Cross sectoral it's such a common space right now […] the cross sectoral multidisciplinary teams yield the best results. However, […] in most of the industries and fields, the cross sectoral [..] multidisciplinary teams where people actually listen to each other do not happen" [R32]. Overall, joint planning and coordination are essential to managing disasters effectively, particularly at a large scale. While achieving harmonised training and response standards remains a challenge, investing in collaborative systems and multidisciplinary approaches is critical for building resilience and ensuring an effective response when disaster strikes.

5. Insights on HILP scenarios and training

On HILPs scenarios

Scenario building for HILPs is rare	Scenarios traditionally based on mid-range events, not HILPs
	Scenarios are only developed for risks deemed 'critical'
	For business reasons, there is less scenario planning for HILPs than HIHPs
	People lack the imagination needed to suggest HILP scenarios
Challenge: it's hard to convince people of the need for HILP scenario building	Hard to convince senior management: higher frequency events take priority
	It is challenging to convince authorities to fund HILP preparedness
	People are sceptical or try to reduce HILPs to simple factors
	People cannot afford to plan for the worst event they can imagine
Opportunities: it's easier to get buy in for HILP scenario building after a major event or before a high value/prestige situation.	Easier to convince people after a major event
	Proactive provisions for the unknown are rare – but do occur in high value, high prestige situations
Purpose and benefit of using HILP scenarios	Use HILP scenarios to identify breaking points in the system
	Use HILP scenarios to identify common assumptions, constraints, and needs
	Use insights from HILP scenarios to generically plan for consequences
	HILP scenarios force people to think beyond preventative measures (what happens when prevention fails)
Uncertainty inherent in HILPs demands out of the box thinking	Decisions need to be made against highly uncertain future projections
	HILPs require people to adapt to scenarios that did not exist before
	Climate change introduces uncertainty: historical scenarios are out of date
	HILPs require the capacity improvise
How to improve scenario building for HILPs	Use counterfactual analysis and red teaming
	Focus on trigger points
	Focus on feedback loops
	Exercises should challenge assumptions
	Culture is an important factor to consider
	Consider risk tolerance and impact tolerance
	Creativity is important for scenario building
	Include challenges related to communications and information management

	Develop an envelope of scenarios based on a systems approach
	Multiple threats can be put into one theme
	Bring different types of risk – not always the same ones
	Provide tools that show best, worst, and catastrophic scenarios + escalating measures
	Engage societal stakeholders (or the exercise remains theoretical)
	Focus on the operators managing the affected systems
	Prevent organisational politics from getting in the way of failing and learning – the point of HILP scenarios
	Use of Anytown to avoid "that wouldn't happen in this place for reason X"
	Throw the kitchen sink at it
Recent developments in scenario building	Shift from ad hoc tabletops to scenario planning and modelling
	Use of counterfactual analysis
	Focus on trigger points instead of scenarios
	Use AI / predictive analysis
	Use of a crisis cell exploring "what if" scenarios

TABLE 8 ON HILP SCENARIOS

Scenario building for HILPs is rare

Due to the ways in which risks are assessed and prioritised, scenario building for high-impact, low-probability (HILP) events is rare. Generally, scenarios are developed around mid-range events rather than extreme cases. As one participant explained, "When we make emergency plans we generally where we can base them on scenarios. The scenarios we use traditionally have been mid-range events... The upshot of that is that we know that we're gonna have to deal with larger events whether we could really classify them as HILPs is another matter. Larger yes but how much larger?" [R4]. Additionally, scenario development is often restricted to risks deemed "critical" under formal assessment frameworks. As another participant noted, "You know when we conduct assessments of risk for us we have the risk matrix, and we decide you know what is the probability of that risk occurring. You know if it is low medium high and then the criticality of it based on our experience. Anything that is in red you have to do something about it [...] every year you have to test a crisis, and you have to use the scenario. But the scenario has to be based on one of those risks that you have identified that are at the high criticality under the assessment so that that's mandatory." [R10].

In the business sector, this imbalance is even more pronounced. Resource allocation decisions often favour preparing for higher-probability events, as businesses perceive a greater return on investment in such cases. One participant reflected, "I think in the business environment there's less scenario planning and less preparation for high impact low probability... when you're prioritizing resources and views about thinking about that environment... I'm gonna go for the higher probability events and put more money and invest and time into that." [R11]. Perhaps most fundamentally, the rarity of HILP scenario building reflects a broader failure of imagination. Planning for the unthinkable requires the ability to conceptualise events far outside normal

expectations, yet this capacity is often lacking. As one participant explained, "So there was a lack of imagination to put forward those scenarios. There was a lack of imagination to dream the unthinkable and just say well what would happen if we weren't like that? And what would we do?" [R19]. This absence of imaginative thinking, combined with systemic biases towards more probable events, limits the scope and effectiveness of planning for HILPs.

Challenges and opportunities in HILP scenario development

The development of scenarios for HILP events faces many challenges, primarily stemming from scepticism, resource constraints, and psychological barriers. One of the main obstacles is convincing senior management of the necessity for such planning, as they often prioritise higher-frequency events. As one respondent noted, "I would say, you know, selling this as a potential scenario to the senior management. This is the biggest challenge. The weakness of this kind of thing is defining this low frequency high probability event for an organisation. I think this would be the biggest challenge and the most difficult part to define what kind of scenario would fit into this scope [...] Unfortunately, they are trying to focus on events that are occurring more and more so medium to high probability events and less [on] low probability events that can have a high impact" [R6].

Beyond managerial resistance, there is a broader difficulty in persuading people of the necessity of HILP scenario planning. As another respondent stated, "I think one of the challenges is trying to get people to realise that it needs to get done…" [R16]. This is compounded by the limits of human imagination and a tendency to underestimate the potential ramifications of large-scale events. One participant shared, "The ramifications of such a large-scale event are just very, very difficult to imagine. Even if you have the mandate like I do in my organisation to draw the cart of, yeah. But let's think about the worst-case scenario. The worst of the worst. Even then, our human imagination, has its limits… When you have to transfer that message then to a board or management level and to ask for resources to well to be invested in preparedness, then it gets really, really difficult" [R27].

The concept of "low probability" itself can be misleading, creating a barrier to taking HILPs seriously. As one respondent explained, "I think people are misled by the low probability and then have difficulty imagining the impact. Why would they…? With the high probability high impact, people have more incentive to take it more seriously" [R27]. Others have observed that people often resist engaging deeply with HILP scenarios, reducing them to oversimplified factors or dismissing them outright. One participant remarked, "When it comes to exercising, how many people on exercises that you have observed, I've tried to say, but that will never happen or they kind of fight the scenario… or they just break it down into a very simple factor that they can deal with" [R19]. Securing funding for HILP preparedness is another major hurdle, as authorities and finance ministries are reluctant to allocate resources to scenarios perceived as unlikely. "The issue is that what we observe when we prepare for HILP is that it is extremely hard to convince our authorities, our ministries of finance to fund the preparedness for high impact low probability emergencies," explained one participant [R29]. Psychological discomfort also plays a role, as HILP scenarios often involve frightening possibilities that people prefer to avoid discussing. For example, a respondent shared, "In my experience, it's been thought about and discussed very briefly, but then dismissed… it's also incredibly scary to think about, so people have moved on from that conversation quite quickly" [R23].

Moreover, practical limitations mean that even plausible worst-case scenarios are often left unaddressed because they are seen as too costly to plan for comprehensively. "We have the

plausible worst case… Hopefully it's not an asteroid impact. It is instead the largest event we dare plan for or dare think about… Well, we can't afford to plan for it because we'd have to have sea walls that are 20 metres high and things like that," noted one respondent [R04]. However, opportunities for advancing HILP scenario development do exist, particularly in the aftermath of significant events, when public and organisational buy-in increases. "On the aftermath of kind of big incidents, it was far easier to get buy-in for exercises and people would just sit and say OK throw me the worst-case scenario because gosh we've just played out some pretty poor things," explained one participant [R19]. Concrete examples include the Swedish Government's resurrection of Cold War-era contingency plans in response to shifting geopolitical threats [R09] and the reassessment of tsunami-nuclear disaster scenarios following the Fukushima incident [R02].

Proactive planning for the unknown, while rare, does occur in high-value, high-prestige contexts where stakes are particularly high. As one participant observed, "Proactive provisions for the unknown [are rare], whereby coping with a situation which is novel… This is seen in high value, high prestige situations. May be a singular view or events. Where there is high monetary value" [R22]. These instances highlight the potential for more forward-thinking approaches to HILP preparedness when the perceived value justifies the effort. The essential approach is to adopt an agnostic perspective in planning and scenario development—focusing on the impact and failure points rather than on the trigger itself.

Purpose and benefit of using HILP scenarios

HILP scenarios can serve as powerful tools for enhancing creativity and imagination in planning. By envisioning extreme events and their cascading effects, they challenge organisations to consider the unthinkable and develop strategies that are both practical and adaptive. They can be vital tools for improving preparedness and resilience by testing systems, uncovering commonalities, and pushing planning beyond preventative measures.

One key purpose of HILP scenarios is identifying breaking points within systems. As one expert explains, "If we want to stress test and find the breaking point of a system we need to... put the system in front of a situation that at a certain moment it needs to recognize that we cannot face the situation, or we cannot find the solution for this situation. [...] A scenario that will look at the breaking point needs to make people very aware that if they don't discover their breaking points they will not be able to find solutions to increase the threshold of the breaking" [R29]. This process helps organisations understand their vulnerabilities and develop strategies to enhance resilience. A key difference between HILP and HIHP scenarios is the requirement for risk agnosticism when identifying systemic risks, as well as the scale at which the scenario is executed. For instance, a hospital or school plan should not be developed from an HILP perspective if there are insufficient resources to support effective planning.

HILP scenarios also reveal shared needs, assumptions, and constraints across different types of events, enabling planners to focus on commonalities. One practitioner observes, "You'll look at 10 HILPs. Doesn't matter if you get them right or not... The important thing is to figure out that in 999 of them, your needs, constraints, limitations, and assumptions will be roughly the same and these are the ones you should be planning for" [R20]. By identifying these shared elements, organisations can create more versatile and efficient plans. Additionally, using multiple scenarios allows organisations to develop strategies and training programs that apply to a broad range of risks. As one expert explains, "The commonality... both of those types of events have huge commonalities; you just need them to adapt depending on the level of the impact. So, preparation,

prevention, training—it's all these common aspects that are good for both of these types of events" [R33].

Generic planning is an important advantage of HILP scenarios. By focusing on consequences rather than specific triggers, organisations can streamline their continuity plans. For instance, "If you can generically plan for consequences... you only need three business continuity plans. It doesn't matter which of the 10,000 different risks actually manifest, those are the only three possible consequences... and you just pull out the appropriate plan or plans to stay in business" [R13]. In addition, HILP scenarios force organisations to think beyond preventative measures and prepare for situations where prevention fails. A practitioner notes, "If you try to engineer your way against a once-in-so-many-years flood and you only focus on the preventative side, then you will see at the moment will come that the threshold against which you have been protecting yourself will be exceeded and then you haven't invested" [R34]. This highlights the need to invest in broader resilience measures.

Uncertainty inherent in HILPs demands out of the box thinking

The unpredictable nature of HILPs compels organisations to move beyond traditional methods, embracing flexibility, innovation, and a willingness to develop new strategies for unprecedented challenges. Decision-making under HILPs involves dealing with "a highly uncertain projection of the long term future" [26].

This uncertainty challenges traditional decision-making processes. One respondent highlighted that decision-makers must "make decisions differently when you understand that you're building your decision on a highly uncertain projection of the long term future" [26]. Key questions include: How can flexibility and innovation be cultivated? Where should the process begin, and who should be prioritised for participation? While some progress has been made in integrating these considerations into planning, "huge gaps" remain in understanding and processing the technical information required for such scenarios [26]. HILPs often involve scenarios that have no historical precedent, forcing organisations to develop new strategies. As one respondent stated, "we need to create new plans and new strategic approaches to this type of scenarios which we didn't have before. So, it's a learning curve" [33]. The inherent uncertainty of climate change exacerbates the challenge, as traditional historical scenarios are no longer adequate. For instance, one respondent explained that while scenario modelling exercises are being used in planning, "all of that comes with a lot of uncertainty" [26]. Additionally, countries face challenges in developing scenarios for phenomena like shifting rainfall patterns or increasingly frequent extreme weather events, such as "what used to be a 50-year typhoon now is a once in a 2-year typhoon" [21]. Therefore, the capacity to improvise is critical when dealing with HILPs. As one respondent put it, "hoping for the best is not a plan" [33]. Instead, the ability to adapt existing plans to unforeseen circumstances is "one of the most strategic capacities" available [33]. However, bureaucracy and regulatory constraints can hinder innovative approaches, even when public entities recognise their necessity [21].

