

Cambridge Centre for Risk Studies

Scenario Best Practices

DEVELOPING SCENARIOS FOR THE INSURANCE INDUSTRY

Centre for
Risk Studies



UNIVERSITY OF
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DEVELOPING SCENARIOS FOR THE INSURANCE INDUSTRY

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1. Introduction

1.1 The Insurance Industry

The insurance industry comprises companies that provide risk management by underwriting the risks of individual entities and pooling them to spread the risk. An insurance contract guarantees that, on the occurrence of a specified uncertain future event, the insurer provides a payment to the insured, and thereby assumes the risk. In return, the insured (or policyholder) pays a premium, or a regular fee, to the insurer for providing the coverage. Insurance is critical in providing financial security to people and organisations performing their daily activities and operations; or undertaking new and risky ventures. There are several classes of insurance available to accommodate a diverse range of customers with an array of risks, which are often categorised by their asset type or the entity being insured. Examples include property and casualty, accident and health, or auto insurance.¹

In addition to offering traditional coverages for known risks, supported by comprehensive industry experience and understanding of their occurrence, insurers must

also continually adapt to emerging and uncertain risks. Today, such risks are manifesting at an unprecedented rate as the world is challenged by growing complexity and interconnectedness between systems. To fulfil the consequent demand for insurance coverage against emerging risks, insurers must first evaluate such uncertainty and ensure they can withstand potential losses and operate sustainably. The insurance industry shares key financial and operational risk exposures with the wider financial sector, but is also uniquely exposed to insurance risk, so internal assessments of risk must account for the complexity of interactions between both an insurer's assets (premiums invested to cover liabilities) and liabilities. One means of planning for the future is using scenario analysis (or 'stress testing'), a longstanding practice within the industry, but which continues to grow in importance as the market becomes more aware of its benefits and regulatory requirements call for robust internal risk management.

1.2 Why Use Scenarios?

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

In the insurance industry, these tools continue to evolve in response to advancing consideration and regulation of enterprise risk management, both within the industry and for the insureds that the industry indemnifies. Scenarios are increasingly being used by underwriters, analysts, risk managers, actuaries, and other stakeholders in the (re)insurance community to better understand the characteristics and consequences of unknown, uncertain, or unexpected future events.

A critical distinction is made between scenarios that examine emerging trends, which are of concern for long-term strategic planning; and those that consider catastrophic shocks, which trigger severe loss across a potential range of insurance classes, and so represent acute operational risks. This report is primarily written to address the latter, and on the design and uses of shock risk scenarios, which are increasingly in demand to overcome the challenges posed in today's and the future risk landscape.

¹ For a complete listing of the types of insurance, please refer to Multi line Data Definition initiative (Cambridge Centre for Risk Studies, in collaboration with Risk Management Solutions, Inc. 2018)

1.3 Report Rationale and Intended Audience

This report intends to outline best practices for scenario analysis within the insurance community, and to provide a practical framework to assist practitioners engaging with shock scenario development.

Within the report, we explore key features of, and commonalities and differences between, insurance specific scenarios, and suggest how and for whom they can be used effectively. Due to the varied applications of scenarios and their associated development methodologies, we focus the methodology discussion on shock risk scenarios, and draw commonalities from various shock scenario development techniques. As a variety of scenario use cases have unique requirements and maturity in the practice, development methodologies do vary. However, we propose that there is a general process which can be adapted and modified for these various uses. By providing key criteria and considerations for scenarios in the form of a scenario development framework, we hope to equip the reader with the necessary tools and context to develop coherent, comprehensive, and intelligible scenarios, which therefore effectively fulfil their intended purpose.

This report provides insurance-specific recommendations for scenario development, and has been published in parallel with another report² which similarly outlines best practices for scenario development in the disaster risk reduction community. The insurance industry has a rich expertise in risk assessment tools to price risk, employing scenarios that tend to be expert-driven, scientifically supported, and product oriented. In contrast, within the diverse community of disaster risk managers, scenarios often serve to explore and incorporate the culture and experience of various stakeholders in a more participatory approach, for which emphasis may be placed as much on what is learnt in the scenario process as the end result. Developing the two reports in parallel has provided valuable insight into the merits of contrasting scenario approaches and has informed the best practices advocated in both.

Report Aims

This report aims to address scenario best practices through the following considerations:

- 1 The role scenarios play within the insurance community;
- 2 The common and contrasting characteristics and typologies of scenarios;
- 3 How scenarios are currently employed and might be further or better used in methodologies to address emerging risks;
- 4 Current scenario limitations and critiques specific to the insurance community;
- 5 Stress test scenario guidance for catastrophe risk analysis;
- 6 How scenario development and applications might adapt in the future.

1.4 A Framework for Scenario Development

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

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



Figure 1: Scenario development framework for the insurance industry



2. Understanding Scenarios

2.1 What is a Scenario?

Scenarios are descriptions of potentially plausible events that may occur in the future, leading to a particular set of outcomes. They are based on assumptions about key driving forces, interconnections, and relationships, and have the ability to capture the uncertainties and complexities of a system in a coherent manner. Scenarios are not intended to comprehensively describe the future, but rather to highlight focal elements of different plausible futures and to highlight the key factors that will drive future developments. Sometimes the terms scenario, projection, and prediction (as well as others such as forecast and outlook) are used interchangeably, but while all are tools to investigate the future, each is nuanced in its meaning. A prediction can be defined as a subjective (probabilistic) statement that something will happen in the future, while a forecast is the most likely expected development.³ In contrast, a projection is a (probabilistic) statement that something *will* happen under certain conditions, allowing for significant changes in the boundary conditions that might influence a prediction. A scenario-based projection is a hypothetical construct of what *could* possibly happen conditional upon fundamental assumptions.⁴ These assumptions

allow some of the uncertainties that complicate more exact statements on the future to be set aside for the benefit of a scenario exercise. The dimensions of what constitutes a plausible event changes as external forces shift. As a result, the scenario process is inherently an evolving one, and scenarios which have been developed and are relied upon should be maintained and updated regularly to reflect current conditions.

Sometimes scenario development and scenario analysis (also called scenario ‘thinking’ or ‘planning’) are differentiated. Development means speculating about the uncertainty surrounding the future and envisaging different plausible future outcomes, or, in other words, to create ‘memories of the future’.⁵ Scenario development is the necessary foundation for scenario analysis, and the two are closely linked. Scenario analysis can be understood as the integration of scenarios into decision making. Here, we explore both scenario development and analysis together as the scenario process and use the terms collectively.

The Probable, Possible and Plausible

When considering the future, we often add ‘probability’, ‘possibility’, or ‘plausibility’ qualifications to emphasise relevance or importance. These notions are implicitly defined, but often not clearly differentiated and so are confused. Is a plausible future also probable? Can one future be more plausible than another? Should any conceivably possible future be considered? Care should be taken in using these terms in the description of scenarios. Key elements of the three qualifiers are summarised here to establish a distinction between them, but this concern cannot be resolved by reducing each to a definition. Scenario users should note that these terms do not have any universal value, and so should ensure the distinction between them is made sufficiently clear to be useful.⁶

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

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

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

2.2 Types of Scenarios

Scenario design and development processes can be commonly distinguished and classified, based on the development process, their purpose, or certain characteristics.⁷ In practice, these typologies are rarely binary or independent, and instead can be imagined as a multi-dimensional matrix with unique outcomes. This section proposes a series of distinctions which are commonly used to define scenarios. We encourage

practitioners to consider them as they construct scenarios in the context of their scenario aims, within the process of ‘Framing the Scenario(s)’ (Step 3 in the Scenario Development Framework). These typologies are illustrated in Figure 2, and discussed in detail within this section.

What is the scenario for?

Understanding Tail Risks	Understanding Emerging Risks	Strategic Planning	Accumulation Management
To identify and understand extreme, low probability risks	To imagine and comprehend new or evolving risks	To define a resilient strategy for the future that alleviates risks	To explore possible extreme or maximal correlated losses to insurance portfolios

How can the scenario benefit stakeholders?

Aid Communication	Demonstrate Due Diligence	Identify Bias	Sensitivity Analysis	Addressing Uncertainty
To contextualise complex risks and promote stakeholder understanding	To assess risk exposures and understand their financial implications	To explore partialities that stakeholders may hold towards certain decisions	To investigate the power and variance of controlling variables on a risk	To expand understanding of the range of plausible outcomes

On what timescale does the risk materialise?

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

Which is the more important scenario outcome?

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

Who owns and contributes to the scenario process?

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

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

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

Figure 2: Framing a scenario – scenario typologies and applications

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

Trend Risk Versus Shock Risk Scenarios

Scenarios can be developed to consider either sudden-onset, shock events that emerge quickly or unexpectedly, or slow-onset, trend phenomena that emerge gradually over time. The type of risk dictates how the scenario is developed and how it may be used.

Trend risks require users to consider temporality and identify both short-term signals and long-term impacts. The latter are likely to be less noticeable than short-term events and are difficult to align with organisational decision making, which tends to focus on much shorter future outlooks; as a result, it can be more difficult to incentivise mitigation measures for long-term threats. If effective action is taken, there is the benefit of having enough time to determine the best method to mitigate or alleviate the risk. Trend risks are typically not insurable

yet are a topic of increasing interest within the insurance sector, for example, as seen in the corporate uptake of an Environmental, Social, and Governance (ESG) agenda, and in response to growing awareness of the increasingly pronounced impacts of climate change. Insurers are increasingly needing to make decisions on how to address trend risks, whether it be through an adaptive process to keep losses within an insurable window, or the discontinuation of certain insurance policies. To best support these decisions, trend risk scenarios remain an important component of scenario analysis, regardless of whether the risk is currently insured.

In contrast to trend risks, shock risks are sudden events which may not have been anticipated and trigger impacts that materialise rapidly. The focus of these scenarios is

The Origin of Trend Scenarios

Trend risk scenarios have historically been used within operational or strategic planning and have roots in policy and operational settings. The Cold War futurist, Herman Kahn, and others at RAND Corporation, are regarded as among the founders of the construction and use of scenarios in the 1950s and 1960s, primarily in the security arena (e.g., how a country would function after a nuclear conflict), and encouraged the philosophy of how to ‘think the unthinkable’.⁸ He described a scenario as:

“a set of hypothetical events set in the future constructed to clarify a possible chain of causal events as well as their decision points”.⁹

Other notable research was being undertaken at the time by the Stanford Research Institute, who offered long-range planning facilities to support their military and business consulting. They were among the first to formalise and utilise scenario planning techniques for decision making by businesses and governments.

Kahn’s scenario methodology used mathematical models and forecasting techniques and set a



The value of Shell’s futuristic approach was first realised in the 1973 Arab–Israeli (Yom Kippur) War, when the first oil embargo caught most companies by surprise. Shell had considered and strategized for the implications of an oil price shock, and thus overcame the worst shocks, and emerged from the crisis as the sector leader.

