LLOYD'S

Emerging Risk Report – 2015
Innovation Series

UNDERSTANDING RISK

Emerging Liability Risks

Designing liability scenarios

ARIUM
RISK ARCHITECTURE

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Executive summary

Liability exposure management poses complex challenges for insurers.

Liabilities often stem from a complex interaction of legal and socio-economic factors which can make this kind of problem hard to represent and the exposures hard to capture in a form that lends itself to systematic study.

Lloyd's is investigating different methods that aim to reduce uncertainty in this area, and this report presents an approach developed by Arium which harnesses the power of supply chains to understand and quantify liability events.

Arium has developed a conceptual framework and set of software tools to assess exposure to liability catastrophes across many lines of business.

The platform uses publicly available trade data to help define the spread of potential liability for a harmful product or service through industries with potential exposure, resulting in a map of the event footprint. Information about the harm caused is combined with policy information to filter and refine this map, which is then used to calculate an aggregate loss for the scenario. To calculate insured losses, the scenario may be split into sub-scenarios, and parameterised to calculate a per policy loss. The report provides a more detailed description of this framework.

Mapping supply and distribution chains illustrates the fact that liability can arise in industries beyond that from which a potentially harmful product or service originates.

Mapping supply chains can also help insurers review their entire portfolio, both to look for areas of risk accumulation – where they may want to run scenarios – and to identify areas of opportunity, where little insurance is currently written and there is limited connection with insured risks.

The scenarios and harmful effects described in this report may not arise.

It is important for insurers to consider harmful events that are unlikely to occur. The aim of this report is to investigate the potential impact of some unlikely scenarios, not to predict that events will occur.

Scenarios can be developed using data from a diverse range of sources both within and outside an organisation.

While this collaborative approach is resource-intensive, it can enable more thorough design and stress testing of scenarios, and can provide an opportunity for all parties involved to build upon their existing knowledge relating to particular liability risks. Once the outline of a scenario is created, it can be modified or extended as new information comes to light.

For liability scenarios and the resulting loss estimates to provide meaningful insights for insurance practitioners, portfolio data is best captured in a format that is optimised for analysis.

The portfolio data requirements for liability risk have some similarities to those required for property, the appropriate information used to identify possible risk accumulations shifts from geographical units to supply and distribution chains. To run scenarios and accumulations, basic corporate information needs to be appended to policy data for each client. Although this process introduces new potential sources of error, it is likely to result in a more accurate, consistent and comprehensive dataset than most insurers currently possess.

This report sets out case studies of both a financial and a non-financial liability scenario, developed using the framework.

The scenarios were developed through the collaborative input of Lloyd's market participants and external experts, and are intended to provide an illustrative guide for constructing the types of liability scenarios that insurers could benefit from considering as part of their exposure management and underwriting strategies.

Event-based stochastic modelling allows a broader investigation of the impacts of a given thematic risk.

This report touches upon the potential to develop a stochastic modelling capability for liability exposures, and proposes mechanisms by which this could be achieved.

Introduction

Despite continuous progress in modelling capabilities for property exposure to natural catastrophes, liability exposure management and scenarios for liability losses have remained opaque and difficult to conceptualise, let alone model. This is because liabilities often stem from a complex and dynamic interaction of legal and socio-economic factors which can make this kind of problem hard to represent and the exposures hard to capture in a form that lends itself to systematic study.

Lloyd's is investigating different methods that aim to reduce uncertainty in this area, and this report presents an approach developed by Arium which seeks to harness the power of supply chains to understand and quantify liability events. The methodology for formulating and validating scenarios detailed in this report is based on the development of liability scenarios with liability underwriters and external experts as part of a Lloyd's pilot project run between March and September 2015.

The aim of this paper is to provide practical guidelines for the construction of liability scenarios. The paper starts by introducing the concepts of liability scenarios for insurance purposes and contrasting them with the familiar framework used for property catastrophe. It then moves on to provide a step by step outline of the approach used by Arium for liability scenario design. Two case studies are presented to provide worked examples of the approach, corresponding to a financial scenario based on Ponzi schemes and a non-financial scenario based on e-cigarettes. Finally, possible avenues for stochastic modelling of liability risks are discussed.

This report, written by Arium, presents one approach to the challenge of understanding emerging liability risks; Lloyd's hopes that it will inspire further contributions to drive innovation in the insurance industry.

Scenarios

The word scenario is derived from the Latin *scena*, meaning an imagined situation. Scenarios are used in insurance to estimate the exposure of an insurance portfolio to different occurrences; the outcomes are used to inform exposure management and underwriting strategies. The essential underlying component of a scenario is the narrative description, which should articulate a situation that is representative of the nature and scale of future losses. It is important to note that a scenario is not a prediction; rather it should capture a class of event to which insurers wish to investigate their potential exposure.

Why are scenarios important for liability accumulations?

Scenarios can be used by insurers with exposure to liability risks in a number of ways:

- To provide a practical approach for stress testing a portfolio's exposure to liability catastrophes.
- To support risk management by identifying possible accumulations and opportunities.
- To support underwriting activities by highlighting where policy terms and exclusions might be useful.
- To help with capital adequacy assessment and reserving estimates.
- To demonstrate an audit trail on scenarios for regulatory purposes.
- To provide a framework for understanding the nature and potential impact of events on a portfolio.
- Structured scenario analysis helps capture how knowledge about a particular emerging risk is evolving over time, and can highlight questions for research.
- Historical scenarios provide a way to benchmark underwriting scenarios as the portfolio evolves.

What distinguishes liability catastrophes from natural catastrophes?

There are several important differences between liability and natural catastrophes that have impeded the development of liability scenarios:

Long-tail liabilities
Liability exposures may surface a long time after a harmful event. Once they have surfaced, the actual bottom line may take years or even decades to be determined.

Loss reserving
Post-event casualty losses may not immediately be known and may evolve, whereas post-event property losses are typically quickly reserved.

Source of liabilities
While earthquakes and storms can be understood as manifestations of physical laws of the earth or its atmosphere, liability scenarios can arise from complex interactions among the socio-economic, environmental, health and legal environments. These can be harder to capture in terms of mathematical equations.

Lack of well-defined geographical boundaries
Liability exposures do not necessarily take place within well-defined geographical boundaries. In abstract terms, this means it can be harder to define a measure of closeness for two exposures. It also means that geographical diversification may be less relevant for liability than for property exposures.

Non-repeating events
Large liability events are normally non-repeating – a particular product or service is unlikely to trigger similar losses again as legal and economic environment changes will often be made in response to a loss, although there may be future losses of a similar type. For property exposures, only the nature and placement of properties is likely to change significantly over a short timeframe, not the perils themselves.