Recent developments in scenario building

Recent developments in scenario building reflect a transition to more structured, anticipatory, and data-driven approaches that go beyond traditional methods. Organisations are moving away from ad hoc tabletop exercises towards comprehensive scenario planning and modelling. One respondent highlighted this shift, stating, "We haven't been doing scenario planning or modelling at all unless it was... here's a potential crisis. Let's sit down and do a tabletop, which is not the same. It was not like future preparation and so we're only doing all of that now. So that is the new

aspect of it [...] we're doing a lot more modelling which is quantification and that has not been traditionally done" [R5].

Another key development involves the use of counterfactual analysis[9] to explore outcomes that could have occurred under different circumstances. A respondent explained, "This if you like, is the employment, perhaps even on a large scale of counterfactual analysis. What didn't happen but might have done. Downward counterfactual analysis - it could have been much worse. Upward counterfactual analysis - it could have been a lot better, a lot less serious. We generally go for the downward, of course, but counterfactual analysis has been experimented on things" [04]. This approach provides insights into both potential risks and missed opportunities, offering a broader perspective for planning. In addition, some organisations are shifting their focus from scenarios to trigger points, which provide observable and factual markers that can be used to anticipate cascading events. One respondent explained, "We are not looking at scenarios anymore... we are much more strongly into trigger points... because trigger points are something that is factual, that we can observe, and where we can generate a sequence" [R8].

Advances in technology, particularly the use of AI and predictive analysis, are also increasingly used in scenario building. AI enables organisations to process and analyse data more efficiently, as one respondent noted, "We have significantly changed speed and modelling of those trigger points also using more AI... we use predictive analysis to help us to challenge the analyst... it's a very good way to increase the better fine-tuning of what the analyst is producing as the report" [R8]. Another added, "AI gives that ability to more quickly structure that data and analyse that data... we can make better predictions or better understanding" [R11]. Finally, the use of dedicated crisis cells to explore "what if" scenarios is becoming more prominent. These teams are tasked with anticipating how a crisis might evolve by constructing cascades of potential events. One respondent described this approach: "A team within the crisis cell in charge of 'what if' scenarios helps us anticipate the options of the evolution of the crisis, and that is called anticipation [...] The scenario is a cascade of 'what if?' So, we, from the context, identify what would be the cascade or the likely cascade after deploying all the prevention means" [R14]. These advancements represent a clear evolution towards more creative, dynamic and predictive approaches in scenario building.

How to improve scenario building for HILPs

Improving scenario building for HILPs involves enhancing tools, methods, and approaches to address complexity and unpredictability, all while fostering trust, creativity, and a more systemic perspective. Unpredictability poses the greatest psychological challenge for DRM experts. They often attempt to predict what cannot be predicted, failing for many clear reasons. Instead, they should shift their focus to anticipation and develop agile response systems—recognising that precise prediction is simply not feasible. A key step is helping people understand the unimaginable: "Actually, the catastrophic, almost by definition, has escaped most people's imagination, and so putting in place tools for that that enable you to look at best case, worst case, catastrophic case and to have escalating measures based on the outcome is a very powerful tool" [13]. Another expert encouraged a greater emphasis on creativity: "You should be very creative... They need to think about, but what about this particular one, which is also a high risk, high impact, low, low probability" [10].

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[9] In the AGILE project, counterfactual analysis plays a central role in the Tier 1 stress test. This test examines a scenario in three steps of increasing depth, with a counterfactual analysis conducted at the end of each step. See AGILE D4.1.

Scenario building should also embrace the principle of learning through failure. Exercises must challenge assumptions and include higher management to normalise the idea that failure can be a valuable learning opportunity, though organisational politics often create obstacles. As one expert explained, "Things will go wrong which would be impactful in real life. This is political. Higher management. They want a perfect parade. But this prevents people from speaking out. There should be a full task, with higher management included, but need to understand it's okay to fail and learn" [22]. In addition, a systems-based approach is crucial: "What we need then is an envelope of scenarios. The scenarios need to be based upon a systems approach... our assumptions have to be listed and tested" [R4]. Mandating that crisis exercises push organisations to the brink, as another expert suggested, helps expose vulnerabilities and limitations: "Make it compulsory. By law, it's necessary. That crisis management exercises challenge planning assumptions" [20].

Counterfactual analysis and red teaming further reinforce scenario building. They allow planners to consider alternative outcomes, as one respondent noted: "My argument on that is that OK... What didn't happen but might have done" [4]. Another added, "The other approach there is Red's teaming. Where we take the scenario... and let's see what's wrong with our scenario or our planning" [4]. Focusing on trigger points, rather than static scenarios, makes scenarios more adaptable: "We don't have one scenario... we look at trigger points. Why? Because trigger points are something factual that we can observe, and where we can generate a sequence" [8].

It is equally important to engage the operators of affected systems—those who truly understand the infrastructure and operations at stake: "If I would want to really focus on some sort of scenarios, I would work with the people who manage the systems that are actually going to be affected as opposed to the people who are going to respond" [41]. Cultural factors also cannot be ignored: "The cultural understanding and the cultural connection must be established. Otherwise, they're gonna say, 'Yeah, yeah, yeah. No, no, no.' And they're gonna do nothing" [8]. Meaningful stakeholder engagement ensures that plans consider societal priorities and practicalities, moving beyond theoretical exercises: "You really have to engage with stakeholders about who's going to pay, who's going to move, who's going to do this, and who's going to do that" [34].

Using tools like Anytown can sidestep objections that certain scenarios are irrelevant in a given location: "We've developed... Anytown, which tries to take a bit of a sort of abstract view... when we've talked to people about certain scenarios, the response is that wouldn't happen, or it wouldn't happen like that in this place" [23]. Finally, maintaining feedback loops ensures continuous improvement and the integration of lessons learned from past events into future planning: "What is missing here for me is the... feedback loops. How to integrate feedback from what had happened in the past?" [6].

On training for HILPs

How to train for HILPs effectively	HILP training should build on planning / training for regular events
	HILP training needs to include building the right organisational culture and flexibility
	HILP training requires top-down and bottom-up approaches in parallel
	HILP training needs to develop out of the box thinking

	HILP training should involve scenario-based exercises
	HILP training should use scenarios not already covered in contingency plans
	HILP training should be practical, cost-effective, and address uncertainty
Challenges to HILP training	People assume HILPs won't happen
	Hard to convince people that HILP training is worth their time

TABLE 9 ON TRAINING FOR HILPS

Why train for HILPs

When a HILP occurs, established protocols get thrown out. As one expert observed, "with COVID, you know, and we all had probably done at organizations, you know, an infectious disease drill. But once that hit, it's like everybody in the organization wanted to get involved. And so, what was what you thought was going to be the root, the playbook got thrown out and all of a sudden executive leadership is getting in and making the shot, calling the shots." [R16]

Challenges in organising HILP training

Organising HILP training can be challenging. People often assume HILPs will never occur, leading to a lack of urgency in addressing them. As one respondent explained, "One of the main things that impacts people's kind of perspective on HILPs is I guess it's a human behavioural thing that people make massive assumptions and often the main assumptions that people make is that these things are just never gonna happen" [R9]. This mindset can undermine both individual and organisational commitment to HILP preparedness. Another challenge lies in convincing the broader population of the value of HILP training. There is resistance to investing time in preparing for events perceived as unlikely. One respondent noted, "Yeah, I think training the population and raising awareness is always important and never without results. The population usually appreciates it. I think what's tricky and challenging is convincing them that even though such an event might only occur once in their lifetime, it's still worth spending time understanding and preparing for it" [R24]. Iin this context, it is important to note that HILPs are generally only identified after they have happened and not when a trigger provokes such an event.

How to train for HILPs effectively

Classical approaches to training are suboptimal as it is not possible to train for the specifics of a HILP. Effective HILP training requires a multi-faceted approach that combines strategic vision, operational readiness, and creative problem-solving. Holistic planning is critical, starting with basic preparations before introducing special situations. This avoids fragmentation and ensures effectiveness. "The idea of a holistic approach is the most important concept... We should start with basic planning and then train people to handle special situations" [R25]. In other words, HILP training should build on existing planning for regular events, adding layers to address residual risks. One respondent noted that training should involve "a scenario-based approach that is on top of the baseline... complemented with response and recovery for the fraction of the remaining risk" [R14]. Starting with the probable and gradually incorporating the unexpected allows participants to develop a deeper understanding of risk and preparedness. As one respondent put it, "You need to train for the probable first so people understand this is probability and this is a probable event. But you do need to train for the fantastic" [R12].

Scenario-based exercises are a cornerstone of HILP training, enabling participants to engage with realistic situations and dynamic challenges. Tabletop exercises, for instance, provide practical opportunities to develop competence: "The training should involve tabletop exercises... So, it's all about the setup of the training" [R25]. Scenarios should evolve during training, introducing layers of complexity to reflect real-world conditions. "I started for instance with the floods in Mozambique we had in 2000, so they get the first input... and then every day we added something... The scenario developed, and at the end, we had a final exercise" [R28]. Using a parallel top-down and bottom-up approach is crucial. One respondent explained that HILP training must simultaneously engage strategic, tactical, and operational levels: "Begin at the political level, convincing them of the need to prepare, train, and create awareness for HILP events. At the same time, take initiatives from the operational level and work toward the strategic level" [R2]. This ensures alignment across all layers of an organisation.

Planning should develop flexibility and adaptability, fostering a culture that embraces uncertainty. "You need certain skills for that. You need certain culture for that... Companies they neglect... low probability high impact events. It's a cultural aspect in my view in many organisations" [R6]. HILP training must also encourage creativity and out-of-the-box thinking while remaining grounded in realism. "You can get really creative with training for HILP events so long as you are bounded by real physics or real laws and real probabilities" [R22]. Exercises should also challenge participants to handle situations outside standard contingency plans, helping them develop the flexibility to address novel scenarios: "They had to go off the books and into the engineering documentation to solve it" [R22]. Finally, training should address the inherent uncertainty of HILPs, equipping decision-makers to manage unpredictable and evolving risks. "Decision makers need to understand that climate models often have a high degree of uncertainty... How do you actually deal with that uncertainty? I think that's a huge need in terms of capacity building and training" [R26]. By integrating these principles, HILP training can foster a culture of readiness, adaptability, and creative problem-solving.

Strategic foresight, lateral thinking, and counterfactual analysis

Horizon scanning	Horizon scanning is about imagining the future
	Current risks (the present) emerging risks (the near future) horizon scanning (mid-distant future)
Importance of strategic foresight and lateral thinking	Their absence is a common point of failure
	Strategic foresight can ensure a common operational picture during an event
	Creativity allows people to invest in HILP preparedness before it's too late
	Strategic foresight and lateral thinking should be incorporated into business as usual
Current practices	Businesses need to predict new trends/needs – so horizon scanning risks should be a natural thing (but isn't for many organisations)
	Companies do more scenario planning than horizon scanning
	Some organisations don't consider the medium-distant future

	Some companies have tunnel vision when horizon scanning
	Companies use horizon scanning but lack the capacity for lateral thinking
	Considering downward counterfactuals is rare
	End-users cannot tweak the assumptions that inform the models they use.
Opportunities for improving strategic foresight	Provide simple, straightforward tools
	Use AI to explore more crisis triggers / hotpots
	Combine historical insights (e.g. re vulnerabilities) with future variabilities (e.g., re climate change)
	Foster critical thinking and trust
	Need (respect for) diversity of inputs and consideration of equity implications
	Encompass cultural considerations and stakeholder engagement
	Planning team should not be isolated, but next to decision making
	Start with the worst case scenario and work backwards
	Learn from near misses
	Learn from the military
	Learn from the humanitarian sector

TABLE 10 ON STRATEGIC FORESIGHT

Horizon scanning

Horizon scanning is a forward-looking process aimed at identifying and understanding potential risks, trends, and developments over the long term. It differs from current risk management, which focuses on immediate concerns, and from emerging risks, which are more mid-term in nature. As one respondent explained, "The reason why I call it horizon scanning and not emerging risks or whatever is because I think horizon scanning is long term. Emerging risks is mid and then risks are current, right? If you look at it as from a scale perspective" [05]. At its core, horizon scanning is about exploring how the future might unfold. It requires creativity and foresight to anticipate scenarios that could significantly impact organisations or societies. "Horizon scanning is about imagine how the future would look like... imagine this is how is the future, how it's gonna be the future" [06]. This process supports resilience by encouraging organisations to think beyond immediate and predictable outcomes, embracing a wider range of possibilities. For instance, during the COVID-19 pandemic, horizon scanning provided a framework for considering different recovery patterns, such as V-shaped, U-shaped, and W-shaped curves. One respondent highlighted the importance of challenging conventional assumptions, noting, "Everybody was like, it's gonna be a V and at the worst it's a U. Whereas we were constantly saying it's gonna be a W and it's gonna be quite a few W throughout, right. It's gonna be up and down" [05]. This underscores the value of horizon scanning in preparing for fluctuating and complex scenarios.