Image 1: Herman Kahn of RAND Corporation (National Archives, 1963)

precedent for the future of scenario planning.¹⁰ In the 1970s, this methodology was adapted by Pierre Wack’s newly formed Planning Scenario team at the Royal Dutch Shell Group for use in a corporate setting, primarily to anticipate developments in the volatile oil and gas markets. ‘Shell’ scenarios were notable for their trend risk analysis and strategic planning purposes, and followed seven broad steps¹¹:

- 1 Decide drivers for change/assumptions
- 2 Bring drivers together into a viable framework
- 3 Produce seven to nine initial mini scenarios
- 4 Narrow down two to three scenarios
- 5 Draft the scenarios
- 6 Identify the issues arising

to identify events which might “shock” the system and have a valuable role in tactical planning. The impact of such scenarios is likely to be acute, rather than accruing slowly as in the case of trend risks, and they are more commonly hedged by conventional insurance products. The impacts associated with a shock event will demand an immediate response from the insurance community. The focus of this report is on shock risk scenarios, which have a wider variety of typologies and methodologies specific to the insurance industry. The dialogue within the report is written from a stress test perspective yet is often applicable in trend risk discourses.

Although stress test scenarios in the form of shocks have been used by the insurance industry for decades, their use via modelled catastrophe theory was precipitated in the insurance industry following Hurricane Andrew in 1992. At the time, Hurricane Andrew was the most

expensive insured event recorded, and triggered over \$16 billion in losses.¹² The financial impacts caused eleven insurers to go out of business in the state of Florida and caused heavy strain on the global insurance community.¹³ In the following years, the insurance focused credit agency, A.M. Best, required American insurers to report their modelled losses. Lloyd’s of London similarly introduced their realistic disaster scenarios (RDS) in 1995 (see Section 5 for an example RDS, Business Blackout, used as a model case study for scenario development). The intention of these scenarios was to provide a communal exercise for insurance organisations to stress their portfolios and identify any potential weaknesses which do not meet regulatory thresholds. The application of stress tests quickly evolved beyond regulatory purposes and has become a valuable tool in risk exploration and response planning.

Exploratory Versus Normative

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

Exploratory efforts ask, ‘*what if?*’, as a helpful way to create a ‘future memory’.¹⁴ This approach explores a wide and contrasting range of potentially plausible futures as a function of diverging assumptions (in other words questioning ‘*what would happen if this happens?*’), with the aim of widening the scope of options considered by users and stimulating imagination and creative thinking about the future. The focus here is on learning about the process under analysis, raising awareness, developing a descriptive assessment of plausible futures, and taking a specified issue or environment as the subject of analysis.¹⁵ Exploratory scenarios often apply a forecasting approach, defining scenarios on the basis of a set of imposed rules defined from the base year onwards.¹⁶

In contrast, normative scenarios primarily ask, ‘*what for?*’. To utilise such a scenario for decision making, a more narrowly defined set of criteria and objectives must be explicitly defined.¹⁷ A normative approach typically uses scenarios that are formulated in technical, quantitative terms (and thus have less emphasis on narrative) so that the paths to desirable, or undesirable, futures can be analysed. The intention is to evaluate the impact of a set of variants concerning specific interventions (behaviours and decisions) relative to a baseline, based on some form of valuation.¹⁸ Such efforts tend to focus on delivering a product, in the form of a specific alternative to address a problem, or an advising tool for evaluating alternatives.¹⁹ A normative approach can be more easily combined with a backcasting approach (as opposed to forecasting), defining scenario pathways only after first describing the end-points and reasons back from these end-points, and exploring short-term decisions to make these changes happen.²⁰



12. (Grant 2015) 13. (Grant 2015) 14. (Tourki, Keisler, and Linkov 2013)
 15. (Riddell et al. 2018; Tourki, Keisler, and Linkov 2013) 16. (Van Vuuren et al. 2012)
 17. (Birkmann et al. 2015) 18. (Henrichs et al. 2010; Tourki, Keisler, and Linkov 2013)
 19. (Tourki, Keisler, and Linkov 2013) 20. (Robinson 1990; Dreborg 1996)

Participatory Versus Expert-Driven

Another divergence in scenario design concerns who ‘owns’ the process, with a key distinction made between top-down, expert-driven (or ‘analytical’) approaches and bottom-up, participatory approaches. Both have advantages and disadvantages, and each may serve different purposes, although they are not necessarily discrete, with effective scenarios often including elements of both. We emphasise the importance of participation in the scenario process, since this dimension is often undervalued or excluded in insurance applications of scenarios.

Expert-driven approaches have the objective of providing rigorous descriptions of plausible futures, including details that are well supported by available science.²¹ Such approaches are oriented towards decision makers, and as a result tend to neglect other stakeholders. They are analytical in approach and allow for exploration of large-scale phenomena, for example global climate change, which may pose logistical difficulties to participatory approaches.

In a participatory approach, scenario developers work together with stakeholders, namely the people potentially affected by scenario outcomes, rather than delivering scenarios as a top-down means of education. Participation targets and integrates stakeholder needs and values, and while scientific and technical knowledge remains important, such approaches makes use of cultural perspectives, knowledge, and experience beyond the involved experts to dissect complex issues. No group knows everything, and each will learn from others through the scenarios, providing everyone is represented in the discussion. Effective communication of scenario information is much easier than accurate communication of technical information (such as probabilistic risk). Such diverse engagement is effective in developing community understanding and investment in decision making, builds trust, and encourages broader acceptance of the ultimate scenario outcomes.²² Participatory approaches enable scenario developers to understand, examine, and discuss the links between phenomena at different scales – for example how global or sub-national trends relate to the vulnerability in specific regions or municipalities.²³

Scientific and technological developments have driven an increasing role of technology and expertise in scenario approaches but demands for improved participation and accountability; and criticism of technical expertise, have also grown. Within the insurance industry scenarios are generally expert-driven, although there has been a recent effort to better involve stakeholders. Examples include community partnerships and local risk planning initiatives, or the rise of social impact bonds.²⁴

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

Intuitive versus formal processes

Process design refers to how scenarios are developed, or their methodological aspects, ranging from intuitive to formal approaches. Intuitive processes focus on qualitative knowledge and are participatory, incorporating many perspectives from a wide range of backgrounds and knowledge bases.²⁵ In contrast, formal processes regard scenario development as an analytical and systematic exercise, and so depend on quantitative inputs to build conceptual or computational models. They are exclusive in the way they only incorporate views from specific stakeholders or areas of expertise.²⁶

Process versus product orientation

The scenario development process can be at least as important for the user as the product, for example if a scenario is intended to support a specific decision. A process-oriented scenario includes the user in development, so that they may learn from the experience and feedback to enhance scenario efficacy. However, in many contexts, scenarios are instead communicated in a linear process, with an end product deliverable such as a report and or a quantification of loss. In this case the product is typically more important than the process, with the potential advantage of reaching a target audience beyond those participating in the process. If this is the case, quality, transparency, and legitimacy need to be emphasised in order to ensure scenarios are relevant to the user community and can be readily used for planning and decision making.²⁷

Qualitative versus quantitative

The distinction between qualitative and quantitative information is clear in scenario development, but the contrasting methods may be, and perhaps should be, combined. Qualitative information, specifically narratives, provide logic to scenario assumptions and help to define plausible future developments in situations where formal modelling is not possible. They provide an effective way to derive information at different scales or for different topics (for example regional scenarios nested within global narratives). Quantification, via modelling, adds scientific rigour to scenarios, expanding on numerical estimates of futures developments (often based on simulation tools) where relevant and reliable information is available. Quantitative outputs can strengthen communication through clear definitions and rules.²⁸

21. (Star et al. 2016) 22. (Star et al. 2016) 23. (Birkmann et al. 2015)

24. For more information on social impact bonds see (Social Finance Inc. 2012)

25. (Van Notten et al. 2003; Tourki, Keisler, and Linkov 2013)

26. (Tourki, Keisler, and Linkov 2013) 27. (Van Vuuren et al. 2012) 28. (Henrichs et al. 2010)

Deterministic Versus Probabilistic

Scenarios are also characterised as either deterministic or probabilistic. A deterministic scenario is created by selecting a specific set of parameters and conditions, while a probabilistic scenario considers a multiplicity of outcomes, each with its own probability of occurrence, depending on the probability distribution of the input parameters and conditions.²⁹ A deterministic scenario treats the probability of occurrence as finite, whereas probabilistic modelling is intended to address the uncertainty with a ‘complete’ probability distribution of synthesised events.

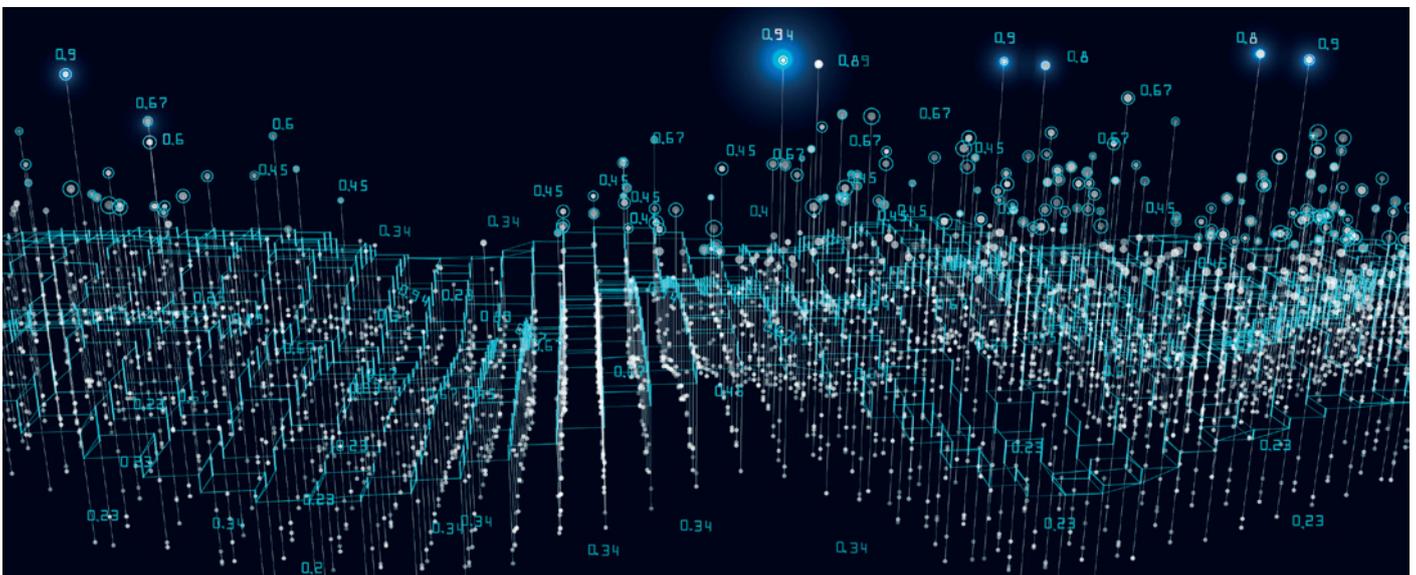
Deterministic scenarios are recognisable by their focus on the causal chain of circumstances that will give rise to unusual or extreme outcomes. They are an effective means of exploring phenomena speculatively or hypothetically when they are not very well understood or there is a high degree of uncertainty.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

In comparison, production of a probabilistic scenario is possible when the underlying process is well understood, and the causal parameters can be characterised with estimates of their occurrence rates and distribution. Each step in the causal chain has a defined distribution of outcome likelihoods, and the model stochastically samples from this distribution in many simulations. The probability of an outcome and its uncertainty structure is very sensitive to the assumptions made for the input parameters.³⁰ By incorporating random variations into the model, stochastic outcomes show a range of scenario outcomes, and the likelihood of these permutations. Techniques for probabilistic modelling are well understood and documented, and are used in analysis, such as natural catastrophe modelling, where the subject phenomena have been comprehensively studied

and for which it is possible to estimate the uncertainty distributions of the underlying variables.