Changing environment
Natural catastrophe exposures typically move in multi-decadal cycles or trends, whereas liability exposures typically undergo frequent and rapid step changes due to factors such as new legislation and economic events. These step changes only sometimes come to bear in natural catastrophes.

Hidden liabilities
Liability policies benefitting conglomerates often include coverage for all subsidiaries, and there is a risk of accumulation if insured limits apply to each subsidiary within a group. Multi-location policies in property insurance can pose a similar risk, but information on the location of all insured properties is often easier to access than detailed information on insured entities' corporate structures.

Shifting losses
Liabilities of the parties who are primarily culpable within a liability chain can be shifted to and borne by other parties in the chain who could be considered less at fault. Even where joint and several liability is not imposed, where for example a pharmacy responsible for introducing fungal meningitis into inoculations quickly goes bankrupt, other parties such as doctors and

hospitals who purchase and administer the inoculations could end up bearing much of the loss under their malpractice policies. This can also happen with goods imported from outside a given jurisdiction, where the injured party can look to those importing or selling the goods for redress rather than having to pursue the culpable party in another jurisdiction.

Additional costs
Defence costs and possible damages for non-economic losses, such as pain and suffering, can create a liability exposure even if there is no adverse judgment or demonstrable economic loss.

Multiplicity of coverage
Liability insurance encompasses a number of different types of cover, including product liability, public liability, professional indemnity and directors' and officers' (D&O) liability. Each underwriter may have a sense of the potential accumulations within their own line, but larger accumulations may cross several different lines of business.

Designing scenarios

Using supply and distribution chains in liability exposure management

One of the key challenges in liability exposure management relates to the nature of the portfolio data collected and retained. Simply coding a portfolio in a granular and systematic way can help to identify potential accumulations within a single industry.

Taking a meat contamination scenario as an example[1], table 1 presents a breakdown of a hypothetical portfolio at a basic level, showing aggregation of exposures by industry.

Table 1:

Industry	Exposure
Accommodation and Food Services	$686m
Health Care and Social Assistance	$676m
Beverage and Tobacco Product Manufacturing	$514m
Food Manufacturing	$323m
Wholesale Trade	$244m
Food and Beverage Stores	$196m
Chemical Manufacturing	$173m
Plastics and Rubber Products Manufacturing	$36m
Grand Total	$2,849m

When trying to compute a credible loss figure for a meat contamination scenario, the high-level classification in table 1 is probably going to be overly inclusive. Such broad industry categories as 'Food Manufacturing' are likely to contain an array of different activities, not all of which will deal in the product giving rise to this particular loss. This issue can be addressed by introducing more granular coding. Table 2 shows the same portfolio with granularity provided by North American Industry Classifcation System (NAICS) coding, ordered by total exposure within that industry.

Table 2:

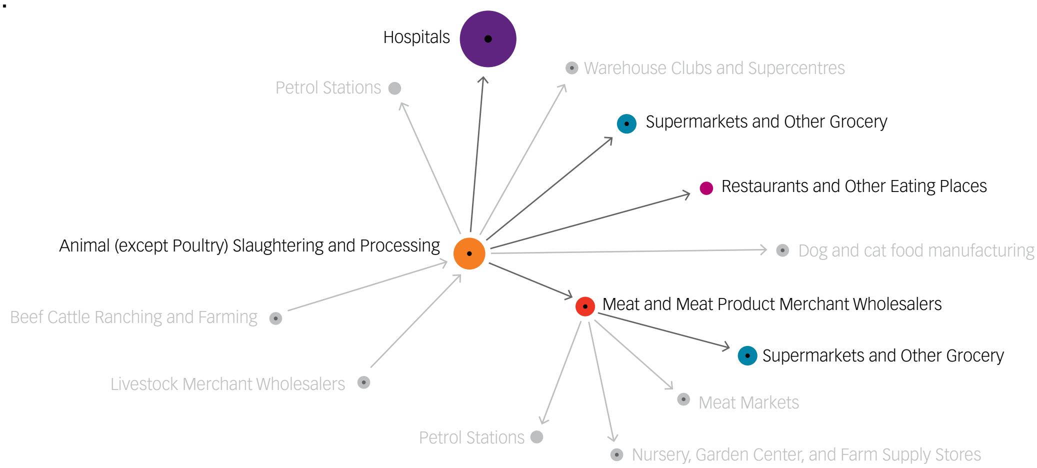
Industry	Exposure
General Medical and Surgical Hospitals	$651m
Food Services and Drinking Places	$486m
Tobacco Manufacturing	$386m
Supermarkets and Other Grocery (except Convenience) Stores	$184m
Plastics Material and Resin Manufacturing	$163m
General Line Grocery Merchant Wholesalers	$135m
Soft Drink Manufacturing	$108m
Drinking Places (Alcoholic Beverages)	$107m
Fluid Milk Manufacturing	$100m
Other Grocery and Related Products Merchant Wholesalers	$96m
Animal (except Poultry) Slaughtering	$79m
Mobile Food Services	$65m
All Other Miscellaneous Food Manufacturing	$54m
Other Snack Food Manufacturing	$38m
Perishable Prepared Food Manufacturing	$30m
Plastics Packaging Film and Sheet (including Laminated) Manufacturing	$25m
Psychiatric and Substance Abuse Hospitals	$25m
Dry, Condensed and Evaporated Dairy Product Manufacturing	$23m
Beverage Manufacturing	$20m
Food Service Contractors	$15m
Meat and Meat Product Merchant Wholesalers	$13m
Caterers	$13m
Convenience Stores	$13m
Plastics Pipe and Pipe Fitting Manufacturing	$11m
Artificial and Synthetic Fibres and Filaments Manufacturing	$10m
Grand Total	$2,849m

In this example, 'Beverage Manufacturing' is unlikely to be part of a meat contamination scenario and can therefore be excluded from the analysis. By using richer data in this way, insurers can pinpoint aggregates with more precision.

Pivot tables can be particularly useful for reviewing the largest concentrations of exposure in a single industry. However, real life liability scenarios can cause claims in industries which may not be the source of the product or service causing harm. It is therefore important to understand not just the origin but also the spread of a product throughout the economy – both its supply chain and distribution chain. One of the most effective ways of understanding a product's supply and distribution chain can be to visualise these relationships in the form of a 'map'.

Figure 1 is a sample map of the economy for the meat contamination scenario, with node sizes reflecting the exposures given in table 2, and arrows reflecting the direction of supply. Nodes without exposed policies are greyed out.