Importance of strategic foresight and lateral thinking

Strategic foresight and lateral thinking enable organisations to anticipate, prepare for, and effectively manage HILP events[10] that are often dismissed as improbable or unimaginable. These practices not only enhance operational readiness but also address critical points of failure that can exacerbate crises. Foresight plays a crucial role in ensuring a common operational picture during emergencies. As one respondent noted, "Improvisation is inevitable. But it needs to be reduced to a minimum by foresight and planning and readiness and preparedness... When you have multiple agencies responding to an event, especially if it is a large complex event, then it is absolutely vital to have common shared situational awareness" [04]. By fostering shared understanding among stakeholders, foresight helps reduce inefficiencies and improves coordination.

Lateral thinking is vital for investing in preparedness for HILP events before it's too late. One respondent highlighted that organisations often fail to act in advance, saying, "If it happens, it will be too late to invest anymore in preparedness when the emergency takes place" [29]. Scenarios such as a chemical, biological, radiological, or nuclear (CBRN) event require imaginative thinking to allocate resources and train staff before the crisis occurs. A consistent failure in dealing with disasters stems from a lack of imagination, anticipation, and prediction. This was emphasised by a respondent who stated, "The catastrophic, almost by definition, is going to be a failure of human imagination" [13]. Historical examples, such as the Grenfell Tower fire, illustrate how narrow planning assumptions—like underestimating the need for surge capacity—can lead to catastrophic outcomes. "They forgot... you then have a major city or major conurbation with no fire brigade because it all be sat around dealing with one event" [12]. Similarly, the COVID-19 pandemic revealed a failure to consider unconventional measures like lockdowns, which were initially dismissed as unrealistic: "There was a lack of imagination to dream the unthinkable" [18].

Incorporating strategic foresight and out-of-the-box thinking into routine practices is critical to avoiding such oversights. A respondent suggested that "out-of-the-blue" scenarios should be included in planning exercises: "Even though it seems like a totally crazy scenario... imagine people were dealing with this, plus the aftermath of pandemic, plus it starts burning... all of these vectors together... make the task very strenuous for anybody to deal with" [32]. By integrating such scenarios into business-as-usual operations, organisations can better prepare for overlapping and compounding crises.

Challenges: denial and a lack of interest

The main challenges to using strategic foresight do not stem from a lack of capacity or inadequate tools. One major challenge is the lack of political interest in addressing HILPs. Despite their potential for devastating consequences, low-recurrence events often fail to capture the attention or commitment of policymakers. As one respondent explained, "Not all HILPs... are completely unpredictable. But often there's a political lack of interest in dealing with or bothering about these events that might occur once in 20 or 30 years. I think there is more... a governance problem" [R1]. This is in part due to the fact that HILPs are generally recognised only after they occur. A fire in Portugal, for instance, might initially appear to be a routine emergency. Over time, however, it could develop into a HILP as a result of numerous foreseeable and unforeseeable factors. Another

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[10] These approaches are also valuable for HIHP events, however, a deep understanding of systemic risk and mental flexibility are especially important when dealing with the unexpected.

significant barrier is the unwillingness of individuals and organisations to confront difficult possibilities. A respondent described their experience trying to raise awareness about the likelihood of the Russian invasion of Ukraine[11] in late 2021. Despite clear signs, the internal response was dismissive: "There weren't many people who were really going to entertain that sort of conversation... Partly because it was running into Christmas... but also again surely in this day and age... we're not contemplating yet another war on European mainland. So, people just didn't wanna hear it" [R9]. This mindset reflects a broader resistance to acknowledging scenarios that challenge existing assumptions or bring discomfort. Even when evidence is compelling, there can be a delay in taking action due to cognitive or organisational inertia. In the Ukraine case, early warning allowed for contingency planning, but it took time and effort to "build a coalition internally of people who started to agree with what we were talking about" [R9]. This underscores the difficulty of overcoming denial and rallying support for proactive measures in the face of impending risks. These challenges highlight the importance of fostering political will, creating cultures that value foresight, and developing strategies to engage stakeholders who may be reluctant to confront uncomfortable realities. Without addressing these barriers, even the best foresight tools and methodologies risk being underutilised or ignored.

Current practices in strategic foresight

Current practices in strategic foresight reflect both progress and ongoing challenges. Downward counterfactuals—exploring how a situation could have been worse—are rarely considered, even though they can provide critical insights into risk landscapes. As one respondent noted, "This whole idea of asking these questions about how much worse things could have been... these are questions people just routinely don't ask... but to my mind it should be simply because... at least you can identify events on the risk landscape on the risk horizon" [35]. This oversight highlights a wider failure to fully utilise imaginative and reflective foresight practices.

Horizon scanning, although increasingly common, often lacks lateral thinking or the natural integration with ongoing business. Organisations "are forcing themselves to do it, but actually it should be a natural thing that you're doing" [15]. However, many companies focus narrowly on peer actions or regulatory requirements, leading to tunnel vision. For example, in financial services, "It's a bit of a paralysis... not could that volcano over there? Or could we have the flooding? Or could we have XYZ of these more, umm, disaster-type situations occur?" [15]. This limited scope undermines the potential for identifying diverse and cascading risks. Scenario planning is currently more prevalent than horizon scanning, with companies relying on available data and trends. One respondent noted, "Scenario planning is more focused on the trends and the data that you have. And I think companies are doing more scenario planning than horizon scanning" [6]. While scenario planning is valuable, the emphasis on existing data often limits the exploration of less tangible or unexpected risks.

The lack of capacity for lateral thinking is a significant gap in current practices. Many organisations focus on holding foresight meetings and exploring emerging risks, but they fail to consider the cascading effects of events. As one respondent observed, "The cascading effect requires lateral thinking... Could we actually be impacted by something seemingly unrelated to us? Well, yes, actually, we could. But they're not very good at that" [3]. Another limitation is that some organisations fail to consider the distant future. This short-term focus is described by one

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[11] Respondents differed somewhat in how they conceptualised HILPs. Another viewpoint is that the war itself was not a HILP, but the subsequent effects on business, the economy, energy, travel, sports, and culture made it one.

respondent: "We still live just for today... we only look at what's in the gonna be on the rise for 6 to 12 months" [16]. Such a limited time horizon restricts organisations' ability to anticipate and prepare for long-term challenges.

Additionally, end-users of models often lack the ability to adjust underlying assumptions, which constrains the adaptability of foresight efforts. Models are typically calibrated to historical realities, leaving users unable to experiment with specific variables. "All the decisions are taken by the model developer... You wouldn't be able to go and change that assumption and then see the impact" [38]. This rigidity limits the scope for testing alternative futures or adapting models to new insights.

Opportunities for improving strategic foresight

Opportunities for improving strategic foresight lie in simplifying tools, leveraging technology, fostering collaboration, and learning from past experiences while incorporating diverse perspectives and addressing cultural and equity considerations. One important opportunity is to provide straightforward tools that are accessible and practical for decision-makers. As one respondent explained, "It's not always about the definition... what matters to the public entity is having that capacity in-house. Understanding and having access to the right tools, which are simple, straightforward... as simple as your heads-up display in a car" [21]. Simplifying the interface and usability of foresight tools can empower organisations to make better-informed decisions. Examples of simple tools include scenario planning templates, futures wheel visualisation tools (simple diagrams), and user friendly data dashboards. Each of these tools focuses on a clear, intuitive interface to make strategic foresight more accessible and less time-intensive for officials and practitioners. The integration of AI into foresight processes offers another key opportunity. AI can enhance the identification and modelling of crisis triggers and hotspots, allowing for faster and more thorough analysis. One respondent observed, "We have significantly changed speed and modelling of those trigger points also using more AI" [R8]. This enables organisations to process vast amounts of data and uncover patterns that may otherwise remain hidden.

Fostering critical thinking and trust among diverse stakeholders is essential to strategic foresight. Groups must include scientists, operational experts, and strategists to encourage robust, multi-faceted analysis. One respondent noted, "You have to have critical thinking... and you have to have the trust... that they will be courage enough or not afraid to share their thoughts and visions" [40]. Building trust among participants ensures that all perspectives are heard and valued. Diversity in inputs and explicit consideration of equity are crucial for effective foresight. Policymakers need to explore "who are the winners, the losers, the values, the equity element to sensibility elements... and find ways to include those in their deliberations" [34]. This ensures foresight practices address societal impacts holistically and equitably. Cultural considerations and stakeholder engagement also present opportunities for improvement. Incorporating local and organisational cultures into scenario planning strengthens the relevance and acceptance of foresight efforts. "Foresight and resilience is this cultural consideration... and the engagement of stakeholders... is missing in many parts of the world" [06].

Collocating planning teams with decision-makers enhances their influence and integration into the decision-making process. As one respondent stated, planners must be "entrusted and empowered" to act as "the organisation's devil's advocate" and placed "right next to the decision making" rather than being isolated [20]. Learning from military practices, such as red teaming, offers a structured way to test assumptions and identify weaknesses in plans. Red teams "try to

destroy your efforts to plan something" by critiquing scenarios and assumptions, which helps refine strategies [04]. Similarly, the humanitarian sector provides valuable insights into rapid and large-scale impact assessment tools that are less developed in other regions. "We should be able to work more like this... also to prepare our population" [27].

Combining historical data on vulnerabilities with future variability insights improves scenario development. Stress testing must "take into account the future climate variabilities" while also leveraging lessons from past experiences [21]. This approach supports planning for both the worst-case scenario and near-miss events, which can serve as wake-up calls for preparation. "If you actually develop a model for near misses, you can learn an awful lot from digging into these" [35]. Lastly, using storytelling and creative methods can make foresight efforts more engaging and relatable, helping participants imagine the future more vividly. As one respondent highlighted, "Are you able to relate to what it would be to live in a world where the sea level is 5 meters higher? Stories... help you learn that" [34]. By addressing these opportunities, strategic foresight can become more effective and impactful in preparing societies for complex and uncertain futures.

Creativity, Imagination, and Lateral Thinking

The meaning of creativity in disaster management	Creativity is about horizon scanning
	Creativity is about imagination (not art)
On recognising the value of creativity in scenario building and training (current practices)	There is limited recognition of creativity in current practices
	Creativity is key to fostering mental flexibility through scenarios and training
	Level of recognition varies by team, training domain, organisation, sector, country, and region
Creativity is not used much in current trainings and scenarios	There is a lot of conformity
	Use of creativity is unusual – there is a lack of imagination / thinking out of the box is rare
	Tried and tested methods are preferred
	Current practices lack creativity because they focus on "normal" disasters
	Current practices heavily influenced by traditional, often military, approaches
	Current practices are highly controlled
	Trainings lack creativity – they are based on an established curriculum
	Trainings lack creativity – they are based on what was learned during tabletops.
	Trainings and scenarios may become more creative over time
Examples of how creativity is used in current trainings and scenarios	Creativity plays a central role in tabletop exercises; it's the most important part of their design and execution
	Innovative visual approaches (e.g., maps with 3D elements)
	AI tools from movie production to design crisis scenarios

	Techniques borrowed from war gaming with participants split into "red team" vs "blue team"
Rationale for using creativity in scenario building and training for HILP events	A changing world requires new approaches
	It's now it's normal to talk about scenarios that were not normal a couple of years ago
	Creative approaches are useful for exploring evolving threats
	HILP management requires lateral thinking
	Creativity can help people understand that HILPs can occur
	HILPs offer business opportunities – you need creativity to spot them
	There is great scope for using creativity in training
	People enjoy creative approaches to training and scenario building
	Creativity can foster dialogue & drawing on multiple perspectives
	Creative approaches can foster out of the box thinking
Barriers and concerns related to the use of creativity in scenario building and training	People don't like the change, instability, and uncertainty of a new approach
	View that too much creativity is counter-productive
	Introducing a HILP event during a tabletop requires courage
How to foster adoption of creative approaches	Sectoral regulations facilitate creativity, openness, and sharing
	Communicate (business) motive for approach
How to use creativity effectively?	Creativity should be paired with communication, contextualisation, and be goal oriented
	Facilitation to encourage people to think of absolute worst case scenarios is key
	The use of creativity in training and scenario building needs to be moderated.
	New tools and technologies could facilitate the use of creativity
	Look at the games industry for ways to bring creativity in
	Design scenarios and training environments that are immersive and challenging
	Scenarios should challenge assumptions and simulate situations where failures will occur
	Scenarios & training need to be realistic and embedded
	Include students, businesspeople, and bureaucrats
	Use novelists to write the script for training

TABLE 11 ON CREATIVITY, IMAGINATION, AND LATERAL THINKING

What is creativity?