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

Probability theory is critical in the industry, where the likelihood of future events is required to develop a policy or price a premium. This is true even where significant uncertainty exists, and it is in this case where deterministic scenarios can be particularly important to address uncertainty, providing reference points on a journey towards probability. It is also important to note that probabilistic scenarios are only useful when understood, and where decision makers are not familiar with the theory, it may be unhelpful or even misleading. For example, return periods, or recurrence intervals, are standard calculations for describing the magnitude of potential events – such as a 1-in-100-year flood – but are prone to misconceptions and misuses that are well acknowledged but still widespread.³¹ In cases where communicating scenarios to non-experts is required, it may be that probability should not be depended on, and a deterministic approach could have greater value.



29. (Renard, Alcolea, and Ginsbourger 2013) 30. (Lorenz 1963) 31. (Serinaldi 2015)



3. Using Scenarios in the Insurance Industry

This section documents the various roles that scenarios play within the insurance industry and explores who is using, or could better use, scenarios. The application of scenarios can be broadly categorised into universal uses of scenarios, and those specific to the insurance industry.

3.1 General Scenario Uses

The action of developing a scenario carries a series of benefits, some of which are simply a consequence of the scenario building process. We highlight a series of outcomes that were often cited by insurance industry representatives whose comments informed the development of this report, and were notably consistent, regardless of a scenario's intended use or application. These are individually discussed below.

Supporting Decision Making

Scenarios can be highly effective tools in support of decision making, offering a creative and structured mechanism to test and validate decisions in a scenario planning process. When managers make decisions about the future, concerning either near-term operations or long-term strategy, they cannot only expect positive outlooks, and must also be proactive in preparing for negative events. This proactive outlook is a key characteristic of enterprise risk management, contrasting with the typically reactive approach of traditional risk management. Scenarios facilitate discussion on how risks can be planned for and be managed or mitigated effectively with robust decisions and strategies. Further, decision makers must factor in the associated risks on the belief of a certain set of assumptions, the validity of which scenarios test.

Aiding Communication

Scenarios routinely function as a communication tool in the industry, facilitating the sharing of ideas, risks, or responses. Communication may occur formally during the distribution process, or more informally during the development and research phase. Scenarios are especially valuable when discussing abstract ideas, or complex risks, as they provide examples and context to the issue, ensuring a consistent interpretation and understanding. Furthermore, by providing a well-crafted scenario which is mutually accessible to multiple parties, consumers of the scenario have an equal platform for communication across different sectors or areas of expertise.

Demonstrating Due Diligence

The insurance industry is required to practice due diligence to keep themselves and their insureds safe. One component of due diligence is recognising what risks exist, and where vulnerabilities exist within the organisation. Scenarios assist in achieving this due diligence, as they provide a systemic and comparable platform for examining these risks, and a sheltered sandbox to identify and test potential vulnerabilities. These exercises can aid in answering questions such as what silent exposure may exist, or if there is clash potential on existing policies. By addressing areas of uncertainty and taking informed risks, insurers can demonstrate that potential consequences have been considered and reasonable precautions have been taken.

Identifying Bias

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

Scenarios to Support Robust Decision Making

Deep Uncertainty

Deep uncertainty exists when decision makers do not know, or cannot agree on, a system in question and its boundaries, the probabilities of model inputs, or the consequences of interest and their relative importance.³²

Such uncertainties persist for many drivers of global change, including environmental, economic, or technological developments. Societal perspectives and preferences also change over time, including stakeholders' interests and their evaluation of plans. As the future unfolds, plans are adapted to developments, so decisions are part of the storyline and an essential component of uncertainty.³³

Innovative analytical approaches³⁴ of 'decision making under deep uncertainty' are emerging to cope with uncertainty, and to help decision makers evaluate robust and adaptive management strategies. They help to build a consensus between stakeholders with different values, priorities, and solutions, who can agree on a decision for very different reasons.³⁵ The process reveals future threats, as well as opportunities, confronting each plan. This paradigm relies on exploratory modelling, typically involving scenario approaches that harness speculation and imagination to consider 'unknown unknowns'.³⁶

Robust Decision Making

Robust decision making (RDM)³⁷ is one example of a defined approach for analysing deep uncertainty, which uses iterative, model-based scenario analysis.

The RDM methodology helps decision makers to identify and improve robust strategies by testing them against a very large exploratory scenario set (of hundreds of possible futures) to reveal their strengths and limitations. Statistical analyses of model iterations identify the key conditions under which strategies fail to satisfy their objectives. RDM also has a participatory component, with stakeholder deliberation used to define (un)desirable outcomes, and to rule out implausible scenarios.³⁸

Robust strategies will satisfy decision makers' objectives in many scenarios, rather than being optimal in any single future.³⁹ In other words, they are 'good enough', rather than optimal options, aiming to minimise regret rather than maximise expected utility. RDM also helps to compare strategies along other dimensions such as cost, feasibility, and social acceptability.⁴⁰

RDM has been widely applied to explore where deep uncertainty exists, including in the domains of climate change⁴¹, risk and resource management⁴², and insurance specific applications, for example the feasibility of terrorism insurance⁴³. An important consideration of RDM is that it requires large amounts of quantitative information and a high degree of expert knowledge.

Sensitivity Analysis

Insurers are required to make assumptions and estimates daily, considering many different variables and evaluating their potential interaction with one another, towards making a cost-benefit analysis. Scenarios can assist in this process, as they allow users a sheltered environment to explore uncertainties and investigate alternative futures which may arise, incorporating a greater appreciation of the direct and indirect impacts of their decision choices today.

Addressing Uncertainty

Scenarios expand understanding of a range of plausible outcomes, each supported by a defining sequence of events. Humans inherently expect that change will occur gradually and that the future will reflect the past. By generating deeper insight into the underlying drivers of change, scenarios may demonstrate how and why changes could develop quickly and otherwise unexpectedly, and which drivers do or do not have the ability to cause consequential change.⁴⁴

Systems Thinking

The capability to capture interconnectivities between complex systems, or ‘system of systems’, is critical to scenario planning. Systems thinking is a holistic approach to address complex interconnections and causal relationships, rather than on snapshots and independent aspects, of a problem. Given the abundance of resources on this topic, only a brief overview is provided here, with an emphasis on the importance of wholly understanding systems when using scenarios. The approach exposes that which is not immediately obvious, providing a lens to detect underlying controlling forces and relationships between individual components, to understand the entirety of a system. The iceberg analogy⁴⁵ (Figure 3) is a useful way to illustrate systems thinking and enable practitioners to appreciate the deeper perspective. As humans, we typically notice events in the world around us (the ‘tip’ of the iceberg) in a reactive and counteractive mode, only seeing a small part of the underlying dynamics. Only when we look below the (water) surface for patterns of behaviour can the event be better understood with scenarios that explore how interconnectivities may control the future. Delving further into understanding these dynamics at a structural level enables exploration of the structural level of various risks facing an organisation.⁴⁶

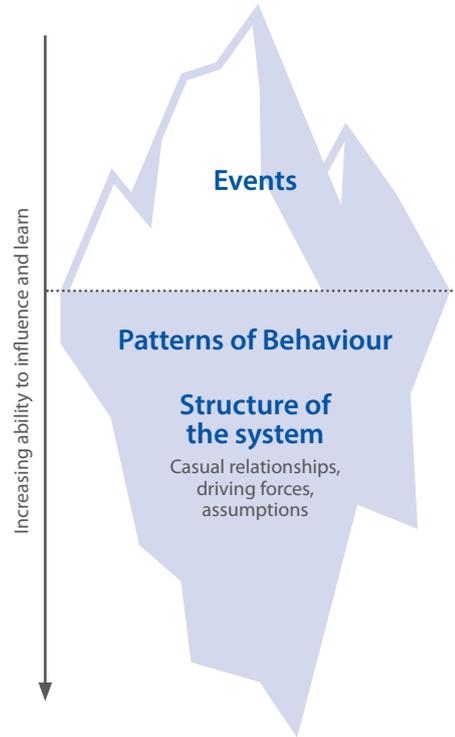


Figure 3: Systems thinking – the iceberg analogy (adapted from Senge, 1990; Van der Merwe, 2008)

3.2 Insurance Use Cases of Scenarios

In addition to the generic benefits that scenarios provide during the development and decision-making process, scenarios have specific and unique benefits to the variety of users within the insurance industry (Table 1). This report proposes that the insurance applications can be categorised into four use cases. These uses overlap and share common traits and should be recognised as interconnected components. These use categories are summarised in Table 2, and are described on the next page.

(Enterprise) Risk Managers	Regulators
Accumulation Controllers	Claims Managers
Underwriters	Risk Capital Controllers
Pricing Actuaries	Business Planners
Advisors	Investment Manager
Transaction Intermediaries	Product Designers

Table 1: Example scenario users within the insurance industry

Use Category	Description	Example Uses	Trend	Shock
Understanding Tail Risk	Identify extreme, low probability risks	Reinsurance purchasing, counterfactual analysis	✓	✓
Understanding Emerging Risk	Identify new and undefined risks and policies	Understanding policy wording, trialling a concept, problem verification	✓	✓
Strategic Planning	Identify risks and opportunities for an organisation	Short-term and long-term planning, particularly with regard to strategic response to opportunities or threats	✓	
Accumulation Management	Identify maximal potential losses and potential for risks to scale	Probable maximum loss (PML) identification, clash scenarios		✓

Table 2: Uses of scenarios within the insurance industry

45. (Kauffman 1980) 46. (Van der Merwe 2008)



Understanding Tail Risk

Within the insurance industry, a tail risk refers to an extreme and highly unlikely event which has significant and often immediate consequences. The term 'tail' originates from statistics – for example, if outcomes are distributed according to a standard bell curve (normal distribution), then outcomes that are more than three standard deviations below or above the expected outcome (the mean) only occur in 0.3% of cases – these are the tails of the distribution. These extremes, with either positive or negative impacts, are, by definition, highly improbable and difficult to predict.