Figure 1:

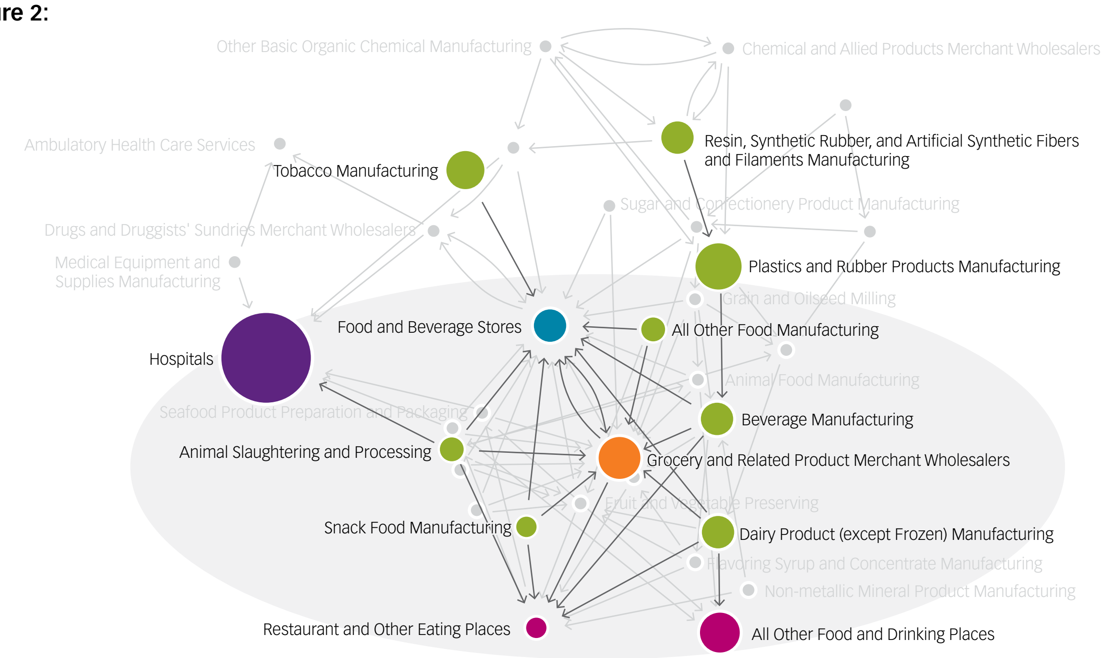


Once more, this view changes the assessment of the aggregate from a scenario. Mapping supply and distribution chains illustrates the fact that liability can arise in industries beyond that from which a harmful product or service originates. By capturing this component of liability risk, the approach can yield a potentially more accurate assessment of the total aggregate from a scenario.

Mapping supply chains can also help insurers review their entire portfolio, both to look for areas of accumulation where they may want to run scenarios – areas of highly interconnected insured risks – and for areas of opportunity, where little insurance is currently written and there is limited connection with insured risks.

As previously discussed, it is arguably easier to understand which risks could be caught in the same scenario for property catastrophe than for liability, as such exposures will normally be located in close proximity to one another. This understanding is not so readily available with a liability portfolio because clusters of liability risk are not primarily geographically related, and because the risk may end up being borne by different parties than those that caused it. However, overlaying a liability portfolio on a map showing links between all industries in an economy can flag these clusters, as shown in figure 2 below. This is the approach used in the framework presented here.

Figure 2:



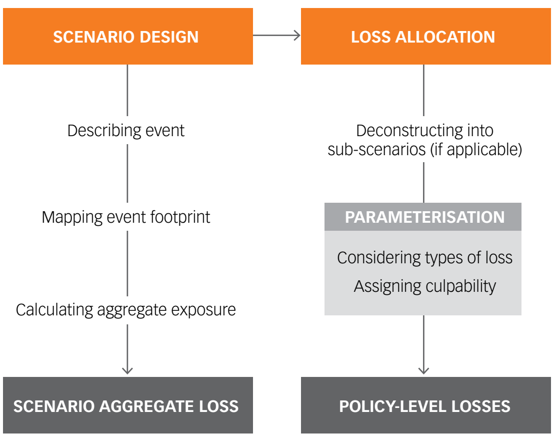
Developing liability scenarios

Box 1
An **event** or **scenario** is an occurrence of harmful action(s) that can impact one or more affected parties and encompass one or more mechanisms-to-harm.
A **mechanism-to-harm** is a specific mechanism that triggers an adverse outcome to a consumer of a product or service. Where a scenario may manifest with multiple different mechanisms-to-harm or different parties, losses, jurisdictions or other parameters, it can be deconstructed into **sub-scenarios** corresponding to these different mechanisms. Each constituent sub-scenario within a scenario – or the scenario as a whole, where it cannot or need not be deconstructed – can be parameterised according to severity into different scenario losses.

The approach to developing liability scenarios presented in this report uses background data to help define the spread of a product or service through industries with potential exposure, resulting in a map of the event footprint. Information about the mechanism and magnitude of harm is used to filter the map, and portfolio information is used to constrain the map to only capture eligible policies where a loss may be possible. This is then used to calculate an aggregate loss for the scenario. To compute insured losses, the scenario is deconstructed into sub-scenarios if applicable, and parameterised to calculate a per policy loss.

This process is summarised graphically in figure 3.

Figure 3:



The following pages provide a more detailed description of this process.

Step 1: Describing the event

What defines an event is that it has a narrative. Events can share a common narrative even where the losses are not all the same, or where the industries affected are different.

For example, with a surgical implant scenario, one narrative may be that medical professionals surgically implant foreign objects into patients, and the implant causes harm to a number of these patients. This kind of risk can be made systemic by the fact that harm does not solely arise from the negligent act of any single professional, but from some (perceived) flaw or limitation in the component or procedure. Creating a narrative in this way can help to clarify who may be implicated in such liability cases and can limit the relevant distribution chain. This kind of narrative is implicit in a property catastrophe model, as the nature of the peril and how the harm is caused is that much more apparent for natural hazards.

The more specific the scenario, the more it is possible the portfolio can be filtered so that just those policies potentially impacted by that scenario are included within the analysis. So arguably it follows that the greater the specificity in both the scenario definition and in the policy parameters of the portfolio, the smaller the potential aggregate and loss.

Elements of description
Before starting to model and parameterise scenarios, it can be useful to write a brief description of the event. This description could include:

- **Narrative:** a qualitative description of the event.
- **Scope of the event:** for example, for a surgical implant scenario, the event could be concerned with all implants, just invasive surgical implants, temporary or permanent implants, or a specific type of implant such as a pacemaker.
- **Who is causing the harm:** for example, for a breast implant scenario, harm could be caused by the breast implant manufacturer, the component supplier of silicon, or could originate from multiple sources.
- **What mechanism causes the harm (the 'mechanism-to-harm'):** for example, endocrine disruptors can cause harm if ingested, inhaled, implanted or otherwise absorbed by a person, but different harms or degrees of harm may result from these different mechanisms.