Creativity involves envisioning possibilities and imagining the future, making it an essential component of foresight and planning. One respondent equated creativity with horizon scanning, explaining, "Creativity is about horizon scanning. Creativity is about how the future would look like. For me, again, this is how I interpret creativity" [R6]. However, another perspective differentiates creativity from imagination. While creativity can involve producing something novel or distinctive, it does not always require deep imaginative thought. As one respondent illustrated, "My son took a pen and designed my carpet this morning. There was a lot of creativity but there was not much imagination on that one" [R7]. This suggests that creativity encompasses a spectrum of activities, from purely inventive acts to those grounded in visionary thinking. In essence, creativity involves both the act of creating and the capacity to imagine, making it a versatile and multi-dimensional concept that is crucial for processes like HILP management.

On the recognition of creativity in current training and scenario building practices

Creativity is acknowledged as an important element in training and scenario building practices, but its recognition varies significantly across sectors, regions, and organisations. Several respondents highlighted the insufficient recognition of creativity. One noted, "To what extent is creativity recognized in current practices of training? I would say limited" [R4], while another stated, "I don't think it's appreciated very much" [R5]. Creativity is often overlooked despite its role in assembling effective training programmes, as one respondent observed: "Pulling together good training is a creative act and I think it is undervalued" [R22].

Fostering mental flexibility through creative approaches is seen as critical, particularly for preparing for HILP events. Creativity in training encourages participants to think beyond conventional scenarios. For example, one respondent emphasised the need for "this mental flexibility to think outside the box and say, 'OK, something could happen that's beyond what I'm prepared for'" [R2]. Another pointed out, "You should be very creative and thinking to make people be more flexible... they need to think outside the box" [R10]. The level of creativity recognised in training depends heavily on contextual factors. One respondent stated, "It depends on the maturity of the team in the domain on which you are training" [R14], while another noted, "It also depends which country you're looking at, which region you're looking at... In central Europe, traditionally the training methods are less participant-driven" [R24]. Similarly, the public sector was highlighted as an area where creativity is sometimes better recognised: "Within the public sector... the emergency planning that you do... is way more exciting because... you've got all those groups coming together, bouncing ideas, and trying to deliver something that's more practical" [R19]. However, some organisations and sectors do actively prioritise creativity. A respondent from a multinational company stated, "We're very open to be creative and finding ways of so for us is key" [R10].

Creativity is not used much in current trainings and scenarios

Creativity remains unusual and undervalued in training and scenario building, with a general lack of imagination or willingness to think outside the box. One respondent remarked, "It's recognised because it's bloody unusual" [R3]. Another noted, "Often what I discover is that this [...] thinking out of the box is not really existing" [R2]. Resistance to imaginative scenarios is also common, as described by a respondent who said, "The amount of times I've had to say, 'Dispel all myths, don't fight the scenario,' and somebody will come back and go, 'Oh, that'll never happen because of this, that, or the other'" [R18].

A preference for conformity further limits creativity. As one respondent put it, "I think there is a terrible conformism in all of this" [R4]. This conformism is reinforced by the reliance on tried-and-tested methods, which organisations trust because of their proven effectiveness. "People are gonna be like, we know they work, and they work for a reason," explained one respondent [R5]. Consequently, established methods dominate, leaving little room for innovative approaches. In addition, one respondent observed, "The current practices of training are very much focused on the, let's say, normal disasters" [R30]. This focus often excludes high-impact, low-probability events or unconventional scenarios that require more imaginative planning. Traditional influences, particularly from military doctrine, shape many current practices and constrain creativity. As one respondent noted, training is "often very much informed and influenced still by military activities, military doctrine and thinking" [R1]. These approaches are typically hierarchical and structured, leaving little room for unorthodox or adaptive thinking.

Training sessions themselves are often highly controlled, limiting opportunities for creativity to emerge. One respondent explained, "We teach people how to do seminar exercises. We do live exercises which are highly controlled" [R12]. Furthermore, many trainings rely on an established curriculum, which reinforces standardised approaches. "At the moment, it's not really included because you are doing a training, you have your curriculum, and you're using... PowerPoint slides and that's it" [R28]. Finally, creativity in training is hampered by a tendency to base practices on what was previously learned during tabletop exercises, perpetuating existing frameworks rather than introducing novel approaches. "People are practicing what they've learned before in the tabletop exercise" [R25]. Despite these challenges, there is reason to believe that creativity will play a larger role in the future. One respondent expressed optimism, saying, "These trainings are [...] evolving with time. As your scenarios get better, those trainings get better" [R21]. Over time, the integration of more diverse and imaginative approaches could foster greater flexibility and innovation in training and scenario-building practices.

Examples of how creativity is used in trainings and scenarios

Examples of creativity in trainings and scenarios highlight how innovative approaches can enhance engagement, realism, and problem-solving. These methods incorporate visual aids, gamification, and advanced technologies to make exercises more interactive and effective. In tabletop exercises, creativity is described as "the most important part" of the process [R25]. These exercises often rely on imaginative techniques to simulate real-world scenarios in a controlled environment. For instance, one respondent shared an example where physical models were used to bring a scenario to life: "I've seen people photocopy maps, expand it to a certain size, and then have pieces of wood cut to simulate the building shapes and heights. They used toy cars and fire engines to give a 3D visual impact of a scenario" [R12]. This hands-on approach provides participants with a tangible understanding of the challenges they might face.

Another example involved gamification during the London Olympic Games. Transport for London hosted exercises using visual tools like maps and physical markers, including toy trains and coloured beads to represent transport loads. These scenarios were gamified using war-gaming techniques, where participants played roles as "red team" (attackers) or "blue team" (defenders). As described, "You're the good guys. You're the bad guys. It's your turn. What have you done? Team two, it's now your turn. What is your reaction? Discuss rationale, etcetera" [R12]. This interactive format fostered strategic thinking and dynamic responses among participants. Creativity in scenario design also includes the use of advanced technologies. One respondent described using AI tools from the film industry to create realistic crisis scenarios, such as

simulating how Lausanne might be affected by a tsunami. This allowed participants to explore complex, visually detailed scenarios: "We are looking at using an AI tool... to create crisis scenarios. How Lausanne is gonna be destroyed by tsunami and how would we deal with that?" [08]. These tools provide a high level of detail and realism, making the scenarios more engaging and impactful.

These examples demonstrate how creativity can be leveraged to make training sessions more immersive, helping participants think critically and respond effectively to complex challenges. While not yet universally recognised or adopted, these practices show the potential for creativity to transform traditional training and scenario-building methodologies.

Rationale for using creativity in training and scenario building for HILP events

The rationale for incorporating creativity into training and scenario building for HILP events is rooted in its ability to foster flexibility, adaptability, and innovative problem-solving. Creativity addresses critical gaps in traditional approaches and prepares participants to manage unexpected, complex challenges. Creativity is vital because the rapidly changing nature of risks necessitates innovative methods. As one respondent noted, "If the world shifts and it is, you can't keep doing the same things exactly the same" [R5]. The modern landscape includes scenarios that were once unthinkable but are now considered plausible. Another respondent observed, "Now it's normal to talk about scenarios which were not normal, like a couple of years ago" [R39], highlighting the need for imaginative thinking to adapt to evolving threats.

Traditional tools like risk registers often fail to capture cascading and compound impacts, which require a deeper, more imaginative approach to understand their interconnected nature. One respondent noted, "It is really difficult unless you spend quite a bit of time... needling away at people, those compound impacts, the cascade of effects of it will never just be a flood. There will be 101 downstream things" [R18]. Creativity allows organisations to move beyond these limitations, fostering the lateral thinking needed to anticipate and address complex scenarios. This ability to think outside the box is critical for HILP management, as one respondent explained: "It needs creativity. Someone with a bright mind and a broad vision... not having a fixed way to handle a crisis, but rather the ability to think outside the box to manage it" [R1]. A failure of imagination is often cited as a common point of failure, with one respondent stating, "You tend to fail in only three ways. Your information stream is not good enough or the quality of information. Turning that into a viable intelligence picture is not good enough. Secondly, the process of planning and responding to crisis is not good enough. And thirdly, a failure of imagination" [R13].

Preparing for HILPs requires participants to train for scenarios that might initially seem implausible but could have significant consequences. One respondent noted, "People are taken by surprise... they assume it is a more routine vanilla failure... then suddenly, they're overwhelmed by a catastrophe. Because they're not prepared for it... you do need to train for the fantastic" [R12]. Preparing for every possible scenario is impossible, and this principle should be the starting point for planning HILP events. However, by strengthening their ability to anticipate how situations may unfold, disaster managers can build the agility needed to adapt, absorb changes, and keep operations running. Creativity ensures that participants are mentally prepared to address scenarios beyond their routine experiences and encourages them to recognise opportunities that can arise from HILPs. As another respondent explained, "Out of high-impact, low-probability events, no matter how bad they are, come opportunities... it's a question of what's the appetite of the organisation to embrace those" [R9]. For example, the COVID-19 pandemic demonstrated how organisations could use a crisis to accelerate the adoption of remote working technologies,

with one respondent stating, "Within weeks of COVID... suddenly we've got blanket coverage across things like Teams... there's a massive opportunity that's been leveraged from the direct experience of a HILP event" [R9].

Creative approaches also make training more engaging and memorable, helping to cement lessons in participants' minds. One respondent noted, "If we're creative and we're able to make it exciting and fun and also something unexpected, that's where we'll cement the memory in people's heads" [R19]. Creative approaches rely on dialogue, on encouraging participants to share diverse perspectives, and on helping them think outside conventional boundaries. As one respondent put it, "Great minds don't think alike... anybody who could look at the problem differently might have a clue as to what we were trying to solve" [R16].

Incorporating creativity in training also promotes the exploration of non-standard solutions, which are essential for addressing unique and unprecedented risks. Respondents emphasised the need for "mental flexibility" and the ability to "think outside the box" [R2, R10]. Creative exercises allow participants to tackle diverse risks and prepare to act decisively, even when they lack complete information. One respondent stated, "People should think... they should be able to, yeah, make decisions without having everything in hand" [R28]. Overall, creativity transforms training from routine exercises into dynamic preparations for an unpredictable world.

Barriers and concerns related to the use of creativity in scenario development and training

The use of creativity in scenario development and training faces several challenges. One of the key barriers is people's general discomfort with change and uncertainty. As one respondent put it, "People don't like it because they don't like change. They don't like instability. They don't like uncertainty, but that is exactly what you should be trying to figure out" [R5]. This resistance can make it challenging to introduce innovative approaches that deviate from established methods. People are also concerned about excessive creativity overwhelming participants and detracting from the training's objectives. One respondent warned, "Too much imagination, too much creativity will kill the intent and purpose of training... if it's overly used you basically get the opposite effect" [R7]. Overly complex or unrealistic scenarios can confuse participants, making it harder for them to engage meaningfully with the exercise. Another respondent explained, "Sometimes [person] goes above and beyond creativity need, which makes the exercise too complex for the agents to realize because it's overly imaginative" [07]. The challenge of finding a balance between creativity and realism is particularly pronounced when dealing with large-scale scenarios. One respondent observed, "You need to... use as much as you can of available research about understanding the scenario... There can be a danger of you being too creative, too far out-of-the-box, that it starts being idiotic" [41].

Introducing a HILP event into a tabletop exercise requires careful communication and scaling. As one respondent explained, "I think you must be a strong person to bring in a HILP event in the table exercise... It is possible for sure, but it's about communication and scaling" [R25]. This highlights the need for courage and tact in designing and presenting creative scenarios, particularly those involving HILP events, which may challenge participants' perceptions and preparedness. These concerns underscore the importance of striking the right balance between creativity and practicality. While creativity can enhance training and scenario development, it must be applied judiciously to ensure that exercises remain engaging, realistic, and effective.

How to foster adoption of creative approaches

Sectoral regulations and collaborative frameworks can play a significant role in facilitating creativity and openness. In some industries, regulatory requirements have created environments where organisations are more willing to share experiences and explore unconventional scenarios. One respondent described how regulations have enabled this: "The scenarios are bonkers. They are designed by asking what the industry is concerned about... Since the regulations, people are more open to sharing" [R36]. Spaces like Operational Resilience Collaboration Groups (ORCGs) encourage participants to present scenarios and share mistakes, fostering a culture of innovation and mutual learning.