Within the insurance industry, the focus is typically on the severe negative impacts that result in losses, although recognising the improbable positive outcomes also are of interest. As the exercise is hypothetical, variables can be adapted and controlled to explore different potential outcomes and their consequences. These scenarios assist in answering the hypothetical question “what if?” and provide a reference point to build from. As events unfold and the probability distribution of a risk evolves, the definition of a tail risk may also change.

Understanding Emerging Risks

An emerging risk is a new risk, changing risk, or novel combination of risks for which the broad impacts, costs and optimal management strategies are not yet well understood. Emerging risks are driving an increase in insurance exposure. Emerging risks offer opportunities for new products in the market but are also a potential threat to capital adequacy. Understanding the breadth of the risk and its potential consequences can allow insurers to embrace emerging risks and limit unintended exposure. Scenarios are a tool in exploring these risks, as they provide a

platform to develop hypothetical events and consequences. As emerging risks are fundamentally uncertain, scenarios allow exploration of hypothetical events through which these uncertainties can be stressed. This provides a gauge of the potential hazard severity or scale, and what limits or precautions should be taken at the time. When a specific outcome has not occurred in reality, scenarios can be used to see what pay-outs may be triggered, and how different policies may be interrupted should such a risk emerge.

Strategic Planning

Strategic planning is the process by which an organisation defines its strategy for the future, with consideration of trend risks which have the potential to threaten strategic goals. This can range from determining resources and areas of investment, to setting priorities and targets. Specifically, scenarios are often used as they allow users to identify and adjust factors which may impact these goals. Scenarios can be used to project what may occur in the short- and long-terms if conditions remain consistent, but also estimate how the future might vary with various internal and external influences. Scenarios fundamentally support the needs of communication across different stakeholders and areas of expertise and provide a communal platform for

discussion and problem solving. When considering strategic planning, members of an organisation can contribute to scenario building, creating a holistic planning process.

While, as previously discussed, trend risks are typically not insured via the current range of insurance products, insurers are increasingly being called on to address trend risks. Therefore, strategic planning should not only be considered as relevant to an insurer's internal risk management, but also as an opportunity for insurers to address trend risks that threaten the strategies of organisations that serve the industry with business.

Cyber Terrorism: An Emerging Risk

Cyber terrorism has remained one of the most notable emerging risks within the insurance industry and continues to build its reputation as a potential cyber insurance game-changer. Cyber terrorism is defined by the Federal Bureau of Investigations as: ‘any remediated, politically motivated attack against information, computer systems or computer programs, and data which results in violence against non-combatant targets by sub-national groups or clandestine agents’.⁴⁷

Cyber security professionals, governments, and law enforcement are becoming increasingly concerned with the potential for traditional terrorism groups to exploit the cyber landscape to cause physical destruction and human injury.⁴⁸ Insurers have been reluctant to offer coverage for cyber terrorism in their insurance products due to significant uncertainties surrounding the probability and severity of cyber terrorism events. In a recent review of 26 cyber affirmative policies, only 12% of cyber

insurance products offered terrorism coverage in 2016.⁴⁹ The ambiguity around the process of attribution of cyber attacks to terrorist actors has also compounded this uncertainty.⁵⁰

Scenarios have played a key role in the developing the market for cyber terrorism coverage by quantifying the potential exposure (particularly silent exposure) insurers could face when a cyber terrorist event occurs. Research commissioned by Pool Re, the UK’s mutual terrorism reinsurance pool with the UK Government, highlighted realistic cyber terrorism scenarios that could result in significant physical damage and thus trigger silent exposure in property lines. In response to the identification and estimated quantification of this cyber terrorism insurance gap, Pool Re have expanded their terrorism product coverage to include explicit cover for property damage and the resulting business interruption caused by cyber terrorism.⁵¹

Accumulation Management

Accumulation management, also described as aggregation risk management, considers what risks exist within a portfolio of insurance policies for large numbers of claims to arise from the same underlying cause or event. Scenarios of the events that could cause large numbers of simultaneous, correlated losses identify the potential systemic attributes that policy holders might share. This allows insurers to test the loss potential for their specific portfolio to those extreme losses. They also enable the exploration of hypotheses of how the risk might scale or increase in magnitude if a variable were to change. By estimating how large an event might be and how likely it is to occur, an insurer can effectively protect their exposure through limits and exclusions. A use of the scenario might be to help insurers design their terms and conditions, product design, and the limits and deductibles they might offer to protect themselves from taking large systemic losses.

Similarly, in identifying what the maximum loss for insurers might be, exposure limits can be introduced to limit what is insured, or what inclusions and exclusions are considered. This type of scenario is referred to as the Probable Maximum Loss (PML) and is often required when deciding a risk appetite or tolerance of loss for a line of insurance business and can be used to regulate the amount of new business that is underwritten in the future.

Scenarios play a valuable role when discussing accumulation and maximum loss, as they provide a trial ground to explore what types of events would cause broad impacts, especially across multiple portfolios, or classes of insurance. They are also helpful when considering limits and exclusions, as insurers can trial what amount of risk they feel comfortable accepting, in a controlled environment.

47. (Alford 2017) 48. (Broadhurst et al. 2017)

49. (Risk Management Solutions Inc, in collaboration with Cambridge Centre for Risk Studies 2016)

50. (Evan et al. 2017) 51. (Insurance Journal 2018)

3.3 Allocating Risk Capital

Capital modelling is used when deciding how much capital should be priced and reserved to cover potential risks.⁵² The role of capital allocation modelling in the insurance industry is typically focused on ensuring capital requirements for regulatory purposes are met, without significantly impacting daily underwriting decisions.⁵³ This is a method known as ‘Regulatory Risk Based Capital’. Under Solvency II pillar one, insurers are obligated to meet the Minimum Capital Requirement and Solvency Capital Requirement.⁵⁴

To meet these requirements, insurers can either use a ‘one size fits all’ prescriptive model provided by the regulator, which uses a standard formula, or else develop an internal capital model (ICM).⁵⁵ The use of partial or fully internal capital models goes beyond the scope of regulatory compliance by providing greater insight into

a company’s risk profile and is essential for navigating towards efficient capital allocation.⁵⁶

To validate a modelling process of capital allocation, insurers often develop scenarios to assess the resilience of these capital reserves to shock and trend risks. Scenario modelling is used to validate insurers decisions on the allocation of capital across lines of insurance by estimating their exposure to a disaster scenario.

Using clash aggregation modelling techniques, insurers can test their capital allocation reserves based on a disaster scenario that impacts multiple lines of insurance. Clash modelling allows insurers to better understand their potential losses across multiple lines of business and develops a narrative for capital requirements necessary to cover these losses.

Solvency II

In 2009, the European Union Insurance and Occupational Pensions Authority (EIOPA),⁵⁷ a financial regulator body of the European Union, introduced the EU Solvency II Directive. The directive aims to homogenise EU insurance regulation and focuses on an enterprise risk management approach towards required capital standards.⁵⁸ Solvency II is primarily concerned with the level of capital reserves insurance companies should hold to reduce the risks of insolvency.⁵⁹ This legalisation was driven by the events of 2008, when the Financial Crisis and subsequent Great recession highlighted the necessity for insurance companies to manage their capital allocation to remain solvent. To ensure the solvency of EU insurance companies, the Solvency II program has three main areas, known as ‘pillars’:

- **Pillar 1:** Financial Requirements
- **Pillar 2:** Governance and supervision
- **Pillar 3:** Reporting and Disclosure

Pillar 1, known as the ‘quantitative pillar’, puts demands on the required economic capital that insurance companies must hold.⁶⁰ The pillar stipulates two thresholds that insurance companies must adhere to: Solvency Capital Requirement (SCR) and Minimum Capital Requirement (MCR). The SCR requires insurers to estimate the level of capital needed to meet quantifiable risks on their existing portfolios, including one year’s expected

new business.⁶¹ MCR is the lower bound of the SCR and is the level of capital in which regulators would consider the insurer to be in significant danger of insolvency. The MCR is calibrated in the Solvency II regulations as 85% value-at-risk over one year from valuation date.⁶²

Pillar 2 is known as the ‘qualitative pillar’ which sets out clear requirements regarding how the quantitative objectives of pillar 1 should be achieved. The pillar requires companies to design effective systems of governance which are proportionate to the nature, complexity and scale of operations.⁶³ An insurer must have written internal policies in relation to risk management systems and internal controls of the organisation. Under the Own Risk and Solvency Assessment (ORSA) area Solvency II, insurers must action a significant self-assessment of the risk they are exposed to in the short and medium run.⁶⁴ ORSA aims to go beyond the modelling requirements in pillar 1 and for the insurer to think about additional risks the insurer may be exposed to.

Pillar 3 outlines the reporting requirements of company’s risk with respect to which information should be disclosed such as risk exposure and concentration, and the frequency with which this information should be reported.⁶⁵



4. Shock Risk Scenario Development: Insurance Stress Testing

There are many types of scenarios which have been developed by the insurance industry, for particular applications and with differing development methods. During the literature review and consultation process for this report, a wide variety of techniques and development processes were identified in surveys of insurers and stakeholders. There is no standardised approach, consensus, or single proto-typical method in use. Instead, there are common features across multiple methodologies. In this section we focus on the underlying similarities and propose a series of checkpoints to ensure developed scenarios can be applied widely and meet the needs of the broader insurance community.

4.1 A Checklist for Scenarios

The first checkpoint in the scenario development process is identifying who the scenario users are, and how they hope the scenario will be used in the future. Within the insurance community there are an abundance of potential users with individual needs and criteria for a scenario. The best way to gauge these needs is by talking with the intended audience or users and taking the time to understand what they hope a scenario to achieve. Supporting the direct feedback from future users, scenario developers should also reflect on the following:

Background Knowledge refers to the existing familiarity that users have with the subject. This is an indicator for the type of narrative and level of description that should be provided. If the scenario is proposing an event that is novel to the user, the scenario and its associated documentation should provide additional resources regarding the current risk landscape and use additional description when suggesting cascading impacts. Comparatively, if the user is very familiar with the proposed risk event, the scenario can address a different level of detail and specification. The terminology and language used to describe the risk should also be adapted based on the familiarity of the end user with the subject matter. As a standard practice, the scenario should include enough research and reference material so that it remains widely accessible, regardless of the key audience's familiarity.