- **Who or what is harmed:** for example, for a financial mis-selling scenario, the harm could be to consumers only or to both consumers and small businesses.
- **Nature of harm:** the harm could result in injury or possibly death, financial loss, or property or environmental damage.
- **Circumstances of harm:** the circumstances under which a product or service could cause harm.
- **Spread of harm:** for example, with a pacemaker fault, the fault could be systemic, affecting all pacemakers, or a fault with a particular pacemaker batch, make or type.
- **Scope of harm:** the number of people, organisations, investors and jurisdictions that might be impacted by the harm.
- **Period of time over which the harm could occur:** for example, sudden meat contamination is more likely to impact people over a short timeframe, while harm caused by endocrine disruptors may be generated by gradual accumulation over a longer period.

Particularly for emerging risks where data and experience are often not available, much of this information may need to be elicited from conversations with one or more experts. Appendix outlines a series of example questions that may be valuable to consider when meeting with experts in the context of product liability in the UK.

Step 2: Building the event footprint

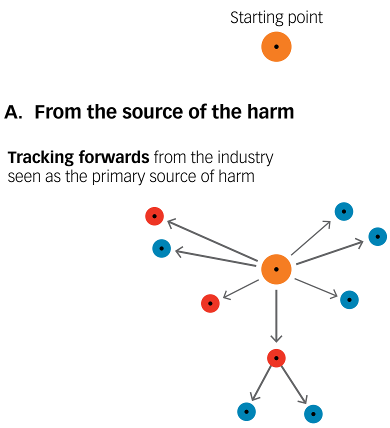
Box 2
In natural catastrophe modelling, the term **event footprint** is used to define the geographical distribution of peril intensity. In liability, the term refers to the mapping of the spread of products or services affected by a given event.

Following the supply and distribution chain for a product or service can highlight the potential chain of liability, and can help identify which industries may be implicated if a product or service is deemed faulty or to have caused damage. This approach tracks the various routes by which a product or service could reach or damage the claimant, bringing in the industries and companies along the route that might be caught up in the event. What the footprint does not do is provide a basis of liability; this is often captured during the parameterisation process.

From the starting point, the aim is to map the event by tracing the product or service back towards suppliers or forward towards customers. This method should capture the entire relevant product or service footprint, filtering out non-relevant industries, so all potentially liable players can be included.

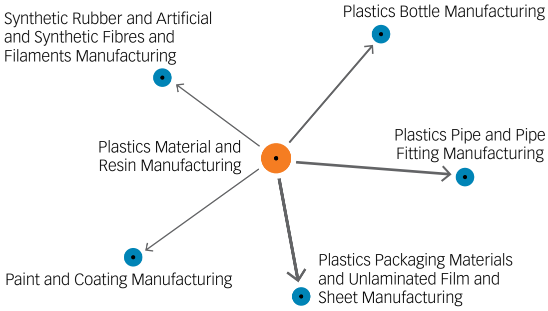
Starting point for the event footprint

The usual starting point for a scenario is the industry seen as the primary source of the harm, but an equally valid approach could be to start the review from the product causing the harm. In either case, the supply chain can be traced back to component suppliers or other advisers, or forward to a finished product and distributors.



Consider the example of harm caused by bisphenol A (BPA)[2,3], an endocrine disruptor. Starting with the source of the harm – which for this example would arguably be the manufacturer of plastic material and resin – and working towards the other end of the supply and distribution chain can help to map the many different products or services that might embody the harm. This can help to map the potential harm from endocrine disruptors, such as through plastic bottles, linings of tin cans, or in plastic water pipes. These different products may have different mechanisms and magnitudes of harm, for example, from inhaling or ingesting. Once mapped, each individual mechanism and its supply and distribution chain can often be separately parameterised.

Figure 4:



A review of the products produced in this industry may also reflect on the scope of the scenario. For example, the industry producing BPA may also produce other endocrine disruptors such as phthalates, which can have similar mechanisms-to-harm. The designer, with input from an expert, may want to consider whether the scope of a scenario is best set for BPA alone or a broader group of endocrine disruptors.

B. From the harmful product

Tracking backwards from the product causing the harm

Starting from the potentially harmful product – in the BPA example this could be soft drinks sold in plastic bottles – the event footprint can be mapped by working backwards through the supply chain to the manufacturers of the product and forwards through the distribution chain towards the customer.

Whatever the starting point, the end outcome of the scenario footprint stage should be a map or set of maps relating to a single trigger; in this example, damage to humans from exposure to certain endocrine disruptors. This set of maps can be used to form the foundation for the design of sub-scenarios that together could comprise a single event – a loss arising from this single trigger – which could include all and only those industries, companies and lines of business implicated in each sub-scenario.

Where to go from the chosen starting point

Track the distribution chain of the finished product through to end users

There is value in mapping the distribution chain because liability – whether it is contractual, breaching a duty of care or strict liability – may not just be attributable to the producers but also to the distributors of the product. It can be important to trace the product all the way to the point of contact with the end user who may be impacted. There may be many ways in which a product can be distributed, or many different products in which it can be incorporated; each branch may expose a different set of possible defendants.

Filtering the chain

Different products produced within the same industry may follow different distribution chains to reach the end user, and any distribution chain that is not relevant to the product considered in a scenario can be filtered out. For example, contact lenses which can be distributed through pharmacies may be produced in the same industry as surgically inserted lenses, which are arguably more likely to reach the end user via distribution to physicians or hospitals.

Track the supply chain back to component suppliers or advisers

The beginning of the supply chain may be either service providers or the producers or suppliers of components or materials. It is usually possible to track subcomponents back to the natural resources or tools used to create them; how far up the chain to go is a matter of judgement. It is also usually possible to track back to service providers. As a general rule, professional

Figure 5:

service providers are responsible for their skill and professional judgement, including the tools they choose to use, so liability may not extend back to the suppliers of, for example, reference material used by law firms or accountants.

Filtering the chain
Suppliers may not be relevant unless they produce a subcomponent that may contribute to the loss if faulty or inappropriate. Those providing services may also be relevant on a similar basis. For example, for a breast implant scenario, both the suppliers that produce the silicon used in the implants and those advising on the grade of silicon to use may be included.

Further filtering of the event footprint

Relevant lines of business
Once the event footprint has been mapped out, the relevant lines of business may be established. These should be considered on an industry by industry basis.

Setting other relevant parameters
Other policy parameters such as location, jurisdiction, policy terms and insured size can be considered. For example, in a financial mis-selling scenario, the legal and accountancy firms advising banks may be more likely to be larger firms with a national or international presence than small local firms. Smaller firms in those professions can then be excluded.

Limitations of supply and distribution chains

However useful, there are limitations that should be noted when using supply and distribution chains as the basis of aggregate calculations:

- A supply chain covers the components and services that form part of a product or service; the distribution chain delivers that final product to the end user. Many supply chains do not specify a distribution chain between the final producer and the end user.