Equally important is the communication of the motives behind adopting creative approaches. Indeed, this should be the starting point for any such endeavour. Creativity must be contextualised and tied to clear objectives that resonate with the audience, whether they are participants or decision-makers. One respondent explained, "Creativity has to go hand in hand with the communication piece... you've got to think about what am I going to get out of this? Why am I diverting time to do this?" [R11]. In corporate environments, this involves demonstrating how creative exercises align with business priorities, such as profitability or operational efficiency. As the respondent emphasised, "How can I talk to my leadership team and tell them or show them why they have to spend a dollar here and divert their time to do this when they're in business... to make money?" [R11]. By connecting creative approaches to sectoral frameworks that support collaboration and framing them as tools to achieve tangible goals, organisations can overcome resistance and build a stronger case for integrating creativity into their training and scenario development practices. This approach ensures that creativity is not seen as an abstract concept but as a practical and valuable asset.

How to use creativity effectively?

Using creativity effectively in training and scenario development requires a structured approach that balances imagination with realism, engages diverse perspectives, and ensures that scenarios are challenging, immersive, and goal oriented. Creativity should not stand alone but be paired with clear communication, contextualisation, and alignment with specific objectives. One respondent highlighted the importance of this alignment, stating, "Creativity has to go hand in hand with the communication piece as well. And then the contextualization and attachment to a goal" [11].

Facilitation plays a crucial role in encouraging participants to explore extreme scenarios. A skilled moderator can guide participants to imagine "the absolutely worst scenarios that might happen" without fear of being dismissed. Even individuals in structured environments, such as uniformed practitioners, respond well to this approach: "Structured workshop ideation or brainstorming process... actually works pretty well" [32]. However, creativity must be moderated to maintain focus and ensure that exercises remain productive. One respondent noted, "It needs to be moderated" [37].

The integration of new tools and technologies can enhance creativity by enabling the creation of realistic and engaging scenarios. For example, one organisation is experimenting with "movie AI tools to recreate extreme crisis scenarios," which allows participants to immerse themselves in the situation and respond to its challenges [8]. Similarly, lessons can be drawn from the gaming industry, where creative design elements such as role-playing and strategy games encourage

participants to think dynamically. "We should be looking at the games industry... there is a whole space there to look at creativity and to bring imagination into exercising" [12].

Immersive and realistic scenarios are central to effective creativity. Scenario design should challenge participants' assumptions, simulate failure, and prepare for both day-to-day and extraordinary events. One respondent stressed, "Mandate that crisis management exercises challenge planning assumptions... The value of HILPs is that it forces you to challenge your way of thinking by thinking beyond traditional scenarios" [20]. However, exercises must remain credible and grounded. "If you're going to do something in creative, it needs to be highly physics credible or very realistic. If it's to actually have any value" [22].

Diverse participation can further enhance creativity. Including students, businesspeople, bureaucrats, and other non-traditional participants in exercises can introduce fresh perspectives. "Students work like crazy... they are not constrained by the budget. They say things that practitioners say, well, that's interesting" [32]. Additionally, novelists or creative writers can contribute by crafting compelling narratives for training scenarios: "You should maybe look to people who write novels... their minds go somewhere else" [40]. To ensure that creativity is effectively applied, it must also be embedded within realistic and relatable contexts. Training should start from everyday emergencies and build toward more complex, long-term scenarios. One respondent explained, "It's based on preparedness measures... starting with solid daily business, everyday emergencies, and then up to real scenarios" [28]. Creativity should be tied to practical outcomes and supported by examples drawn from real life to make the lessons tangible and actionable.

By combining these approaches—goal orientation, facilitation, use of advanced tools, realistic scenario design, and diverse participation—creativity can transform training and scenario development into an engaging and effective process that equips participants to handle complex and high-impact challenges.

6. Guidelines for Scenario Development

An important output of Task1.2 is the development of methodological guidelines for integrating systematically the role of strategic foresight and lateral thinking in STT1 scenario development (T4.1) and evidence based planning (T5.1). They are provided below.

Scenarios should support planning and preparedness

The main purpose of scenarios is to provide planners with insights into the needs, constraints, and assumptions that shape disaster management in different situations. By fostering a deeper understanding, scenarios can help prevent rushed problem-solving during crises. They can highlight available capacities, resources, and support networks, enabling disaster managers to balance thorough planning with the flexibility to improvise during incidents. By exploring best-case, worst-case, and catastrophic scenarios, planners can develop structured responses that escalate based on clear indicators. Scenarios can also support the mainstreaming of preparedness across sectors and the integration of disaster risk management into regular planning processes.

Scenarios should inform planning, training, and exercises, which all play essential roles in effective disaster management and must work together. Training should address strategic, tactical, and especially operational levels. It must integrate lessons learned, preparation, and up-to-date guidelines to remain current and actionable. All staff, not just core team members, should take part in training so everyone gains the necessary skills and familiarity with their roles. To prevent training fatigue, a balanced "training diet" should expose participants to specific types of problems, operations, or subsystems without overwhelming them, ensuring they are ready for unexpected challenges. Effective training and scenario development require senior leadership support, as their endorsement guarantees engagement and accountability.

Scenarios can play a vital role in preventing gaps between disaster management plans and their actual implementation, for example, by highlighting the plan's unrealistic assumptions about available resources. Accountability measures also play an important role. Although some organisations develop thorough plans and conduct training to meet legal requirements, there are usually no mechanisms to ensure those plans are actually followed. As a result, important insights from preparatory exercises are sometimes ignored, and what should be a valuable resource for preparedness never translates into real-world action. This common failure to implement plans shows that preparedness efforts need clear accountability measures at the regulatory level and must be grounded in realistic assumptions derived from scenarios at the organisational level.

Engaging stakeholders

Scenario building and training for high-impact events must be conducted in a safe, trusting environment. Participants, including senior leaders, can feel exposed when engaged in creative role-playing exercises, so establishing trust is vital to encourage open engagement. Employing a structured "sandbox" approach and using well-designed tabletop exercises allows teams to explore complex system dependencies and practice operational procedures in a controlled setting. Skilled moderators play an essential role, prompting participants to consider worst-case scenarios and draw upon their diverse personalities and backgrounds. Recognising cultural and linguistic nuances is also crucial, as mismatched content or inappropriate examples can alienate participants. Through thoughtful engagement, relationships and networks can be built, common understanding forged, and even shared values developed.

Using cross boundary approaches

Disaster management is most effective when approached from a cross-industry, multidisciplinary perspective. Scenario-based exercises, wargames, and tabletop simulations that consider cascading effects and involve stakeholders from different sectors, governance levels, and even across national borders can generate fresh insights and foster innovative ideas. Bringing together scientists, experts, business leaders, bureaucrats, and students encourages creative thinking, challenges established assumptions and leads to more robust preparedness strategies. By combining strategic, regional, and operational viewpoints in a shared environment, stakeholders deepen their understanding, improve communication, and ultimately achieve more effective disaster resilience and response. Such an integrated approach enables organisations and governments to incorporate risk-informed decisions into all areas, including infrastructure, education, and social protection systems.

Effective preparedness also requires involving stakeholders at every level, from national and regional authorities to local governments and businesses. A layered governance structure, guided by the principle of subsidiarity, ensures that those closest to the potential impact are best positioned to understand and respond to it. In government, this means local authorities are responsible for risk assessment, planning, and prevention, with higher-level support engaged only when necessary. Such an arrangement promotes context-specific emergency plans that anticipate regional hazards and strengthen resilience throughout the national territory. In a business context, global guidance provides an overarching framework and mandates testing of critical scenarios, ensuring that local operations adapt mitigation measures accordingly. Regular testing and assurance processes confirm that these plans are both present and effective.

For large-scale and unpredictable events, coordinated approaches transcending national and sectoral boundaries are essential. Joint planning at regional, European, and even broader levels may be required, as some scenarios demand international assistance and collaboration. Standardising training, harmonising response procedures, and establishing shared standards is already challenging for common disasters, and these difficulties only intensify in truly exceptional incidents. Large-scale events can surpass existing capacities, forcing a reconsideration of coordination and communication methods. This highlights the importance of cross-sectoral, multidisciplinary teamwork, although achieving genuine cooperation—where participants truly listen to one another—is not easily accomplished.

Using generic versus hazard specific approaches

Risk agnostic approaches to preparedness can be more effective than hazard-specific ones because they address underlying principles that apply to many different disasters. By focusing on needs, constraints, and limitations that apply across the board planners can develop flexible solutions —such as in the areas of leadership, coordination, and communication—that remain useful whether the crisis is an earthquake, a flood, or an entirely unexpected event. This approach encourages a more adaptable mindset, making it easier to respond effectively when surprises occur. Yet "generic" scenarios can be difficult for people to grasp, as they often find it more intuitive to prepare for clearly defined, concrete hazards. Exposing people to a variety of hazard specific scenarios over time can help build the capacity to generalise and respond, ensuring that preparation does not hinge on predicting a specific cause but on understanding how to manage whatever scenario arises.

Developing effective HILP scenarios

How to improve scenario building for HILPs	Use counterfactual analysis and red teaming
	Focus on trigger points
	Focus on feedback loops
	Exercises should challenge assumptions
	Culture is an important factor to consider
	Consider risk tolerance and impact tolerance
	Creativity is important for scenario building
	Include challenges related to communications and information management

	Develop an envelope of scenarios based on a systems approach
	Multiple threats can be put into one theme
	Bring different types of risk – not always the same ones
	Provide tools that show best, worst, and catastrophic scenarios + escalating measures
	Engage societal stakeholders (or the exercise remains theoretical)
	Focus on the operators managing the affected systems
	Prevent organisational politics from getting in the way of failing and learning – the point of HILP scenarios
	Use of Anytown[9] to avoid "that wouldn't happen in this place for reason X"
	Throw the kitchen sink at it (try lots of different things)

TABLE 12 DEVELOPING EFFECTIVE HILP SCENARIOS

Using HILP scenarios can help organisations push their systems to the limit, revealing weak points and guiding them toward solutions that improve resilience. Examining several of these scenarios together highlights underlying similarities—shared assumptions, constraints, and needs—that inform more effective preparation, prevention, and training. Instead of planning for every possible threat, organisations can focus on the broader consequences that arise, creating more versatile continuity plans. HILP scenarios also encourage looking beyond preventive measures, ensuring that when prevention fails, robust response strategies are in place, ultimately leading to a more resilient approach to managing extreme events.

The uncertainty inherent in HILPs demands thinking beyond conventional approaches. Traditional methods often fail to address HILPs effectively because decision-makers must plan for futures that are not only long term, but also highly uncertain, particularly in the face of climate change. Historical scenarios become unreliable as conditions shift, making it essential to develop new strategies that account for unprecedented changes like shifting rainfall patterns and more frequent extreme weather events. This is not easy, as there is often a lot of resistance to using HILP scenarios[12]. However, fostering the ability to adapt and improvise is vital. While plans are important, so is the flexibility to modify them when circumstances change. HILP scenarios highlight the need to combine existing knowledge with creative thinking, enabling organisations to embrace uncertainty and respond effectively to unforeseen challenges.

Recent developments in scenario building show a shift from ad hoc tabletop exercises to more systematic scenario planning and modelling. Traditionally, scenario building was limited to reactive exercises based on hypothetical crises. Now, organisations are using more modelling and quantification, driven by the increasing scale and impact of high-risk events. Counterfactual analysis is also gaining traction, examining both downward scenarios—what could have been worse—and upward scenarios—what could have been better. A notable change is the new emphasis on trigger points, which are observable and factual indicators that allow organisations

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[12] See "Challenges and opportunities in HILP scenario development"

to develop sequential responses. Advances in AI and predictive analysis are improving the speed and accuracy of identifying and modelling these trigger points. AI also contributes to structuring and analysing data, refining predictions, and improving analysts' reports. Another innovative approach involves crisis cells dedicated to exploring 'what if' scenarios. These teams anticipate how crises may evolve by considering possible cascades of events and integrating prevention strategies into their analyses. This anticipatory approach ensures a more structured and forward-looking response to complex crises.

Improving scenario building for HILP events requires a more expansive, flexible, and creative approach than conventional methods. In addition to the traditional focus on considering best, worst, and catastrophic scenarios, it also entails looking at escalating factors and trigger points and the development of measures that prompt timely action before a HILP fully materialises. Counterfactual thinking and red teaming are useful ways to stress-test assumptions and challenge existing plans, while exercises must be designed so that failures and mistakes occur openly, allowing lessons to be learnt. Resistance from higher management, cultural differences, and entrenched organisational politics can stifle such learning, so there is a need for greater openness and an acceptance of the importance of continuous improvement. Considering the social and infrastructural systems affected by a crisis, incorporating feedback loops, and engaging meaningfully with stakeholders can help ensure that scenarios capture complex realities. There should be an explicit focus on the operators managing critical systems, involving them in scenario-building to understand potential knock-on effects. Tools like "Anytown"[13] can prevent scenarios being dismissed based on local specifics ("that wouldn't happen here"), ensuring broader relevance. Finally, scenario development should not remain purely theoretical but must be grounded in real decision-making contexts, employing a range of methods and creative approaches to ensure that what might initially seem implausible scenarios can be taken seriously, planned for, and learned from.