User Resource is the amount of time and human capital that the user can be expected to dedicate to read and interpret the scenario. The resource allowance should dictate the length and detail of a scenario. Should the scenario be intended for a user interested in new and emerging risks over a long-term period, more resources may be allocated to reviewing an extensive report and background material. If, for example, the user is focused on the clash risk of a specific area, there may be a greater urgency to understand potential outcomes and losses, and so fewer resources would be available to review an extensive report.

Existing Guidelines refer to the rules and regulations that may have been put in place by the user regarding the scenario's development and presentation. This is most commonly seen in the case of regulators and authorising bodies, who are required to review and compare large numbers of scenarios in a short period of time. Prior to the development of the scenario, one should check to ensure that available guidelines required by the user are reflected. These guidelines might include the types of scenarios required, the number of variants included, and the loss estimation process.

Audience refers to how the user intends to share the material, and whether it will remain as an internal resource, or be published externally for public use. Public scenarios will require significantly more documentation and reference material than those for internal use, to mitigate potential ambiguity.

4.2 Scenario Development: a Stress Test Perspective

The next several checkpoints in scenario development relate to its construction. The intention of the report is to provide an accessible resource and guide for developing scenarios, but the process is varied and often attuned to the specific needs and interests of stakeholders.

Accordingly, the steps discussed below are recommended checkpoints to consider as a practitioner works through the scenario process. Users should adapt the methodology to create scenarios which work best for them, given their audience, resources, and desired use. Further, while it outlines a linear step-by-step structure for clarity, we encourage the scenario process to be an iterative one, in which stakeholder engagement provides opportunities for review and revision to ensure it succeeds in fulfilling its aims.

A case study of a worked example of scenario development using this framework is provided in Section 5, based on the 2015 Lloyd's Business Blackout Report⁶⁶, originally developed to address emerging cyber risk within the insurance industry.

There are various types of scenarios which can be used within the insurance industry (Section 2.2). This section focuses specifically on stress test scenarios, which are among the most widely used scenario types and carry the greatest potential for external agency development. Many of the recommendations made for stress test scenarios are broadly applicable to other forms of scenario development.

A stress test is an exercise conducted within the insurance and finance community to explore an organisation's limits and define the magnitude of event that would 'stress' the institution. This is often measured in terms of financial capital, with stress tests imagining extremely expensive events leading to an influx of insurance claims or financial losses. Stress tests often focus on rare and extreme events (tail risks) which result in a dramatic impact.

Within the insurance industry, stress tests are a common requirement for external regulation and internal planning and are a recognised means of evaluating the robustness of an institution, both currently and in the future. The process of developing a stress test involves both creating a hypothetical event and identifying the consequences that event would have upon the organisation/insurance sector. This report suggests that the scenario development process is best considered an iterative progression rather than a linear trajectory. This is due to ongoing adaptations and adjustments which are made as a researcher learns more during the scenario's development. The process is summarised in Figure 4. The process can essentially start at any phase within the process, though most will find it logical to first identify a risk or question. Others may start by formulating intended scenario outcomes and work backwards, which is a reverse stress test.

Exploring Knowns and Unknowns

In 2002, the US Secretary of Defense, Donald Rumsfeld, stated:

"There are known knowns. There are things we know that we know. There are known unknowns. That is to say, there are things that we now know we don't know. But there are also unknown unknowns. There are things we do not know we don't know."⁶⁷

Although the saying was intended for a national security perspective, the same intention can be applied to a broader risk perspective and our understanding of potential hazards. Rumsfeld correctly suggested that there are certain unknowns which we are aware of and can in turn effectively prepare for. Alternatively, there are unknown unknowns, or unidentified risks, which are difficult to imagine or plan for in advance.⁶⁸ Within the insurance community, it is the unidentified risks which carry the greatest uncertainty and can have some of the most consequential financial impacts. Although risk management is designed to consider potential emerging risks, there are some risks for which management is not possible.

The role of stress test scenarios within the insurance industry is to identify what type of extreme events might occur, and what impacts would result. By shifting away from what is likely or known and focusing on what is plausible (either now or in the future), a broader interpretation of the risk landscape can begin to emerge. It is unlikely that scenarios will identify an unknown unknown risk, but they can encourage organisations to widen their knowledge of their known unknown risk environment and reduce the surprise of a shock event.

When researching the subject, it is also helpful to identify similar historical incidents, which can provide precedent for the proposed event. Alternatively, counterfactual analysis considers events which might have occurred but didn't. Counterfactual analysis can be especially helpful when considering event outcomes which have never happened before.⁶⁹ By anchoring aspects of the scenario in existing events, the scenario maintains its credibility and relevancy.

66. (Cambridge Centre for Risk Studies 2015) 67. (Rumsfeld 2002)
68. (Kim 2012) 69. The Economist 2017)



Figure 4: Outline of the scenario development framework for the insurance industry



Step 1: Scope the Risk

This step aims to contextualise the objectives and resultant decisions of the process. It is logical to approach the scenario process with the statement of a problem or research question to be answered, most simply by defining a specific risk facing an organisation. For example, within the insurance industry, a common theme is to better understand potential or emerging risks and identifying how they may affect the insurer’s portfolio. A research question typically starts broadly (e.g. ‘what are my silent cyber exposures?’) and evolves to a more specific question during development (e.g. ‘what are my silent cyber exposures to an industrial explosion event?’). The problem or question will be refined throughout the research and development process. Stress test scenarios are particularly helpful when identifying exposure to unlikely but extreme events. Although these events are difficult to assign a probability, extreme scenarios are still valuable in investigating interconnectivities and indirect impacts.

Where the risk is uncertain or unknown, the research question should instead aim to define the issues or vulnerabilities that the scenario exercise aims to expose. In this case, the desired outcome of the scenario process is likely to identify one or more risks to an organisation. A reverse stress test is an alternative way of framing a question or problem, instead focused on the hypothetical point of failure that would cause an organisation to become unviable. The scenario then forces users to identify the vulnerabilities which exist and might cause such an effect. Reverse stress tests are helpful in highlighting the potential for failure and addressing any false sense of security concerning the robustness of a business and its resilience to a shock.



Step 2: Conduct Background Research

Background research should include consultation of the relevant sources of knowledge, including the academic literature for a scientific understanding of the topic, as well as the knowledge of insurance industry experts and associated stakeholders within and beyond the sector. Each dimension of risk should be considered: the hazards, whether acute, shock events, or slow-onset, trend phenomena; exposure of an organisation, sector, market to a hazard; and vulnerabilities at each of these levels that have the potential to drive loss. A distinction should be made between idiosyncratic risks that affect a single organisation, and systemic risks that drive a major collapse in a specific sector or the broader macroeconomy.

Various stakeholders in the insurance community are often willing to help at this stage and can provide nuanced advice specific to certain risks. Speaking with subject area experts outside the insurance industry can provide a balanced perspective, as they have different perceptions of risks, vulnerabilities, or potential impacts. Establishing both an internal and external perspective is valuable for this reason. This process alone may be valuable in widening the view of known unknowns, highlighting risks that do not yet feature on an organisation’s radar.



Step 3: Frame the Scenario(s)

Here, framing the analysis refers to consideration and definition of the key aims, benefits, and characteristics of the scenario process. It is the process of determining what type of scenario is most appropriate for the current use case.

As discussed, to be effective, scenarios should blend approaches and typologies to fit their purpose. Figure 5 intends to guide this framing with a series of questions that aim to provoke consideration of key practical decisions in the process:

What is the scenario for?

Understanding Tail Risks	Understanding Emerging Risks	Strategic Planning	Accumulation Management
To identify and understand extreme, low probability risks	To imagine and comprehend new or evolving risks	To define a resilient strategy for the future that alleviates risks	To explore possible extreme or maximal correlated losses to insurance portfolios

How can the scenario benefit stakeholders?

Aid Communication	Demonstrate Due Diligence	Identify Bias	Sensitivity Analysis	Addressing Uncertainty
To contextualise complex risks and promote stakeholder understanding	To assess risk exposures and understand their financial implications	To explore partialities that stakeholders may hold towards certain decisions	To investigate the power and variance of controlling variables on a risk	To expand understanding of the range of plausible outcomes

On what timescale does the risk materialise?

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

Which is the more important scenario outcome?

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

Who owns and contributes to the scenario process?

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

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

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

Figure 5: Framing a scenario – scenario typologies and applications



Step 4: Develop Candidate Scenarios

Developing candidate scenarios typically occurs in tandem with the research process and involves imagining the distinct features and narratives of potential scenarios. This should be a free-thinking exercise and includes exploring threat types and characteristics, key variables and controlling factors, as well as expected consequences and impacts. Informed by the background research, a list of candidate scenarios should be formalised. It is helpful at this stage to make the candidate list as extensive as possible. Developers should consider the key question or problems during this process and attempt to list scenarios that satisfy the required criteria, while ensuring they remain plausible and true to the reality as understood from the background research. For each of the candidate scenarios, consider what risks are measured, and what types of consequences they may lead to. Once a series of potential scenarios have been listed, they will be ranked and selected for further development.

There are several methods to rank and select scenarios, which are largely based on user preference and a scenario’s intended application. Two common approaches include the use of an impact uncertainty matrix, and the uncertainty breadth approach. In the impact-uncertainty matrix (Figure 6), outcomes are projected upon a matrix which gages both impact and uncertainty. Scenarios which have high impact and high uncertainty are thought to benefit the greatest from further research. This is followed by scenarios which have either a high impact or high uncertainty. Those which are certain and unimpactful are deemed least appropriate. The uncertainty breadth approach is an alternative method which selects scenarios that cover the greatest range of outcomes. In this case, multiple scenario variants would be selected that are the most different from each other and had the least amount of overlap. The uncertainty breadth approach is especially valuable for emerging risks which typically have more unknowns.



Step 5: Develop a Narrative

A detailed narrative expands the scenario description to provide the required detail on which to build the analysis. The narrative should include a variety of dimensions of a future event, including context, triggers, timelines, geography, responses, and implications. When determining these factors, it is helpful to once again refer to the intent of the exercise expressed when scoping the scenario (Step 1). Geography, timelines, and event triggers are particularly relevant within the insurance context, as they determine whether insurers bear liability and which policies will be triggered.