- Many supply chains are based on industry, not product, and much of the data available about an insured entity is also based on industry rather than product. As a result, supply and distribution chains may be overly inclusive and include products or services that may not be relevant to a particular scenario.

- Industry supply chains often do not map company to company relationships, so it can be very difficult to identify which particular companies are trading with others. However, mapping all the fast-changing private contractual relationships within an economy is challenging.

- A supply chain may not differentiate products and services used in an organisation's infrastructure from those incorporated into its products. For example, a restaurant may also purchase lights and electrical power as well as food; while these will show in the supply chain, they are arguably unlikely to impact on food contamination.

- Supply chain data may distinguish products for consumption from those used in fixed investment, and may not provide the same level of detail for both.

- The data underpinning many chains is based on revenue, which, depending on the value of the product or service, may not correlate with the number of products or services sold or their potential harmfulness.

- Mapping of global supply chains may sacrifice accuracy for breadth; conversely, single economy supply chains may have more accuracy and depth but less geographical breadth.

- An industry-based supply chain may be particularly useful for systemic or large liability events, but not for isolated cases taking place within a single industry.

- Supply and distribution chains may not effectively capture those potentially liable in cases where there is no economic relationship between the culpable parties. This may be the case in some environmental pollution events, for example.

Using expert input in the scenario building process can help to overcome some of these limitations. However, there remains inherent uncertainty in which companies may be implicated where a risk is not completely systemic as it might not involve all producers, suppliers or distributors in an industry.

Step 3: Calculating the aggregate

Once the footprint for the entire loss event has been mapped out and filtered according to the mechanism-to-harm and relevant lines of business, the scene is set to calculate an aggregate for the scenario. This is the sum of all exposures on the map, taking into account all filtering that has been applied. Particular policies or sets of policies may have exclusions or modifications that limit their coverage and can therefore be removed from the calculation where appropriate.

While relatively crude, aggregates can still be useful in a number of ways. Aggregates often play a role in discussions with regulators and ratings agencies – although not normally used to set capital, they can still be used to demonstrate that exposures to a certain type of scenario are limited. Aggregates can also help in assessing diversification: as with geographical maps in the property catastrophe sphere, mapping the economy can help to promote diversification of liability portfolios across different sectors and supply chains. This can be used to spot accumulation risk, as well as opportunities for directing further capacity.

Sources of information and expertise for scenario creation

Unlike natural catastrophe models, there is currently no accepted methodology to automatically generate a large number of scenarios for liability catastrophes. However, as with natural catastrophes, a comprehensive assessment of liability risk requires the consideration of a broad range of eventualities. This multiplicity of perils and coverages, combined with the uncertainties inherent in liability, points towards the need for a collaborative approach to scenario creation to effectively gather the required information and expertise.

Scenarios can be designed using data from a diverse range of sources and contributors, including:

- Various functions within (re)insurance organisations, including underwriting, claims, actuarial and exposure management functions.
- Independent experts or expert bodies.

While this collaborative approach to scenario development is necessarily resource-intensive, it can facilitate more thorough design and stress testing of scenarios. The other perceived advantage of this approach is that it can provide an opportunity for all parties involved to build upon their existing knowledge relating to particular liability risks, by enabling:

- **Sharing of expertise and data that may be distributed within an organisation:** it is useful to connect different functions within an organisation, together with external expert sources, to build up an effective exchange platform for ideas and scenario creation. At present, different departments and units may be creating liability scenarios in different ways. By working collectively to design a scenario, one can capture and then build on the combined knowledge, and a library of scenarios can be created and shared across an organisation.
- **Sharing of expertise and data from different organisations:** at the same time, the process should enable exchange of non-competitive data across organisations, or from expert to insurer.
- **Gathering of expertise over time:** expertise and data available can provide a snapshot of current risk, but it can also be useful to capture the additional knowledge and expertise that builds over time in scenarios. Simply having a tool to help reflect back assumptions in a consistent way can lead to improvements in understanding that can then be reflected back in the scenarios.

Other sources of information

In addition to experts both within and outside an organisation, there are other sources of internal or publicly available data that can be used to help inform scenario parameters. Each scenario can use and blend information from a range of sources.

Loss experience
For events of a type that have occurred in the past, loss history or experience can be used to help inform the scenario parameters. In a pacemaker example, it may be that the pacemaker manufacturer will bear most or all (under strict liability) of the responsibility for a faulty pacemaker. However, others such as those who selected and implanted the pacemaker or those monitoring the pacemaker may also be implicated if, for example, a faulty or defective pacemaker is knowingly implanted into a patient's body.[a, 4-7] Allocation of responsibility for a faulty pacemaker between the industries implicated in the scenario is required. This could be based on experience of individual losses and the extent to which the manufacturers versus various professionals have historically ended up bearing the loss.

Law
The apportioning of responsibility between parties may also be done on the basis of a legal assessment of liability. This is particularly useful for emerging risks where claims data is non-existent or limited, or where the event is unlikely to be similar to prior events.

Research
Research can tap into any relevant information that is available but exists outside of an organisation's expertise or loss experience, and may include crowdsourcing or the use of big data.

This framework for scenario design provides a systematic way of approaching liability risk, capturing both individual and collective knowledge. The process is arguably best done collectively, with underwriters, claims specialists and, particularly for emerging risks, one or more experts working in collaboration with one another. There is no expectation that a scenario will be perfect from the start, but instead will be directional and reflect the understanding and knowledge at the time at which it was developed. Once the outline of a scenario is created, it can readily be modified or extended as new information comes to light or with further comment from others.

[a] *Manufacturer liability for defective heart defibrillators has been considered in the preliminary ruling of a European court case[6].*

Deterministic loss allocation

Loss allocation is the way in which losses to companies and their insurance policies are calculated for deterministic liability scenarios. For a given scenario and total loss to the economy as a whole, available information can be used to estimate losses to individual companies in an underwriter's portfolio.

The most direct way of yielding a credible loss figure for a scenario is to assign losses to policies. The typical starting point for this process is to pick a set of individual policies according to the magnitude of the scenario. The advantage of this approach is that it is usually simple and able to accommodate every possible loss scenario. However, it is work-intensive, and may be hard to trace or scale within an organisation.

An alternative approach relies on an industry or product coding system being in place. This method takes a headline figure for the total loss to the entire economy due to a liability scenario as its starting point, after which a system of cascading shares of culpability can attribute losses to companies, and therefore to policies. This is the approach used within the framework.

The previous section provided a framework for defining the scope and potential spread of an economy-wide scenario. This helped to map the relevant industries and lines of business that may be caught in that scenario and apply all appropriate filtering to company- and policy-level data. The resulting event footprint is assumed to be the starting point here.