Training effectively for HILPs

Preparing for HILPs events calls for more than following established protocols. A holistic, scenario-based approach, built into regular training, should be developed from both the top down and bottom up. Building on ordinary preparedness practices allows the addressing of risks beyond those covered by standard measures, encouraging staff to think creatively, remain flexible, and adapt their skills to unexpected challenges. Instead of rehearsing familiar routines, training should expand capabilities so personnel can respond effectively when usual playbooks no longer apply. Credible scenarios, from large-scale emergencies to smaller but complex incidents, should rely less on rigid plans and more on resourcefulness and realism. Cultivating an organisational culture that values innovation, agility, and the ability to handle uncertainty is vital. Convincing people of the value of training for HILPs can be difficult[14] but such training need not be overly costly. It should balance efficiency with the unpredictability of long-term threats, fostering organisational "muscle memory" ensures quick and decisive action when the unexpected occurs.

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[13] In disaster management, "Anytown" is often used as a hypothetical or model community for training, scenario-based planning, and risk assessment exercises. It allows emergency planners, responders, and policymakers to simulate disaster impacts, test preparedness strategies, and evaluate response capabilities without focusing on a specific real-world location.

[14] See Challenges in Doing HILP training

Integrating strategic foresight and lateral thinking

The purpose and benefit of strategic foresight and lateral thinking

Catastrophic events often result from three recurring failures: a lack of imagination, inadequate anticipation or prediction, and insufficient planning or intelligence gathering. Regardless of operational specifics, this failure to envision the "unthinkable" persists across different contexts. It is a common point of failure. As the world evolves, traditional disaster preparedness approaches are no longer sufficient. Greater creativity in training and scenario development is critical to moving beyond rigid assumptions and isolated risk registers. More training on creativity and scenario-development are needed. By adopting imaginative and flexible thinking, planners can account for cascading and compound effects, envisioning scenarios previously considered unthinkable—such as societal lockdowns during a pandemic or sudden resource surges. Creative training methods encourage participants to explore unconventional situations, fostering adaptability, broader perspectives, and mental flexibility. These approaches not only make participants more receptive to the reality of unlikely events but also help them remember lessons learned more vividly while identifying opportunities that can emerge from crises. Engaging with creative, unexpected methods also stimulates dialogue and encourages innovative thinking, making the process both enjoyable and effective.

Strategic foresight and lateral thinking are indispensable for preparing effectively for HILP events. Strategic foresight takes a systematic approach to exploring potential future developments, trends, and uncertainties to guide decision-making and planning. Central to this process is horizon scanning, which involves envisioning a range of possible futures and preparing for unpredictable outcomes. Creativity, or lateral thinking, complements this by fostering forward-thinking imagination—not through artistic expression, but by deliberately envisioning unconventional possibilities.

Without imagination and proactive planning, emergency responses become overly reliant on costly, less effective improvisation. Maintaining a shared operational picture across agencies is critical to ensuring coherent and coordinated action. By investing in foresight, training, and the resources needed to address extreme scenarios, organisations can avoid being caught unprepared. Historical examples, such as the Grenfell Tower disaster and the COVID-19 pandemic, highlight the consequences of limited imagination and rigid assumptions. These events reveal how reduced surge capacity and outdated thinking leave communities vulnerable. Incorporating strategic foresight and creative scenario planning into routine practice equips leaders to envision previously unimaginable crises. It ensures they have the capacity, flexibility, and creativity required to respond effectively, transforming preparedness from reactive improvisation into proactive resilience.

Current practices and challenges in the use of strategic foresight

Although strategic foresight is becoming more common in managing HILP events, there remain significant limitations and gaps in current practices. Downward counterfactual thinking—imagining how an event could have been even worse—is seldom considered, largely because it appears overly pessimistic and falls outside typical analytical frameworks. While horizon scanning has emerged as a fashionable concept, many organisations treat it as a forced exercise rather than a natural, continuous process of identifying trends or emerging risks. Instead, scenario planning—based more on available data and current trends—tends to dominate, leaving

insufficient scope for creativity and long-term thinking. (In part because people aren't trained to thinking creatively when managing disasters). As a result, businesses and governments often fail to project beyond a short-term view, focusing on immediate challenges rather than preparing for more distant ones. Even when horizon scanning is adopted, the approach can be narrow, with firms looking inwardly or at familiar regulatory environments rather than developing the breadth of lateral thinking needed to anticipate cascading and interconnected risks. Furthermore, while models and data-driven tools inform decision-making, they are calibrated to reflect historical realities rather than allowing end-users to easily alter fundamental assumptions. This restriction of analytical flexibility and openness to alternative futures contributes to a form of tunnel vision, hindering the imaginative, broad-minded approach that strategic foresight ideally requires.

However, the most significant challenge in dealing with HILP events is not the lack of foresight or expertise per se, but rather a lack of interest and support among those in positions of authority. Political disinterest and a general reluctance to engage with troubling prospects can prevent organisations from acknowledging, let alone preparing for, events that may seem far-fetched or unlikely. A clear example is found in the approach to the Russian invasion of Ukraine. Even when the signs were visible as early as December 2021, attempts to start a dialogue on this topic were met with resistance and dismissiveness, largely because people did not want to confront the possibility of a return to large-scale conflict in Europe. In essence, the key obstacle lies in overcoming apathy and denial, ensuring that prudent contingency planning takes place, rather than relying on hindsight to respond once a crisis is already underway.

Opportunities for improving strategic foresight

Opportunities for improving strategic foresight	Provide simple, straightforward tools
	Use AI to explore more crisis triggers / hotpots
	Combine historical insights (e.g. re vulnerabilities) with future variabilities (e.g., re climate change)
	Foster critical thinking and trust
	Need (respect for) diversity of inputs and consideration of equity implications
	Encompass cultural considerations and stakeholder engagement
	Planning team should not be isolated, but next to decision making
	Start with the worst case scenario and work backwards
	Learn from near misses
	Learn from the military
	Learn from the humanitarian sector

TABLE 13 OPPORTUNITIES FOR IMPROVING STRATEGIC FORESIGHT

Improving strategic foresight for HILP events depends on developing simpler, more user-friendly tools that enable decision makers to understand complex scenarios without being overwhelmed. The increasing use of AI can help identify more crisis triggers or 'hotspots' at greater speed and scale. Concrete case studies that demonstrate the effectiveness of this approach are essential to encourage its adoption and application.

By fostering an environment that encourages critical thinking and enables people to trust one another, individuals feel more confident about sharing unconventional ideas and questioning assumptions. Improving foresight also involves respecting the diversity of inputs, including consideration of equity, cultural contexts, and the perspectives of stakeholders not usually consulted. Learning from fields such as the military, which regularly uses practices like red teaming to challenge assumptions, and the humanitarian sector, which has effective tools for rapid impact assessments, can inform a more dynamic approach to strategic foresight. Foresight exercises should not be isolated activities conducted by distant teams; rather, the individuals developing scenarios should be placed close to the actual decision-making processes, for example, by being located in offices near those of leadership. Future-focused scenario work benefits from blending historical insights about vulnerabilities with projections of future variabilities like climate change, working backwards from worst-case scenarios to identify practical steps. Finally, paying closer attention to near misses can sharpen risk perception and preparedness, showing that what may initially seem far-fetched can quickly shift into the realm of the plausible, highlighting the importance of consistent and proactive engagement with strategic foresight.

Current practices and challenges in the use of lateral thinking

The extent to which creativity is integrated and valued in training and scenario-building varies widely, influenced by factors such as team maturity, sector, and cultural context. Some regions and industries show greater openness to novel approaches, and certain organisations—particularly in the public sector—recognise the importance of creativity, encouraging multi-agency collaboration, imaginative thinking, and participant-driven methods. Still, creativity is generally viewed as an add-on rather than a central element. Imaginative, unconventional thinking remains rare, partly because people often resist deviation from established methods and feel uneasy about the instability and uncertainty that new approaches can bring. Introducing a HILP scenario into a conventional tabletop exercise demands courage, as it pushes participants beyond familiar territory. There are also concerns that too much creativity can produce confusion, complexity, and scenarios that verge on the absurd. Long-standing reliance on tried-and-tested methods, frequently rooted in traditional or military-based approaches geared towards "normal" disasters, has led to exercises that are tightly controlled and follow established curricula rather than inspiring innovative problem-solving. Even so, there is a growing recognition that fostering mental flexibility and encouraging participants to think beyond standard scenarios is critical to preparing for HILP events. The core issue isn't the absence of creativity in training, but rather how to develop creativity so that it can be effectively applied when a HILP event occurs. Over time, there has been a noticeable shift toward more creative, dynamic training methods, although this shift is not yet consistent across all contexts.

Tabletop exercises stand out as contexts where imaginative approaches are especially valued. For example, practitioners have employed visual and tactile methods, such as enlarging maps, using wooden blocks to represent buildings, and toy vehicles to simulate movement and loading. This can include using cues to move model trains and coloured beads to indicate passenger flows, creating a more dynamic and interactive learning environment. War gaming techniques are also applied, with teams taking on opposing roles and reacting turn by turn. Additionally, there are examples of integrating cutting-edge tools like AI—originally used in film production—into scenario creation, envisioning dramatic events such as a tsunami destroying Lausanne. These innovations suggest that some trainers are willing to explore new media and tools to engage participants and broaden the scope of crisis exercises.

Opportunities for improving lateral thinking

How to foster adoption of creative approaches	Sectoral regulations facilitate creativity, openness, and sharing
	Communicate (business) motive for approach
How to use creativity effectively?	Creativity should be paired with communication, contextualisation, and be goal oriented
	Facilitation to encourage people to think of absolute worst case scenarios is key
	The use of creativity in training and scenario building needs to be moderated.
	New tools and technologies could facilitate the use of creativity
	Look at the games industry for ways to bring creativity in
	Design scenarios and training environments that are immersive and challenging
	Scenarios should challenge assumptions and simulate situations where failures will occur
	Scenarios & training need to be realistic and embedded
	Include students, businesspeople, and bureaucrats
	Use novelists to write the script for training

TABLE 14 OPPORTUNITIES FOR IMPROVING LATERAL THINKING

Adopting a creative approach to scenario development and training can be encouraged by several methods. Sectoral regulations that mandate transparency and sharing can foster openness and knowledge-sharing, creating an environment where innovative thinking is more readily accepted. Creativity should always be linked to clear communication, contextualisation, and defined objectives, ensuring that participants understand the purpose and value of their engagement. Skilled facilitation is essential to encourage people to consider the worst possible cases without fear of judgment. Emerging tools and technologies, including artificial intelligence and inspiration from the gaming industry, can help trainers design immersive, interactive, and visually compelling exercises. These methods need to be grounded in realism, using familiar references and building upon everyday practices to avoid alienating participants. Scenarios should be challenging enough to question assumptions, simulate failures, and demand critical thought, but remain credible and physics bound. They should purposefully bring about failures (break existing plans and systems) as most of the time people train for success. Involving diverse stakeholders—such as students, businesspeople, and bureaucrats—as well as professional storytellers can bring fresh perspectives and avoid entrenched thinking. Ultimately, combining innovation with realism, well-defined goals, and effective facilitation can ensure that creativity enhances training for high-impact, low-probability events.

7. Conclusion

This deliverable underscores the centrality of **strategic foresight**, **lateral thinking** and **scenario planning** in advancing societal resilience to high-impact, low-probability (HILP) events. By drawing on theoretical frameworks and empirical insights from expert interviews, it emphasises the urgent need to move beyond conventional risk management approaches and embrace innovative, adaptive strategies that address the complex and cascading nature of HILPs.

The theoretical analysis provides a foundation for understanding the unique challenges posed by HILPs. It explores their systemic and dynamic characteristics, highlighting how cascading effects and compounding impacts can overwhelm traditional response mechanisms. The discussion also emphasises the critical importance of addressing uncertainty, fostering adaptability, and integrating advanced modelling techniques to better anticipate and manage risks. Strategic foresight emerges as a cornerstone in understanding and preparing for future risks, particularly those that challenge existing assumptions. The report highlights the transformative potential of tools such as horizon scanning, scenario-based exercises, and creative simulation techniques. These approaches allow organisations to explore a broader spectrum of possibilities, including worst-case scenarios, and to identify gaps in current preparedness frameworks. Lateral thinking complements this by fostering the flexibility and imagination needed to devise non-linear solutions to unprecedented challenges, ensuring preparedness extends beyond the predictable.