It can be helpful to consider scenarios as stories which have a beginning, middle, and end, and the narrative

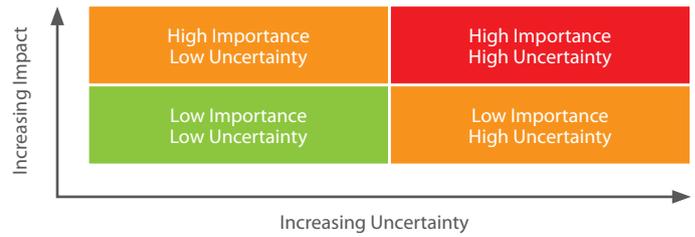


Figure 6: Impact-uncertainty risk matrix

Determining a severity

It can be helpful to estimate what the frequency and severity of the loss may be to a rough first order. This process identifies extreme yet plausible events and can provide some context to the discussion. Insurers often discuss size and severities in terms of ‘return periods’, or the estimated time interval between the occurrence of similar events. For example, a 100-year return period event implies a severity level that only has a 1% chance of occurrence in a given year.⁷⁰

When determining the event severity, it is also helpful to consider the size and scale of the (1) trigger event, and the (2) market response. Often what generates a stress event is a cascading set of incidents which amplify the triggering incident. In this perspective, the trigger event may be common, yet the response may be very uncommon, which results in an overall extreme and unusual event. In most cases, it is advised to not make the scenario too extreme, as ‘game-over’ severities are not actionable. Although there will be scenarios which can be much more severe or stressing, events which result in the failure of society or destruction of an industry as a whole, are often not relevant for traditional stress test users. This is because, in such cases, the insurance industry would be unable to support such colossal losses. Scenarios should be kept potentially plausible and broadly recoverable.

guides the reader through the events and their implications. The narrative is imperative for providing logic and reasoning to the proposed events and assists in making the scenario more applicable and relatable. An effective narrative can also create broader interest and relevancy, increasing the scenario’s utility. Research conducted in the previous steps should be applied to help guide the narrative based on historical precedence. In providing rich descriptive details and elaborating on the cause-and-effect processes, a more holistic impression of the hypothetical event can be drawn, which assists when determining its direct and indirect impacts. One way to expand the narrative in an insurance specific context is by using coverage trigger pathways.

⁷⁰. A return period should not be interpreted as a prediction of when the event will occur. Instead, a return period is the probability of occurrence.

Designing a Scenario Narrative

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

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

Location: Consider where the event trigger occurs (if applicable) and how far reaching the impact is felt. Furthermore, for certain types of insurance, such as liability, the jurisdiction can dictate what types of coverages are available, and the legal liability organisations might hold. Indirect impacts should also be considered in addition to primary impacts. For example, if a terrorism event occurs in South Korea, what international life insurance policies might be triggered for tourists? What international manufacturing operations would be impacted by the interruption? With increasing global networks, event impacts are not limited to the surrounding geographic footprint and can quickly expand to a global scale.

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

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

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

Coverage trigger pathways

Coverage trigger pathways are contextual details that can be added to a scenario and are intended to stress a specific type of insurance by impacting the insured assets. An asset can be either tangible or intangible, and can include: properties (location), contents, people, products, mobile assets, organisations, projects, events, trade agreements, contracts, or intellectual property.⁷¹

The approach requires the users to view all the classes of business insured in the footprint and identify potential events which would stress that line. This can be done in tandem with the traditional scenario narrative and provides a series of statements to base impacts upon when completing the scenario impact assessment. Figure 7 illustrates an example of a scenario narrative, and some coverage trigger pathways which could emerge as specific insurance losses.

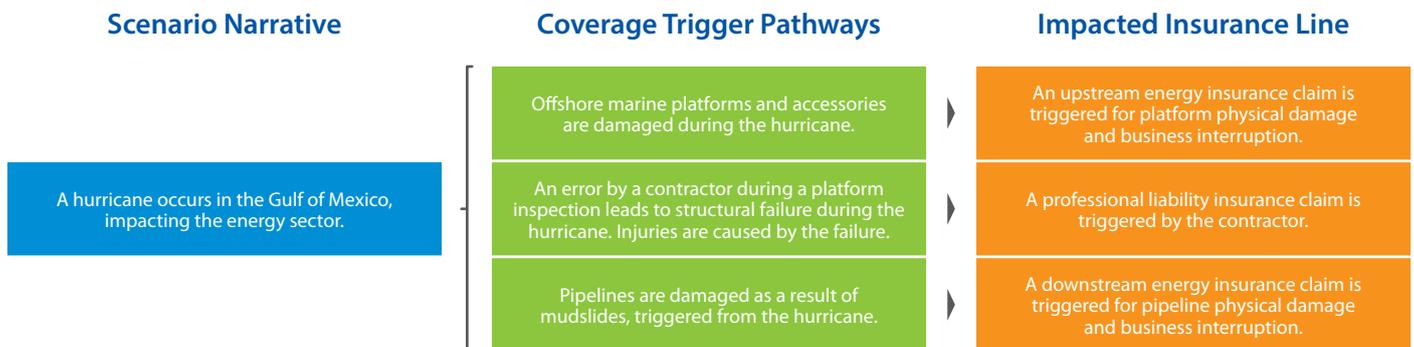


Figure 7: Hurricane coverage trigger pathway for the energy sector

71. (Cambridge Centre for Risk Studies, in collaboration with Risk Management Solutions, Inc. 2018)

Scenario variants

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



Step 6: Assess Impacts and Materiality

Once the scenario event has been developed, the next step is understanding what the potential impacts are to an organisation within the insurance industry, and/or systemic impacts to the industry and wider social, environmental, or economic systems. Consideration of dependencies and interconnectivities between shocked systems with a ‘multi-threat’ approach is critical to understand the hidden and cascading impacts beyond the expected (see Section 3.1 on ‘systems thinking’). For example, the 2011 Tohoku earthquake triggered a tsunami that caused the meltdown of the Fukushima Daiichi nuclear reactor⁷⁴, and the 2017 WannaCry cyber attack impacted the UK’s National Health Service when staff were locked out of their outdated operating system⁷⁵.

Within the insurance community, specific attention is given to the impacts on assets.⁷⁶ Assets are insured by an insurance organisation, and should specific conditions or circumstances arise resulting in financial loss, a payment would be made to the insured. Insurers will have a catalogue of assets which they insure, and their primary interest is how the stress test will affect these assets. Depending on the type of asset, different types of insurance⁷⁷ and insurance coverages⁷⁸ will be made available. These categories of insurance are referred to a ‘classes’ and are often underwritten together.⁷⁹ Accordingly, many stress tests are written to ‘stress’ a specific insurance class, or series of classes.

When determining the assets which will be impacted by the stress test, the following steps are recommended:

1 Determine where the impacts will occur

In the case of a physical event, this is the geographic footprint of the direct and indirect impacts. For non-physical events, this is identifying what systems or networks might be impacted.

Scenario variants are frequently used to show a potential range of outcomes and their severity. The number of scenario variants is dependent on time and resources, but typically ranges from three to seven. When considering the number of scenarios, the centre stage effect⁷² dictates that users are more prone to select the middle scenario.⁷³ As a result, there is benefit in presenting an even number of scenarios, to dissuade the tendency to select the centre as default.

2 Identify what assets will be impacted by the event

Consider what is insured within the footprint of the scenario. Tangible assets would be physically present within the footprint, while intangible assets may be dependent on someone or something within the scenario. Consider business operations, liability agreements, contracts, and insured persons, in addition to traditional physical assets.

3 Identify the incident rate

This might be the proportion of assets impacted, or the replication of the risk. It can be helpful to consider the incident rate as a severity scale, as it is rare that assets all face the same degree of impact. Instead, gradation can be applied to mimic impact variation.

4 Identify existing insurance coverages available to asset

For the assets which are impacted by the stress test, identify what form of insurance they would be covered by. One asset may have multiple policies covering it for different types of risks.

Upon identifying the affected assets and insurance policies, the next step involves estimating the financial loss. Due to the various limits and deductibles which are considered when paying an insurance claim, the estimated total loss can be expressed in several different forms. Common examples include macroeconomic loss,⁸⁰ ground-up loss,⁸¹ gross loss,⁸² and investment portfolio losses.⁸³ These are summarised in Figure 8.

The methodology followed in calculating these loss types varies depending on organisation and the amount of detail available regarding regional assets. In some cases, the specific assets and/or their exposure value may not be known to the scenario developer. In these cases, it is best to estimate based on insurance penetration, historical losses, and known commercial values. If the total insured value of an asset is available, one might

72. The centre stage effect refers to the tendency for people to select the middle item when presented with a list of options (Valenzuela and Raghurir 2009a) 73 (Valenzuela and Raghurir 2009a) 74. (Zastrow 2019) 75. (Ruffle et al. 2018) 76. Assets are anything tangible or intangible which is owned or can contribute value 77. Types of insurance are products specific to a class of insurance. For example, within a marine insurance class, wet insurance includes cargo insurance, hull insurance, and marine liability insurance 78. Examples of insurance coverages include physical damage, bodily injury, or business interruption. 79. Examples of insurance classes include life, health, auto, property, or marine. 80. Macroeconomic loss refers to losses felt by the whole economy, and considers how regional, national and global economies may react to the event 81. Ground-up loss is the entire insurance loss, and does not include deductibles, limits or reinsurance. 82. Gross loss is the ceding company’s loss irrespective of any reinsurance recoveries due. This can be interpreted as the ground up loss which has factored deductibles, limits and other confines, but doesn’t include reinsurance 83. Investment portfolio losses refer to the cumulative losses seen in a collection of assets owned by an organisation or individual.

refer to the severity of the damage, and propose what proportion of the asset's total value would be affected.

Expert judgement can be a valuable resource when estimating loss. Underwriters can be especially attuned to relative asset values, and it is helpful to have their guidance and review in this process. Depending on the type of loss being calculated, deductibles, limits, or reinsurance restrictions may also be applied to the estimate.



Step 7: Communicate and Act

Effective communication of realised scenarios controls the efficacy of the process. Although it may appear trivial, a catchy name that provokes interest is an often-overlooked scenario element that can aid its successful uptake and communication. Then, meaningful, comprehensible, and interesting outputs are essential, and are likely to include both qualitative and quantitative components addressing the scenario impacts and materiality. It is important for the narrative to explain and contextualise the results, and it may often be helpful where multiple scenarios are explored to focus on the most probable and use this as a reference to explore others. The scenario outcomes can inform and prompt decisions and actions where this is the intended purpose, for example concerning an organisation's strategic risk management practices or to manage accumulation risk.

Consider how and to whom the scenario is delivered; this may include internal and or external stakeholders. Internal partners may include different underwriting bodies, risk managers, or strategic planning parties, while external partners might include regulating authorities, governing bodies, or investing partners. When communicating the scenario, one should consider the audience's background on the risk topic and the scenario development process and ensure that they have enough background information to interpret the findings. Importantly, it must be made clear what the scenario is intending to accomplish, and how the findings should be interpreted. The scenario is not a prediction of future events, but instead a thought exercise into plausible futures. Further, stakeholders should feed back to ensure a scenario and its results are plausible and relevant to their needs. It is common for changes and experiments to occur at this stage, especially if different variations or severities of the scenario are being trialled. Most notably, some may be interested in identifying what variables will 'tip' the balance to the point that insurers would be unable to financially recover from the event.