The key stages of the loss allocation process are:

- **Deconstructing the event into sub-scenarios:** Supply chains involving different products and distributions which have different mechanisms-to-harm can be deconstructed into sub-scenarios corresponding to these different mechanisms-to-harm, so each can be parameterised separately. However, not all scenarios will be composed of more than one sub-scenario: some scenarios feature only a single mechanism-to-harm, and can thus be parameterised as a whole.

- **Setting types of loss:** Loss categories are split into distinct packets: economic, non-economic and defence costs.

- **Assigning culpability to companies and policies:** A scenario-specific definition of 'culpability' for the jurisdiction is the expected first-order split of the losses by industry category across the distribution chain. This assigns the losses to industry categories based on the parties considered likely to be held liable in the specified scenario. Between companies, an allocation of culpability can be based on market share, but can be complicated where there is joint and several liability.

- Ground-up losses derived in this manner are then aggregated to the event level and insurance policy terms can be applied to **compute insured losses.**

The following pages will discuss this approach in more detail.

Step 1: Deconstructing the event into sub-scenarios

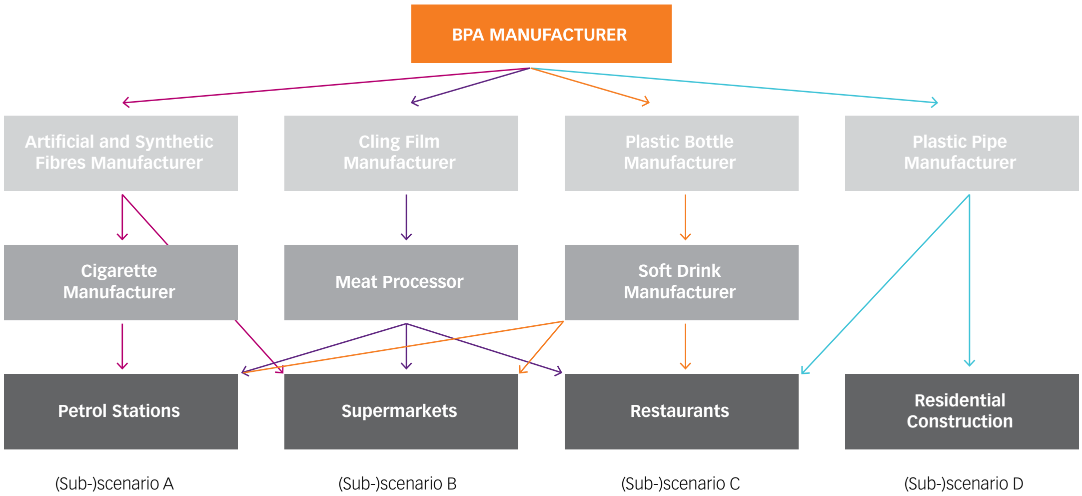
Parameterising scenarios can be made easier by first deconstructing the original event into constituent sub-scenarios, corresponding to different mechanisms-to-harm or where there are different parties, losses, jurisdictions or other parameters.

To illustrate the concept, consider the example of endocrine disruptors:

> The endocrine disruptor BPA may cause harm through a variety of different mechanisms, including ingestion or inhalation. These mechanisms-to-harm are usually connected to a specific supply and distribution chain that manufactures the product from component parts or chemicals, and then sells it down the distribution chain from the producer to the consumer. For example, for the ingestion mechanism-to-harm, a potentially hazardous plastic bottle could be expected to originate with a petrochemical company before being moulded into form and filled with a beverage, after which a wholesaler will deliver it to a supermarket from which it eventually transfers to the consumer.
>
> However, in this example there is also a second mechanism-to-harm, given by inhalation. End consumers may not normally be exposed to inhalation and so the end use of the endocrine disruptors is not relevant to this mechanism-to-harm – instead, the exposure is arguably more likely to relate to those working with the chemicals at production. There may not be a relevant supply chain but rather a duty of care owed by an employer to its employees to provide a safe work environment, with any breach of this duty triggering employers' liability. Thus, ingestion cannot be treated in quite the same way as inhalation.
>
> A possible solution can therefore be to parameterise events on a sub-scenario basis, rather than trying to parameterise the entire scenario at once. These sub-scenarios can then be aggregated to the event level, where policy terms can then be applied. For example, figure 6 shows some simplified sub-scenarios relating to a possible BPA event:[b, 8]

[b] *For non-exhaustive identification of materials containing BPA see Vandenberg et al. 2007[2], Wetherill et al. 2007[3], and Geens, Goeyens and Covaci 2011[8].*

Figure 6:



Step 2: Setting types of loss

A categorisation of losses is typically a function of policy conditions as well as distinctions made in the legal sphere. At the very basic level, there are three different kinds of losses:

1. **Economic losses:** these are losses due to financial damages stemming from a mechanism-to-harm. A typical example is loss of income due to the death of a family earner.

2. **Non-economic losses:** these are losses that are not directly measurable in financial terms. A typical example is compensation for pain and suffering or punitive damages.

3. **Defence costs:** these are the costs arising from defence of legal proceedings.

This split between economic and non-economic losses is made because these types of losses respond differently to certain legal doctrines and policy terms. Defence costs may or may not be included in the policy coverage.

Step 3: Assigning culpability to companies and policies

It is the judgement of the scenario designer as to how the courts are likely to distribute liability, and this can be founded on previous judgments or the current law. By making a statement that "in a case of product liability, with this kind of product, the manufacturer is usually *x*% culpable", it can be possible to allocate the headline loss to sectors in the supply chain.

Within each sector, three questions remain:

1. How many companies are implicated?

2. What is their respective share of the culpability?

3. Are these companies on the insurer's book?

In an isolated case a single company may bear 100% of the culpability, and the only question remaining will be whether they are on the insurer's book or not.

A more difficult question is how to assign culpability in cases where there are several implicated companies, some of which may be within the insurer's portfolio. A possible approach is to identify a metric that should theoretically be proportional to the actual share of culpability within a pre-selected group of companies. Like culpability, this metric should be proportional to the harm done. In a product liability case, one such metric could be turnover, being proportional to number of goods sold. Similarly, a metric that could be used for employer's liability is the headcount of a firm. In this way, market share can be used to transport losses from the industry level to the company level. An important caveat of this approach is that it requires the implicated companies to be as homogeneous as possible with respect to the mechanism-to-harm.

Use of market share within industries

The following paragraphs show a way to link the culpability attributable to an entity to its market share. This is illustrated using turnover, as it can be a more complicated metric to use, but a similar argument can also hold for employee count, payroll and other metrics.