Empirical findings reveal that the lack of imagination and the persistence of traditional, rigid methodologies often hinder effective risk management. However, they also showcase the value of fostering creativity and innovation in scenario building and training. By encouraging participants to challenge assumptions and engage with unconventional scenarios, these practices cultivate the adaptability and strategic mindset necessary for addressing HILPs. The guidelines presented bridge theoretical and practical dimensions, advocating for collaboration, stakeholder engagement, and the integration of advanced technologies such as AI. These strategies aim to embed strategic foresight and lateral thinking into routine planning and decision-making processes, ensuring organisations are equipped not only to respond but to anticipate and mitigate emerging risks. In reinforcing the AGILE project's mission, this report places strategic foresight and lateral thinking at the forefront of resilience-building efforts. It calls for a systemic shift towards innovative, inclusive, and adaptive approaches to disaster preparedness, paving the way for communities and organisations to thrive in an increasingly uncertain risk landscape.

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Appendix A: Interview Question Guide

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AGILE Semi-structured Interview Question Guide

1. *Definition of HILPs*
- The AGILE project has a working definition of HILPs. Is it in line with your experience/ operational understanding of HILPs?
    - If you agree/disagree, why?
- In your experience, is there a common understanding of what HILP events are [in your line of work/sector]?

2. *Expertise on HILPS*
- In your opinion, what are the strengths and weaknesses in how HILPs are prepared for?
    - Prompt: e.g. from the community and technical perspective (such as strategic command, management of organizations or infrastructure).
- In your professional experience, what have been the common point of failures in managing emergencies [triggered by different types of hazards, threats, or risks]?
    - Prompt: e.g. lack of surge capacity after a blackout caused by both a storm and heatwave; missing procedures after a communication failure; or, not enabling community based resources, such as volunteers.
- Do you think there are commonalties between HILPs and High Impact High Probability Events?
- In your opinion, to what extent are different organisations ready for HILPs, including examples from the private or public sector and different sizes of organisations, institutions etc?
- In your professional experience, are there any recurrent vulnerabilities?
    - Prompt: Do you think the common vulnerabilities and/or single points of failures are associated with strategic issues, organizational issues, community failures or all of them?
- In your professional experience, are there any common points of failures that tend to escalate emergencies and crises? Which ones?
- How do you think one could leverage the understanding of recurrent vulnerabilities/common points of failure in training/ scenario building for HILPs?
    - Prompt: Such as integrating them in strategic command training or mid management training.
    - Which level of coordination could be more critical to act on?
- Could, and if so how, strategic foresight and lateral thinking be used more systematically preparing for events distinguished by a lack of precursors and high uncertainty?
    - What do you think could be other tools that could help being more resilient for HILPs and mitigating high uncertainty? E.g. counterfactual analysis.

3. *Statements with Likert-scale point answers*
- In conclusion, could you please answer us to the following questions on a scale 0-3:

To what extent do you think HILP events have similar points of failure?
To what extent do you think HILP and HIHP* events have similar points of failure?
To what extent do you think that common procedures can be used for managing HILP and HIHP events?
To what extent can preparation for HILP events can be influenced by experience/knowledge (of past events)?
To what extent do you think the concept of HILP events can be useful to support the development of new preparation and planning practices?
To what extent does an individual's flexibility (and/or adaptability) help with resilience to HILP events?
To what extent does organisational flexibility (and/or adaptability) help with resilience to HILP events?
To what extent is creativity recognised in the current practices of training?
To what extent could creativity be used for training for HILP events?
To what extent do you think that HILP events *exist*?

*High Impact High Probability

0: is little/no; few/no; not at all; never; inadequate or undesirable state with significant gaps.
1: is basic; limited; lacking; occasional; partial; moderately undesirable state; existence of some gaps.
2: is limited or sparsely present; in progress; applied/developed/ validated with some inconsistencies; somewhat desirable state; few gaps, subject to improvements
3: is mostly or completely present; comprehensive; complete; fully integrated; desirable state with no gaps (See Pescaroli et al. 2020).

- Could you please rank the following from most important to least important barrier for managing HILPs?
  - Unpredictability, uncertainty, operational thresholds, lack of precursors, risk appetite, other.

Closing
- Is there anything that you would like to add or expand on before closing?

Many thanks for your time and contribution!

Appendix B: Participant Information Sheet

Participant Information Sheet for Expert Interviews and Advice

Title of Project

AGILE: Agnostic risk management for high impact low probability events

Name and contact details of the Principal Investigator (PI)

Dr Gianluca Pescaroli (g.pescaroli@ucl.ac.uk): Associate Professor in Operational Continuity and Disaster Resilience & Scientific Lead of AGILE Consortium.

Name and contact details of UCL Research Team

Dr Lauren McMillan (lauren.mcmillan.19@ucl.ac.uk): Research Follow for AGILE.

Ms Mhari Gordon (mhari.gordon.21@ucl.ac.uk): PhD Student in Disasters & Research Assistant for AGILE.

Department

University College London, Institute for Risk and Disaster Reduction

Funding

Horizon Europe, project active from October 2023 to September 2027

You are invited to take part in the data collection for the AGILE project. Before you decide to participate, it is important for you to understand why the research is being done. Please take the time to read the following information carefully. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. You can contact the PI (Dr Pescaroli) with any queries or concerns related to this study at any point.

This project has been approved by the UCL IRDR Local Research Ethics Committee (ID Number: 23120801).

Information about the Research Project

AGILE is a Research and Innovation Action (RIA) project financed by Horizon Europe that started in October 2023, which will last for four years. The consortium has 15 international partners, including research organisations such as Delft University and Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, as well as stakeholders such as the National Commissioner of the Icelandic Police. The project coordinator is Johanniter-Unfall-Hilfe and the scientific lead is Dr Pescaroli (UCL IRDR).

The AGILE project aims at designing, developing, and applying a holistic methodological framework and practical tools for understanding, anticipating, and managing low probability high impact events (HILPS) with a systemic risk and resilience perspective. AGILE will combine and integrate a wide range of established and innovative methodologies into a novel and replicable risk and resilience stress testing methodology. These approaches and services will be co-created within a unique transdisciplinary consortium of research organisations, first responders, and local and regional authorities. The project will ultimately improve the strategic and operational risk management capacities and capabilities of stakeholders at local, regional and national level.

The findings are intended to develop guidelines for end user, publication including peer-reviewed journals, relevant blog posts, conference posters and other written forms of information dissemination, as well as oral presentations including national and international conferences and podcasts. The AGILE project aims to bridge research and practitioners to develop a new approach to supporting resilience for HILPs. It is co-created with a transdisciplinary consortium of research organisations, non-governmental organisations (NGOs), small and medium enterprises (SMEs), as well as local and regional authorities.

Further information is available on the website of the project https://www.project-agile.eu – *follow the Jellyfish!*

Your Participation

You have been invited to participate in this study as you have been identified as an expert related to this topic. You are being asked to participate in an interview to develop a better understanding of HILPs and their implications for building resilience, including aspects such as scenario building. It is anticipated that the interview will last between 30 and 60 minutes depending on your availability.

It is up to you to decide whether or not to participate. You do not need to answer any questions if you do not want to and you are allowed to withdraw from the interview at any time, without justification. Your participation is voluntary and refusal to participate will not disadvantage you in any way. If you accept to participate in the study, you will be asked to provide written consent and to specify if you want your transcript to be anonymised. If you decide to participate, you can ask for your data to be deleted within one week from the interview date.

Data Protection Privacy Notice

The controller for this project will be University College London (UCL). The UCL Data Protection Officer provides oversight of UCL activities involving the processing of personal data and can be contacted at data-protection@ucl.ac.uk. This 'local' privacy notice sets out the information that applies to this particular study. Further information on how UCL uses

participant information can be found in our 'general' privacy notice: For participants in research studies, click here (https://www.ucl.ac.uk/legal-services/privacy/ucl-general-research-participant-privacy-notice).

The information that is required to be provided to participants under data protection legislation (Data Protection Act (DPA) and General Data Protection Regulation (GDPR) 2018) is provided across both the 'local' and 'general' privacy notices. The categories of personal data collected for this study may include: name (e.g., consent form). The lawful basis that will be used to process your personal data is: 'Public task'. Your personal data will be processed so long as it is required for the research project. All the information that will be collected about you during the research will be kept strictly confidential.

You have the option to be identified if you wish (e.g., by name or job title) or to be anonymised. If you ask for data will be anonymised, we will remove as much as possible from the transcript traceable information. Before the start of the anonymisation process, you can ask the access to the transcript for checking any sensitive or traceable information within one week of the interview. After the anonymisation process, this procedure will not be possible. If you ask to be anonymised, any reference to the content reported in the interview will be reported with ID numbers such as "Interviewee X635". The anonymisation process will include a double-anonymising process with ID numbers, to minimise the possibility of traceability.

The data collected during interviews and your personal data will be stored in compliance with DPA and GDPR 2018 regulations. If you are concerned about how your personal data is being processed, or if you would like to contact us about your rights, please contact UCL in the first instance at data-protection@ucl.ac.uk.

If you would like to raise a complaint during this research, you may contact the PI (Dr Pescaroli) or UCL IRDR Local Research Ethics Committee (irdr-ethics@ucl.ac.uk).

Thank you for reading this participant information sheet and for considering taking part in this research study.

Appendix C: Consent Form

Consent form for Expert Interviews and Advice

Title of Project

AGILE: Agnostic risk management for high impact low probability events

Name and contact details of the Principal Investigator (PI)

Dr Gianluca Pescaroli (g.pescaroli@ucl.ac.uk): Associate Professor in Operational Continuity and Disaster Resilience & Scientific Lead of AGILE Consortium.

Name and contact details of UCL Research Team

Dr Lauren McMillan (lauren.mcmillan.19@ucl.ac.uk): Research Follow for AGILE.

Ms Mhari Gordon (mhari.gordon.21@ucl.ac.uk): PhD Student in Disasters & Research Assistant for AGILE.

Department

University College London, Institute for Risk and Disaster Reduction

Funding

Horizon Europe, project active from October 2023 to September 2027

If you have any questions arising from the Participant Information Sheet or explanation already given to you, please ask the researcher before you sign the form.

This project has been approved by the UCL IRDR Local Research Ethics Committee (ID Number: 23120801).

Please read the below if you would like to participate in this study:

- I confirm that I have read and understood the Participant Information Sheet. If I have questions, I have asked the researcher. I understand that I can contact them in the future.
- I understand that my participation is voluntary. I am allowed to withdraw from the study at any time without explanation.
- I understand that I can ask to see any data related to me. I can also request for it to be deleted within one week after the interview.
- I understand that the findings will only be used for the purposes explained to me, such as developing guidelines for the end user, journal articles, and conferences.
- I understand that the information collected will be stored in compliance with the Data Protection Act (DPA) and General Data Protection Regulation (GDPR) 2018.

☐   If you agree with the above statements, please tick.

Identification

☐   I do not wish to be identified. I understand that my interview transcript and data will be anonymized, however, it may be possible for my identity to be traced based on my expertise. The research team will take all precautions to minimize the likelihood of this.

or

☐   I wish to be identified. Please tick if you would like the following to be included:

        ☐ Name   ☐ Job Title/ Position   ☐ Institution/ Organization/ University

The boxes below are optional:

☐   I agree to be audio-recorded during the interview. I understand the audio-file will be used to transcribe the interview and promptly deleted.

☐   I wish to receive a summary of findings from this research or notice of related publications.

Name	Date	Signature

Thank you for agreeing to take part in this research!

Appendix D: Slide Deck

AGILE Project's *Working Definition* of HILPs:

Events are context dependent and need to be considered proportionally to the reality affected.

HILPs are shocks that happen with **lower recurrence, distinguished by high levels of uncertainty in their predictability and effects**, and by an element of **surprise or anomaly in the context of reference**. Their impact, which ranges from **serious to catastrophic**, can be thought of in terms of **critical services or critical social functions** that have been affected by triggering events, in which existing or dynamic vulnerabilities and capacities have a determinant role in orienting the outcome and development of the crises.

Could you please answer us to the following questions on a scale 0-3:	0	1	2	3	N/A
To what extent do you think HILP events have similar points of failure?					
To what extent do you think HILP and HIHP* events have similar points of failure?					
To what extent do you think that common procedures can be used for managing HILP and HIHP events?					
To what extent can preparation for HILP events can be influenced by experience/knowledge (of past events)?					
To what extent do you think the concept of HILP events can be useful to support the development of new preparation and planning practices?					
To what extent does an individual's flexibility (and/or adaptability) help with resilience to HILP events?					
To what extent does organisational flexibility (and/or adaptability) help with resilience to HILP events?					
To what extent is creativity recognised in the current practices of training?					
To what extent could creativity be used for training for HILP events?					
To what extent do you think that HILP events *exist?*					

0 - No	1 - Basic	2 - Limited	3 - Mostly
No; little/no; few/no; not at all; never; inadequate; very little	Basic; limited; lacking; seldom; occasional; partial; occasionally; under resourced; not actively promoting or pursuing improvements	Limited or sparsely present; in progress; applied/developed/ validated with some inconsistencies; but not updated; actively promoting or pursuing improvements	Mostly or completely present; comprehensive; complete; fully integrated; full compliance; full validation; applied consistently across; well established; applied and regularly updated; well established across sectors; constantly improving; higher proportion

Could you please rank the following from *most* important to *least* important barrier for managing HILPs?