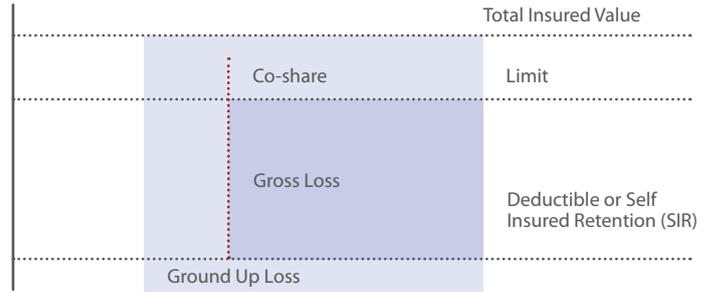


Figure 8: Dimensions of insurance loss



Step 8: Evaluate and Update

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

Sometimes, the most interesting and insightful scenarios are those that initially appear to be the least probable. Scenarios have varying lifespans, intended to be discarded after the exercise is finished or to be kept and reused over a period of years.⁸⁴ Therefore, it is important to acknowledge that scenarios are dynamic. The possibility and character of a scenario will change over time as controlling factors evolve, as will its impact on the insurance industry – including practices, product offerings, and exposures – and wider society – including social, economic, and environmental characteristics – and so it should be updated periodically to maintain relevance and continued utility.

84. (Roxburgh 2009)

4.3 Considerations and Constraints

When discussing scenarios, there is potential to overemphasise their mechanics and impact without providing a balanced critique. This section of the report is dedicated to highlighting the limitations of scenarios and raising awareness of appropriate precautions that should be considered.

Constraints of Probability

Probability is the likelihood of an event occurring and has guided extensive decision making in the insurance industry. The application of probabilities to scenarios has also been a point of contention, however, as there are concerns that it may introduce false confidence and awareness to areas of high uncertainty. To appreciate these concerns, it is helpful to explore probability as a concept. Probability is usually understood via a frequency calculation: the number of ways of achieving a specific outcome, divided by the total number of possible outcomes. Underpinning probability theory, the Kolmogorov axioms state that you must know the event space, or all potential outcomes, in order to define the likelihood of one specific outcome. This perspective implies that probability requires the subject exist within a closed system, where all potential future events can be identified at present and can be accounted for when considering likelihood.⁸⁵ As this is not an option in practice, insurers often accept the ergodic axiom, which suggests that the future is going to reflect the past and present and use that to guide their prediction of the future.⁸⁶ This introduces a series of problems when considering emerging risks, or events with limited historical precedent, and fails to prepare users for events which have never been experienced before. In these environments, probabilities which are dependent on historical events may be misleading, or may imply an over-confidence that all potential outcomes have been explored and addressed.⁸⁷

Cognitive Bias

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

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

Common critiques of the use of probability when considering future risks are not aimed at eliminating the use of probabilities, but instead at addressing the uncertainty and assumptions that they bring.

A related and more theoretical concern is that these probabilistic scenarios remain deterministic in their assumptions. This is because the probabilities of future events are only identifying specific outcomes, which are determined by the modeller.⁸⁸ For example, when considering the possibility of a selected risk occurring in a specific location, one may reduce all outcomes to a short list of, say, four outcomes of different severities and likelihoods. While this may be helpful in simplifying the analysis of that risk, it may also lead to an incorrect sense of certainty that the future may only materialise as one of these four outcomes, and introduces a new risk of not accurately representing the uncertainty of the future.⁸⁹ Furthermore, one must recognise that probability applications do have a place but cannot always be applied. For some risks, the probability is essentially irrelevant, as the outcome is too crucial. Examples include extreme tail risks, or highly unique events which cannot be aggregated into a composite group.⁹⁰ In such situations, probabilities are less important than recognising who is responsible as the risk holder of last resort, and understanding their preparation and response to that risk given its potential impact and available resources.

‘heuristics’ and can be thought of as mental shortcuts or our ‘intuition’.

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

As a first example of a bias, we pick out overconfidence which describes the tendency to be overly optimistic in ignorance of contrary evidence, often in the context of setting a goal. Nobel laureate Daniel Kahneman identifies overconfidence as “the most significant of the cognitive biases”.⁹¹

Below we discuss two common biases influencing scenario development.

Availability Bias

Decisions on probability and judgements are based on the ease with which relevant instances come to mind⁹².

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

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

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

Communication Failures and Misinterpretations of Outcomes

Scenario modelling outcomes are most effective when there is a governance structure in place that promotes clear lines of communication to external and internal stakeholders. Effective communication enhances risk management by providing information that may be used to enhance processes, identify emerging issues, and aid in overall decision making.⁹⁴ If scenario analysis is not communicated sufficiently, the outputs of the scenario could be ignored or the misinterpreted which then negatively impacts business performance.⁹⁵

One of the most common misinterpretations which was reported via this report's consultation process was the interpretation of results as predictions rather than as *possible* futures. Scenarios in an insurance context are not developed to assist insurers in preparing for a specific incident, as it is highly improbable that the specific outcome will occur. Instead, they must be interpreted as thought exercises. By ensuring that the communication

Anchoring Bias

Final estimates or judgements are often reached by adjusting away from an initial "anchor" value, but these adjustments are often insufficient.⁹³

Anchoring bias occurs when we focus decision making on an initial piece of information. An initial value is used as a reference when evaluating and comparing additional information. The outcome may be skewed or influenced by the initial, possibly arbitrary, anchor. An example of this may be seen when estimating catastrophic losses. We often base our estimated losses on a historical precedent and are unprepared when a substantial variation occurs, such as was seen in Hurricane Andrew or the World Trade Centre terrorism attack. Stress test scenarios are routinely used to introduce higher anchoring values, which insurers can plan against. Accordingly, stress test scenarios should be gauged to stress the system and introduce new precedents for insurers to plan against.

efforts reflect this differentiation, scenarios can be effectively used for their intended purpose.

When to Avoid Scenarios

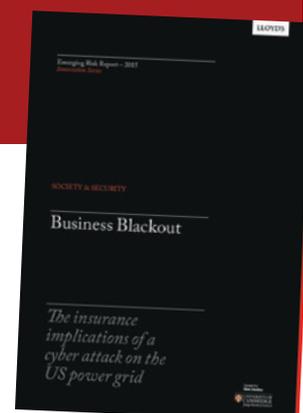
In certain cases, uncertainty surrounding a risk may be so great that a scenario to explore it cannot provide any reliable insights. Scenarios may be harmful in generating a groupthink of their own, whereby they inform the belief that only a defined set of outcomes are possible. Practitioners should be wary of thinking that they have all reasonable scenarios when there are quite different possibilities that remain unknown.⁹⁶

92. (Tversky and Kahneman 1974) 93. (Tversky and Kahneman 1974)
94. (North American CRO Council 2013) 95. (Roxburgh 2009) 96. (Roxburgh 2009)



5. Scenario Development Case Study: Business Blackout

This section presents an example of a scenario's development process, using the method proposed in Section 4 of this report. The example scenario is based upon the 2015 Lloyd's Business Blackout scenario⁹⁷, developed to address emerging cyber risk within the insurance industry. The case study illustrates a practical example of each of the eight scenario development steps.



Step 1: Scope the Risk

The purpose of the *Business Blackout* scenario was to develop a scenario that would explore the potential for losses to occur in many different lines of insurance as a result of a cyber attack against the US power grid. Of concern was the potential for insured parties to experience losses that are indirectly covered within insurance policy terms and conditions, or are ambiguous, not explicitly excluded in policy wordings, known as 'silent' cyber coverage. The scenario sought to identify how much silent cyber coverage might be triggered under certain conditions and to explore whether there might be a need to take more proactive actions to identify and clarify this coverage. In this case, the risk – a cyber attack – was clearly defined and explicitly motivated the exercise, with the objective to explore the uncertainty around the impact of a severe event. A specialist working group of researchers and insurance specialists drew up a long list of potential candidate scenarios and prioritised a scenario where there was a cyber attack that would cause a widespread power outage in the electrical grid in the United States.

To assist with the scenario planning, the development team developed a problem statement. What are the potential insurance impacts of an extreme power loss caused by a cyber attack on the US electrical power grid?



Step 2: Conduct Background Research

Several different topics were researched to better understand the risk landscape. Dominant questions for discussion included:

- What insurance policies might pay out in the event of a lengthy power outage, and how would it be different if the proximate cause were to be a malicious cyber attack?
- How much of a threat does cyber pose to critical national infrastructure, and what evidence is there for cyber hackers targeting the energy sector?
 - Is it possible for a cyber attack to cause a power outage, and how severe could it potentially be?
 - What sort of vulnerabilities could be exploited, and what are the implications for the geographical extent and duration of outages that would occur?
- How often and extensive have outages been to the US electrical grid from non-cyber causes?
 - How did it occur and what was the impact?
 - Have there been “near misses”⁹⁸ from cyber attacks which have occurred before?
- Where are the system vulnerabilities within an electrical grid?
 - How does the electricity grid work, what is its structure and generating capacity?
 - What cyber security measures are in place to protect the generators, transmission systems, and distribution networks for electricity grids?
 - What are future developments for the electricity grid (i.e. Smart Grids)
- What are the planned responses to an electrical grid outage?
 - Are components of the response susceptible to errors?

⁹⁷. (Cambridge Centre for Risk Studies 2015)

⁹⁸. Near misses refers to an event which had the potential for harm but did not materialise.

- What type of cyber insurance (both silent and affirmative) would be impacted by a cyber physical scenario?
 - How big would this be?

When approaching these questions, the team consulted various experts who were familiar with the topic. These experts were found through research networks, recommendations, and introductions, and included members from the insurance industry, the government,



Step 3: Frame the Scenario

In the initial stages of development, the development team participated in a thought exercise to decide what scenario methodology to use. The team discussed the framing questions and agreed in the scenario's direction. These framing questions entailed:

- 1 What is the scenario for?**
The scenario is being developed to understand an emerging risk, cyber, which remains a novel and uncertain threat for which there is only a short history of historical precedents.
- 2 How can the scenario benefit stakeholders?**
The scenario is intending to address uncertainty and expand the insurance industry's understanding of cyber risk and insurance exposures.
- 3 On what timescale does the risk materialise?**
The scenario is intended to be a sudden-onset, shock risk scenario.
- 4 What is the scenario outcome?**
The scenario intends to ask 'what if', and is primarily an exploratory scenario, imagining a future event for which there is no close precedent.
- 5 Who owns and contributes to the scenario process?**
The scenario is intended to be an expert-driven, top-down exercise, and delivered via a report, hosted in the public domain, for repeated use by insurance practitioners.
- 6 Is the scenario required to define the likelihood of an outcome?**
The scenario involves a high degree of uncertainty and is speculative in nature and is therefore deterministic. It includes three scenario variants of varying severity and probability, expressed as annual probabilities (for example, 1 in 50 years).

the energy industry, and the cyber security community. Each expert brought unique insight to the scenario, and were aware of different vulnerabilities, histories, and responses. In addition to the subject matter experts, a wide number of resources were also utilised, including government records, media, and reference databases.