To set the scene, consider a single company in a product liability situation. The basis for identification of some kind of turnover-based measure with culpability is given by two simple equations. First, the turnover of a company can be written as the number of products sold multiplied by the average price charged:

(Turnover) = (Number of products or services sold) x (Average price)

Second, the total economic loss equates to the number of harmful products distributed to consumers multiplied by the average restitution value:

(Economic loss) = (Number of harmful products) x (Average restitution value)

Assuming that 100% of products sold are actually harmful and the company only deals in a single product leads to the following equation:

(Economic loss) = (Loading factor) x (Turnover)

Where the loading factor is given by the ratio of average restitution value to average price (ideally purchaser's price):

$$\text{(Loading factor)} = \frac{\text{(Average restitution value)}}{\text{(Average price)}}$$

This relationship can be generalised to situations where two or more companies are implicated. The main assumption is that all companies involved are highly homogenous. In particular, the argument works best if the average restitution value and the average price are similar for all companies in the group, as this implies that the loading factor between the companies will be similar. If this is assumed to be the case, then the following equation can be derived:

$$\frac{\text{(Economic loss due to company)}}{\text{(Economic loss due to group)}} = \frac{\text{(Company turnover)}}{\text{(Group turnover)}}$$

In other words, because it is assumed that economic loss is proportional to turnover by the same loading factor for all companies, the economic loss attributable to a company expressed as a proportion of the total economic loss then equals the share of a company's turnover of the total turnover of the group.

Share of loss versus share of culpability

A challenging aspect of liability loss modelling stems from certain legal doctrines that essentially lead to a discrepancy between an individual or company's share of culpability and its share of the total loss. The most notable example of this is joint and several liability. Under this doctrine:

> "When two or more parties are jointly and severally liable for a tortious act, each party is independently liable for the full extent of the injuries stemming from the tortious act. Thus, if a plaintiff wins a money judgment against the parties collectively, the plaintiff may collect the full value of the judgment from any one of them. That party may then seek contribution from the other wrong-doers.
>
> Joint and several liability reduces plaintiffs' risk that one or more defendants are judgment-proof by shifting that risk onto the other defendants. Only if all defendants are judgment-proof will a plaintiff be unable to recover anything."[9]

To model this kind of behaviour when one or more defendant becomes 'judgment-proof', data on the capacity of a company to pay out claims, either under its insurance policy or from its own assets, is required.

This section has outlined a methodology for how to allocate losses in order to compute insured losses from scenarios. This is done through a combination of company-size data paired with parameters that can either be backed-out from publicly available information or provided by experts within or outside the organisation.

Loss scenarios are currently a key tool in assessing exposures to non-modelled risks, such as liability classes. Being able to handle deterministic loss scenarios is arguably a key step to create and validate a stochastic model, a topic that is explored further at the end of this report.

Portfolio data

Analysis is only as good as the data on which it is based. Accordingly, for liability scenarios and the estimates of aggregate and policy-level losses they produce to provide meaningful insights for insurance practitioners, any portfolio data fed into the process should be accurately captured in a format that is optimised for the intended analysis.

Available data

Data retained in electronic format in liability portfolios typically includes general policy fields such as lines, limits, excess points, premiums, and some basic data about the insured name and country. Data relating to the nature and size of the insured's business is also available when policies are written – an insurer would not reasonably write a liability portfolio without knowing the nature of the insured's business and the size of that business, whether measured by turnover, employee numbers or payroll. To estimate portfolio accumulations, this data should be captured and standardised.

Augmenting and standardising data

Due to the lack of standard liability exposure management tools to date, insurers may not have known what data to collect beyond the basic policy data, or been motivated to retain that data in a structured, electronically accessible way.

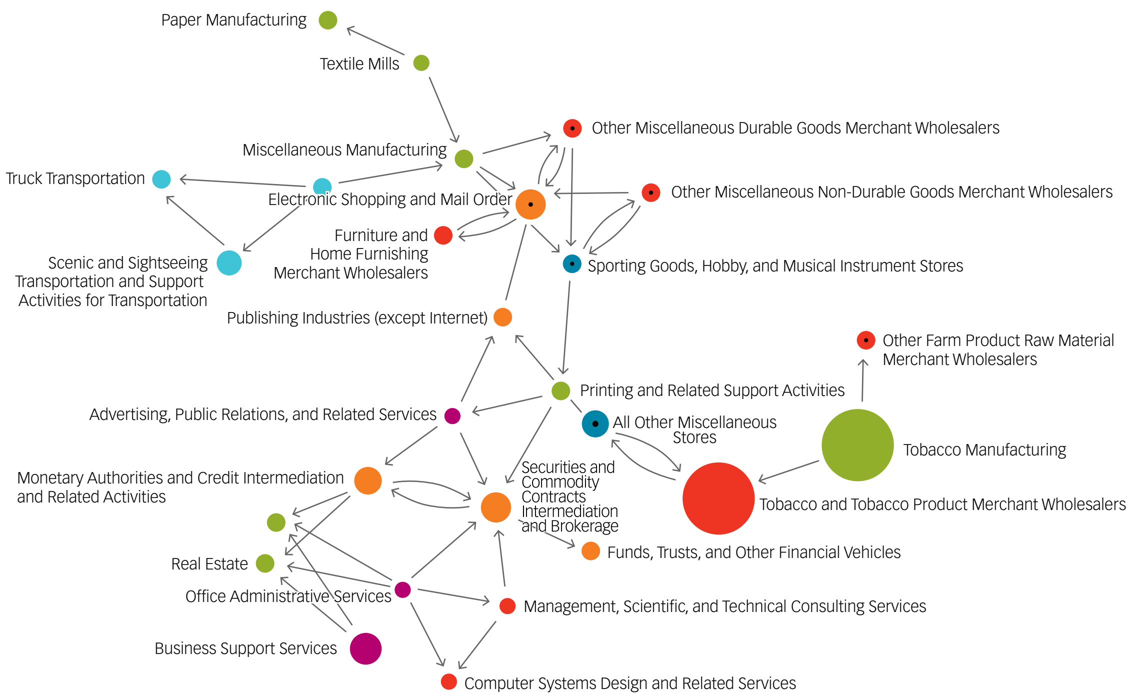
The portfolio data requirements for liability risk are analogous to those for property, where appropriate data collection is essential for risks to be geocoded. Basic information – name of insured and some location details – must be collected for the corporate data needed to run scenarios and accumulations to be appended to each policy. A unique identifier can be used to allow accounts to be matched across different portfolios.

Although this process introduces new potential sources of error in the data – such as through a failure to match accurately or the use of erroneous data held by a corporate data supplier – it also helps ensure that common insureds across different policies are identified, promotes consistency within and between portfolios, and provides quality assurance for portfolio data. As such, attaching corporate information to policy data could result in a more accurate and comprehensive dataset than most insurers currently possess.