![agile](agile logo)

Most Important ⬆

1. _____	a. Unpredictability
2. _____	b. Uncertainty
3. _____	c. Operational thresholds
4. _____	d. Lack of precursors
5. _____	e. Risk appetite
6. _____	f. Other: _____

Appendix E: Categories and Codes

The diagram below shows the coding tree that was developed for the analysis.

Disaster management scenarios and training in general - not HILP specific	Disaster scenarios in general	Scenarios should support planning and preparedness	The main purpose of scenarios is to support planning
			Scenarios can support the mainstreaming of preparedness in all sectors
			Scenarios can highlight what capacity / resources organisations have to improvise
		Scenarios can build understanding of the best, worst, and catastrophic	There is a rush to solve problems without understanding them first
			Scenarios can highlight what capacity / resources organisations have to improvise
		Scenarios should support planning and preparedness	The main purpose of scenarios is to support planning
			Scenarios can support the mainstreaming of preparedness in all sectors
	Disaster management training in general	Training is an integral part of effective disaster management	Need the right people, right equipment, right training, right

			monitoring, and right performance management
			The combination of planning, training, and exercising is key
			People will remember 80% of what they learned and adlib the other 20%
		Challenges related to training in general	Too many trainings – business continuity training gets short changed
			Even people who will never be operational due to their function are trained – (but that's good)
			SOPs and training for different types of events are sometimes missing
			It's rare to have a post-event analysis – so training isn't updated
		Developing and delivering disaster management training effectively (in general)	Support of senior leadership is key
			Involve all staff - not just primary people
			Use past experience
			Involve local actors
			Adapt training to the local culture
			Interconnect training, lessons learned, and preparation
			Train across strategic, tactical, and operational levels
			Use communication specialists to deliver training for the general public
			Create a training "diet" that gives everyone exposure to a particular type of problem, operation, or subsystem.

	The gap between a disaster management plan and its activation (in general)	Plans are often created without mechanisms to enforce their implementation	There are no repercussions for failing to follow processes, leading to plans being effectively useless in practice
			From a legal perspective, organisations may feel they have met their obligations by creating plans and training, but the lack of follow-through undermines their effectiveness
		Insights from planning exercises are not always used	Results of preparatory exercises are sometimes ignored
			Planning does not always translate into actionable preparedness
		Plans are sometimes unrealistic or impractical	Plans are sometimes based on unrealistic assumptions, such as requiring resources that are unavailable
			"Fantasy" plans are ineffective when real crises occur
	Engaging stakeholders in scenario building and training (in general)	Importance of a safe environment and trust	Role-playing exercises can make participants feel exposed, so trust and a safe environment are essential
			Creating an environment where participants feel comfortable fosters engagement and creativity
		Structure exercises around a sandbox approach	Use tabletop exercises to simulate stakeholder interactions, media scenarios, and operational response procedures
			Use a "sandbox" approach to let teams explore systems and their dependencies

			(e.g., simulating restarting systems that are down)
		Use skilled moderators	Skilled moderators can encourage participants to use creativity when exploring worst-case scenarios
			Taking individual perceptions and personalities into account, along with a well-structured and managed tabletop exercise, can foster creativity
		Value of cross-sectoral and multidisciplinary collaboration	Cross-sectoral and multidisciplinary teams generate the best results as diverse perspectives lead to innovative ideas
			Including unconventional participants (e.g., students, businesspeople) disrupts conventional thinking and adds fresh viewpoints
		Exercises must be adapted to the cultural and linguistic context of participants	Intercultural competence is critical for success
			Missteps, such as inappropriate examples or group dynamics, can alienate participants and reduce effectiveness
		Training can facilitate relationship building and networking	Training fosters a shared understanding and can sometimes influence values
			In operational contexts, training also builds personal connections, which are valuable during collaborative work

	Using generic versus hazard specific approaches (in general)	Generic versus hazard specific approaches	It's more effective to provide generic training than hazard specific
			Many disaster management needs, constraints, limitations, and assumptions apply across multiple scenarios
			Need agnostic incident response capability
			You can extrapolate and generalise from all sorts of different and unexpected events
			It's hard for people to understand how to prepare for a generic event – they want specifics
	Cross boundary approaches to disaster management scenario building and training (in general)	Use a multi-level approach	A multi-level approach (regional, national, local) enhances preparedness and response
			Involving stakeholders at various levels ensures comprehensive scenario-building
			Coordination across sectors and boundaries is vital for large-scale events
		The subsidiarity principle - decisions and actions should be taken at the most local level	Aim for decentralisation
			Local actors lead on risk assessment, planning, and preparedness
			Local levels respond first; upper levels intervene only when necessary
			National and regional support ensures preparedness for large-scale hazards
			Organising responsibilities in the shape of a pyramid ensures national

			coverage with tailored local plans
		A multi-level approach in business	Global leadership can mandate specific scenarios (e.g., cyber risks) for testing when deemed necessary.
			Cascading global frameworks and tools for local implementation
			Regular checks ensure plans are tested, and local adaptation occurs
		Cross-industry and cross-domain collaboration	Regular cross-industry exercises improve coordination across industries
			Integrate disaster management into broader planning (e.g., around infrastructure) and build scenarios to assess cascading effects.
			Multidisciplinary teams combine diverse perspectives, improving scenarios and preparedness.
			Use cross-sectoral multidisciplinary teams and ensure that people actually listen to each other (this is rare).
HILP scenarios and training	HILPs scenarios	Scenario building for HILPs is rare	Scenarios traditionally based on mid-range events, not HILPs
			Scenarios are only developed for risks deemed 'critical'
			For business reasons, there is less scenario planning for HILPs than HIHPs
			People lack the imagination needed to suggest HILP scenarios
		Challenge: it's hard to convince people of the need for HILP scenario building	Hard to convince senior management: higher frequency events take priority

				It is challenging to convince authorities to fund HILP preparedness
				People are sceptical or try to reduce HILPs to simple factors
				People cannot afford to plan for the worst event they can imagine
			Opportunities: it's easier to get buy in for HILP scenario building after a major event or before a high value/prestige situation.	Easier to convince people after a major event
				Proactive provisions for the unknown are rare – but do occur in high value, high prestige situations
			Purpose and benefit of using HILP scenarios	Use HILP scenarios to identify breaking points in the system
				Use HILP scenarios to identify common assumptions, constraints, and needs
				Use insights from HILP scenarios to generically plan for consequences
				HILP scenarios force people to think beyond preventative measures (what happens when prevention fails)
			Uncertainty inherent in HILPs demands out of the box thinking	Decisions need to be made against highly uncertain future projections
				HILPs require people to adapt to scenarios that did not exist before
				Climate change introduces uncertainty: historical scenarios are out of date
				HILPs require the capacity improvise
			How to improve scenario building for HILPs	Use counterfactual analysis and red teaming
				Focus on trigger points

			Focus on feedback loops
			Exercises should challenge assumptions
			Culture is an important factor to consider
			Consider risk tolerance and impact tolerance
			Creativity is important for scenario building
			Include challenges related to communications and information management
			Develop an envelope of scenarios based on a systems approach
			Multiple threats can be put into one theme
			Bring different types of risk – not always the same ones
			Provide tools that show best, worst, and catastrophic scenarios + escalating measures
			Engage societal stakeholders (or the exercise remains theoretical)
			Focus on the operators managing the affected systems
			Prevent organisational politics from getting in the way of failing and learning – the point of HILP scenarios
			Use of Anytown to avoid "that wouldn't happen in this place for reason X"
			Throw the kitchen sink at it
		Recent developments in scenario building	Shift from ad hoc tabletops to scenario planning and modelling
			Use of counterfactual analysis

			Focus on trigger points instead of scenarios
			Use AI / predictive analysis
			Use of a crisis cell exploring "what if" scenarios
	Training for HILPs	How to train for HILPs effectively	HILP training should build on planning / training for regular events
			HILP training needs to include building the right organisational culture and flexibility
			HILP training requires top-down and bottom-up approaches in parallel
			HILP training needs to develop out of the box thinking
			HILP training should involve scenario-based exercises
			HILP training should use scenarios not already covered in contingency plans
			HILP training should be practical, cost-effective, and address uncertainty
		Challenges to HILP training	People assume HILPs won't happen
			Hard to convince people that HILP training is worth their time
	Strategic foresight, lateral thinking, and counterfactual analysis	Horizon scanning	Horizon scanning is about imagining the future
			Current risks (the present) emerging risks (the near future) horizon scanning (mid-distant future)
		Importance of strategic foresight and lateral thinking	Their absence is a common point of failure
			Strategic foresight can ensure a common

			operational picture during an event
			Creativity allows people to invest in HILP preparedness before it's too late
			Strategic foresight and lateral thinking should be incorporated into business as usual
		Current practices	Businesses need to predict new trends/needs – so horizon scanning risks should be a natural thing (but isn't for many organisations)
			Companies do more scenario planning than horizon scanning
			Some organisations don't consider the medium-distant future
			Some companies have tunnel vision when horizon scanning
			Companies use horizon scanning but lack the capacity for lateral thinking
			Considering downward counterfactuals is rare
			End-users cannot tweak the assumptions that inform the models they use.
		Opportunities for improving strategic foresight	Provide simple, straightforward tools
			Use AI to explore more crisis triggers / hotpots
			Combine historical insights (e.g. re vulnerabilities) with future variabilities (e.g., re climate change)
			Foster critical thinking and trust
			Need (respect for) diversity of inputs and consideration of equity implications

			Encompass cultural considerations and stakeholder engagement
			Planning team should not be isolated, but next to decision making
			Start with the worst case scenario and work backwards
			Learn from near misses
			Learn from the military
			Learn from the humanitarian sector
	Creativity, Imagination, and Lateral Thinking	The meaning of creativity in disaster management	Creativity is about horizon scanning
			Creativity is about imagination (not art)
		On recognising the value of creativity in scenario building and training (current practices)	There is limited recognition of creativity in current practices
			Creativity is key to fostering mental flexibility through scenarios and training
			Level of recognition varies by team, training domain, organisation, sector, country, and region
		Creativity is not used much in current trainings and scenarios	There is a lot of conformity
			Use of creativity is unusual – there is a lack of imagination / thinking out of the box is rare
			Tried and tested methods are preferred
			Current practices lack creativity because they focus on "normal" disasters
			Current practices heavily influenced by traditional, often military, approaches
			Current practices are highly controlled

			Trainings lack creativity – they are based on an established curriculum
			Trainings lack creativity – they are based on what was learned during tabletops.
			Trainings and scenarios may become more creative over time
		Examples of how creativity is used in current trainings and scenarios	Creativity plays a central role in tabletop exercises, it's the most important part of their design and execution
			Innovative visual approaches (e.g., maps with 3D elements)
			AI tools from movie production to design crisis scenarios
			Techniques borrowed from war gaming with participants split into "red team" vs "blue team"
		Rationale for using creativity in scenario building and training for HILP events	A changing world requires new approaches
			It's now it's normal to talk about scenarios that were not normal a couple of years ago
			Creative approaches are useful for exploring evolving threats
			HILP management requires lateral thinking
			Creativity can help people understand that HILPs can occur
			HILPs offer business opportunities – you need creativity to spot them
			There is great scope for using creativity in training
			People enjoy creative approaches to training and scenario building

			Creativity can foster dialogue & drawing on multiple perspectives
			Creative approaches can foster out of the box thinking
		Barriers and concerns related to the use of creativity in scenario building and training	People don't like the change, instability, and uncertainty of a new approach
			View that too much creativity is counter-productive
			Introducing a HILP event during a tabletop requires courage
		How to foster adoption of creative approaches	Sectoral regulations facilitate creativity, openness, and sharing
			Communicate (business) motive for approach
		How to use creativity effectively?	Creativity should be paired with communication, contextualisation, and be goal oriented
			Facilitation to encourage people to think of absolute worst case scenarios is key
			The use of creativity in training and scenario building needs to be moderated.
			New tools and technologies could facilitate the use of creativity
			Look at the games industry for ways to bring creativity in
			Design scenarios and training environments that are immersive and challenging
			Scenarios should challenge assumptions and simulate situations where failures will occur

			Scenarios & training need to be realistic and embedded
			Include students, businesspeople, and bureaucrats
			Use novelists to write the script for training