Research and background consultation was not restricted to this period of the exercise, but continued throughout the scenario's development.



Step 4: Develop Candidate Scenarios

During the research process, the development team compiled potential candidate scenarios for processes that might trigger an electrical grid failure. These candidate scenarios were based on discussions, near misses, historical events, and key system vulnerabilities, and initially these were very loosely defined. Several emerged from the list of possible scenarios as viable options. These received further investigation to consider their plausibility and were then reviewed by panels of cyber security experts to assess their credibility. This led to the development of three candidate scenarios.

- 1** Hackers manipulate electricity generators' control networks, causing the generators to malfunction. The generators become damaged, and lead to a power outage.
- 2** Hackers interfere with the energy market and falsify a series of purchases. This leads to an oversupply combined with a decrease in demand in the market, triggering bankruptcy and market failure.
- 3** Specific brands of phasor measurement units are manipulated with known software vulnerabilities, causing randomised damage across generators. The response to these attacks, including investigating their cause and replacing the generators, lasts for years.

The three scenarios were reviewed at a workshop attended by external stakeholders and subject matter experts and received feedback and recommendations on each scenarios' feasibility, severity, and interest. Internally, the development team considered which scenario best answered the question proposed and was best positioned to address the uncertainty of a physical cyber attack. Scenario 1 was considered the best suited scenario and was further defined during the workshop.

- 1** A Malware infects generator control rooms and allows hackers to disable safety systems which would usually protect the generators from desynchronisation events. Generators are manipulated to overheat and catch fire.



Step 5: Develop Narrative

Upon deciding the basis for the event, the surrounding narrative and details began to develop. The development team conducted further research to identify the location for such an event to occur and cause maximum impact, and how long the crisis might last before emergency provisions became available. A list of potential impacts was also developed, largely based upon smaller scale precedents. A narrative was created for the scenario to provide the structure for the loss modelling and to communicate the outcomes.

The following is a summary of the scenario's narrative: "A piece of malware (the 'Erebos' trojan) infects electricity generation control rooms in parts of the North-eastern United States. The malware goes undetected until it is triggered on a particular day when it releases its payload which tries to take control of generators with specific vulnerabilities. In this scenario it finds 50 generators that it can control, and forces them to overload and burn out, in some cases causing additional fires and explosions. This temporarily destabilises the North-eastern United States regional grid and causes some sustained outages. While power is restored to some areas within 24 hours, other parts of the region remain without electricity for a number of weeks. Economic impacts include direct damage to assets and infrastructure, decline in sales revenue to electricity supply companies, loss of sales revenue to business and disruption to the supply chain".⁹⁹

To compliment the narrative and assist in the modelling process, a series of coverage trigger pathways were also proposed. These statements aided in determining what the asset was, and what line of business was being triggered by the impact.

For example, when discussing damage to generators, the coverage trigger pathway stated:

- 1 Commercial generators are damaged by the electrical fire, and are non-repairable due to the extent of damage.



Step 6: Assess Impacts and Materiality

With the narrative in place, the next step was calculating the event consequences. Within this scenario, the development team decided to calculate ground up loss. A portfolio loss guide was also written for how insurers could use the scenario to estimate the exposure of, and associated losses to, their own portfolios. Losses were calculated individually for each asset type.

An example of the loss calculation processes used for perishables is described below.

- 1 **Determine where the impacts will occur:** The power outages occur in 15 North Eastern U.S. states, in regions dependent on compromised generators.
- 2 **Identify what assets will be impacted by the event:** Perishables, which require refrigeration, are routinely found in culinary, hospitality, grocery, and medical properties. Marine cargo and chemical facilities also routinely store perishable products.
- 3 **Identify the incident rate:** Of all potential properties, assume a fraction do not carry any perishables. Assume an additional fraction have an emergency generator or alternative power source. Of the remaining properties, we assume that they do not all have the same length of outage, with some lasting days, while others' weeks. A severity gradient was applied to account for this variation of damage.
- 4 **Identify existing insurance coverages available to asset:** The insurance class for the perishable assets depend on the sector from which they arise, either marine insurance or commercial property insurance. The coverage is assumed to be property damage in both cases.
- 5 **Calculate the loss based on asset value:** The loss values were calculated based upon the number of damaged perishables, the ratio of damage, and the value of the perishable. The sum of these values (\$21.4bn) generated a first order estimate of the loss.

During the loss calculation process, interviews were conducted on an ongoing basis. This assisted in developing parameters upon which to base estimates.



Step 7: Communicate and Act

Once losses were calculated, the complete scenario and results, were reviewed by the initial consultation group. This aided in fact checking the proposed events and outcomes and adding additional recommendations that may initially have not been included. The industry loss estimation methods were reviewed with a number of insurers before the scenario was finalised. Examples of questions posed during the iterative process include:

- 1 Is the outage length plausible from a cyber attack?
- 2 Are there any missing logical steps in the narrative?
- 3 Are the losses in the range which you would expect?
- 4 Are parameters used in the modelling consistent with your experience with losses in the area?

Through the publication of the report, the findings were communicated to community stakeholders. A public launch was held to mark the release of the report and disseminate it to a wider audience.



Step 8: Evaluate and Update

The scenario has been widely applied within the insurance industry by a variety of practitioners and was adapted for further use in cyber models. The scenario remains accessible and relevant years after development, although users of this scenario have called for an update to maintain its validity in the changing cyber and insurance markets.

The physical property insurance market has grown and changed in terms of how it covers cyber risk. The scenario will be updated as part as a periodic review process, to ensure it remains useful.



6. Future Perspectives on Scenarios

Scenario development is a constantly developing field of research. Scenario methodologies and applications have advanced substantially in the past decades, with further changes and growth to come. Two of the greatest changes anticipated within the insurance modelling community are the increased availability of data, and the potential for customised modelling supported by machine learning.

Traditionally, insurance scenario modelling has been dependent on the availability of structured internal data, produced on a pre-determined frequency (monthly, annually, quarterly etc.),¹⁰⁰ and desktop research conducted by underwriters and staff. Alternatively, external catastrophe modelling approaches aim to understand potential future losses due to catastrophic, tail risk events, with synthetic loss events in the future. The 'Fourth Industrial Revolution' has spawned a new generation of data collection tools that presents an opportunity for the insurance industry's use. Advanced data mining techniques have generated a substantial increase in the availability and frequency of large and unstructured data sets that can be used for real-time scenario analytics. Much of the data is third-party mined from digital platforms such as social media and is therefore used mainly as a rich source of data for insights into consumer behaviour.¹⁰¹

With an estimated 2.5 quintillion bytes of data being created daily, the insurance industry is increasingly using big data and machine learning techniques to analyse large and unstructured data sets which may aid the scenario development process.¹⁰² Open-sourced data management tools such as Apache and Hadoop are increasingly being used by insurers to disseminate structured and unstructured data sets in

short time horizons. This has aided in the development of real-time analytics in the insurance industry.¹⁰³ Real-time behavioural data opens new opportunities in understanding behavioural risks that have been previously difficult to forecast.

Consumer specific data also heralds the possibility for personalised scenario modelling, based on real-time monitoring and visualisation of consumer behaviour. Examples of customised data collection have been increasingly seen in auto and health insurances, which have been introducing personal monitoring devices to provide more accurate premiums to consumers.¹⁰⁴

The insurance industry is lagging behind many other sectors in investment into AI and machine learning, with only 1.33% of insurance companies investing in AI in 2017 compared with 32% of internet and software companies.¹⁰⁵ However, a survey by Deloitte in 2017 estimated that 95% of insurance executives intend to start or continue to invest in AI capabilities. Indeed, investment in AI in the insurance industry increased by 68% between 2011 and 2014.¹⁰⁶ As investment in machine learning and AI tools continues to grow, scenario development will increasingly involve these tools to create more complex and comprehensive scenarios.



¹⁰⁰. (Clarke and Libarikian 2014) ¹⁰¹. (Clarke and Libarikian 2014; Allen 2018)
¹⁰². (Schroek and Shockely 2012) ¹⁰³. (Schroek and Shockely 2012)
¹⁰⁴. (Insurance Business UK 2018) ¹⁰⁵. (Deloitte Digital 2017) ¹⁰⁶. (Deloitte Digital 2017)

7. Glossary

Accumulation: The combined total risks triggered by a single hazard event.

Backcasting: A scenario technique which identifies a future state and then works backwards to determine possible paths to this future from the present state.

Baseline Scenario: An assumed future with no explicit deviations, used to compare possible futures against.

Cascading Events: An event which triggers an event of another type, to cause a more extreme event.

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

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

Deep Uncertainty: Exists when various parties to a decision do not know, or cannot agree on, how a complex system works, the probability of possible future states, and how important the various consequences of interest are.¹⁰⁷

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

Due Diligence: Care which is taken to avoid harm or damage to other persons or property.

Emerging Risk: An emerging risk is a new risk, changing risk, or novel combination of risks for which the broad impacts, costs and optimal management strategies are not yet well understood.

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

Hazard: A natural or anthropogenic process or phenomenon that may result in negative social, economic, or environmental consequences. A hazard event is the manifestation of a hazard in a particular time and place.¹⁰⁸

Insurance: A contract where an entity agrees to pay an agreed amount in the case of a specific event occurring. Insurance is a form of risk transfer.

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

Prediction: A subjective (probabilistic) statement that something will happen in the future.¹⁰⁹

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

Projection: A probabilistic statement that something will happen under certain conditions, allowing for significant changes in the boundary conditions that might influence a prediction.¹¹⁰

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

Risk: A hazard event with the potential to cause economic and/or societal losses, determined probabilistically as a function of hazard, exposure and vulnerability.

Scenario: Plausible descriptions of how the future might develop, based on a coherent and internally consistent set of assumptions about key deterministic relationships and driving forces.¹¹¹

Shock Risk: Extreme, sudden-onset hazard events that emerge quickly or unexpectedly.

Stress Test: A scenario designed to assess the idiosyncratic vulnerabilities of an organisation to a hazard event.

Tail Risk: Rare events that occur more than three standard deviations from the expected, most probable outcome. The term can be used more generally to describe highly unlikely extreme outcomes.

Trend Risk: Slow-onset hazard phenomena that emerge gradually over time.

Uncertainty: A potential outcome with an unknown probability, which is therefore uncontrollable.

Vulnerability: “The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards”.¹¹²



8. References

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