Conglomerate breakdown of accounts

With property portfolios, the data held by insurers typically provides details of each and every property insured, even where the individual properties are all insured under a single multi-location policy. In contrast, a liability portfolio tends to retain information on only the holding company when a single policy covers a conglomerate, even though many policies will also apply to each and every subsidiary. Just considering the industry, location, size and other details of a single holding company is going to yield limited accumulation estimates, as a conglomerate may operate in several industries. The extensive cross-industry connections a single conglomerate can have are illustrated by figure 7 below – the map shows a single manufacturing conglomerate for which each and every subsidiary is covered by the head office general liability policy. Each node represents an industry and the size of the node represents the number of subsidiaries in that industry. The links represent the direction of trade between those industries.

Figure 7:



Case studies: Ponzi scheme and e-cigarette scenarios

As part of a Lloyd's pilot project, the framework set out in this report was used to develop case studies of both a financial and a non-financial liability scenario.

The scenarios were developed through the collaborative input of Lloyd's market participants and external experts.

FINANCIAL CASE STUDY: Ponzi scheme

For the financial case study, a scenario based on large Ponzi schemes was developed. To help inform the discussion, input was gathered from Lloyd's managing agents with financial lines expertise and from an external lawyer who has previously dealt with Ponzi scheme litigation in the UK.

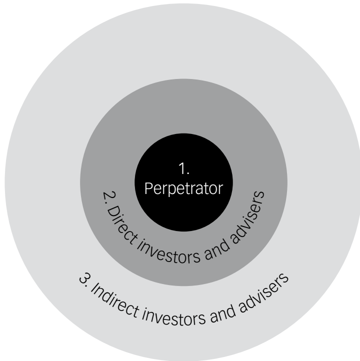
Event description

A Ponzi scheme is essentially a money redistribution scheme, in which investors – investing in a range of assets, which could include land – get back their own capital plus some capital from subsequent investors masquerading as a return on investment. The scheme inevitably eventually implodes, as the actual returns on investment are too small to compensate for the cannibalisation of the capital invested. In some cases legal authorities may instruct earlier investors, who can be paid with a 'return' from the capital of later investors, to contribute back to pay the later investors, but this is widely felt not to be palatable by UK courts. Ponzi schemes are frequently marketed to 'affinity' groups, which are groups of investors who know each other through some common interest such as a church or charity. The damage inflicted by Ponzi schemes is purely financial – although emotional damage and stress are also likely to be caused – and losses are usually suffered by both direct and indirect investors.

The perpetrator of a Ponzi scheme will often be bankrupt by the time the scheme is discovered, and insurance cover, in the infrequent case that the perpetrator has cover in place, will usually not be available due to the fraudulent nature of their actions. However, defence costs may be incurred under D&O insurance and will often not be repaid even if the perpetrator is found liable.

The criteria used to assess comparative culpability is that the greater the duty of care owed, the greater the liability. For the Ponzi scheme scenario, three rings of descending culpability can be identified, including the advisers who owe a duty of care to the investors[10]:

Figure 8:



1. **Primary (criminal) liability:** Perpetrator running the scheme.

2. **Secondary (civil) liability:** Direct investors and their advisers.
   a. **Direct investors** – hedge funds, funds of hedge funds and investment managers or pension funds
   b. **Advisers** – lawyers, accountants and financial advisers to the direct investors
   c. **Insurers of direct investors and their advisers**

3. **Tertiary (civil) liability:** Indirect investors and their advisers.
   a. **Fiduciary investors** – Trustees of endowment/pension funds for non-directly related industries such as universities, hospitals, religious organisations or other charities all have the potential to be sued for their investment decision and lack of appropriate controls
   b. **Advisers** – lawyers, accountants and financial advisers to the fiduciary investors
   c. **Insurers of fiduciary investors and their advisers**

As Ponzi schemes involve redistribution, perpetrators frequently try to set up another cash business to help launder the misappropriated funds. Any bank or party handling or acting as a conduit for these misappropriated funds in principle may be sued in the US, such as for failure to file a Suspicious Activity Report under the Bank Secrecy Act of 1970 and related regulations.[11] Even if there was no advice or duty of care, lawyers, accountants and even brokers can be sued for providing an air of legitimacy to a fraudulent business operation[12], while ratings agencies may also be vulnerable for appearing to endorse some investments.

Box 3
The Madoff Ponzi scheme

The scenario developed in this section is loosely based on the Madoff investment scandal, the largest known Ponzi scheme in history.[13] Over the course of nearly two decades, former NASDAQ Chairman Bernie Madoff convinced thousands of investors to invest in his asset management firm with the promise of consistent profits – in reality, the returns paid to investors were channelled from new investments entering the fund[14]. The fraud was uncovered in 2008 when Madoff admitted to the scheme to his sons, who reported him to the federal authorities. On 12 March 2009, Madoff pleaded guilty to 11 federal felonies, including securities fraud, money laundering and perjury, and received the maximum sentence of 150 years in federal prison[15].

The Madoff Ponzi scheme was an outlier in a number of respects:

- **The magnitude of the losses** – a total of $17bn was apparently invested in Madoff's fraudulent scheme; the combined value of these losses plus their expected returns was originally estimated at around $65bn[13]. Stanford, the next largest known Ponzi scheme, resulted in a loss of around $7bn, and the losses of the many smaller Ponzi schemes are orders of magnitude smaller. The largest Ponzi scheme in the UK has been the Dobb White case, for which losses were in the region of £100m[16].
- **The number of years the scheme survived before imploding** – the Madoff Ponzi scheme appears to have been active for at least two decades; most such schemes do not survive as long before being exposed[17].
- **The amount of assets recovered by the trustee in bankruptcy** – trustees usually recover only a fraction of their total losses from Ponzi schemes, but in the Madoff case the trustee in bankruptcy recouped more than $10bn of the amount invested[18].
- **That it was a regulated business** – most Ponzi schemes are set up by unregulated businesses[19].
- **That there were many institutional investors worldwide** who invested significant funds[20].

Despite its size, the investors' losses in the Madoff Ponzi scheme were largely contained, as most of the investors and advisers were able to absorb their losses.

Mapping the event footprint

Figure 8 above indicates the core industries implicated in the Ponzi scheme scenario – this is used as the starting point for the complete mapping of the footprint of industries implicated. The next step is to filter out the industries that are not relevant to the scenario, such as goods-based industries, some financial institutions – such as the central bank, or securities and commodities exchanges – and claims adjusters. In addition, any industries not directly related could be brought into the footprint if they have pension funds or endowments that could be invested; this could include universities or other educational establishments, hospitals and healthcare, charities or religious organisations. The basis of an action against these institutions could be that those in charge of the organisation had approved the investments or failed to put the appropriate controls in place when investing in the Ponzi scheme.

The resulting event footprint for the Ponzi scheme scenario is shown in figure 9, with the business operating the scheme sitting within the central industry of the map – the securities industry, which includes securities dealing and investment banks – surrounded by its direct and indirect investors, the advisers to the direct and indirect investors, and the institutions receiving deposits and advisory groups.

Deconstructing the event into sub-scenarios

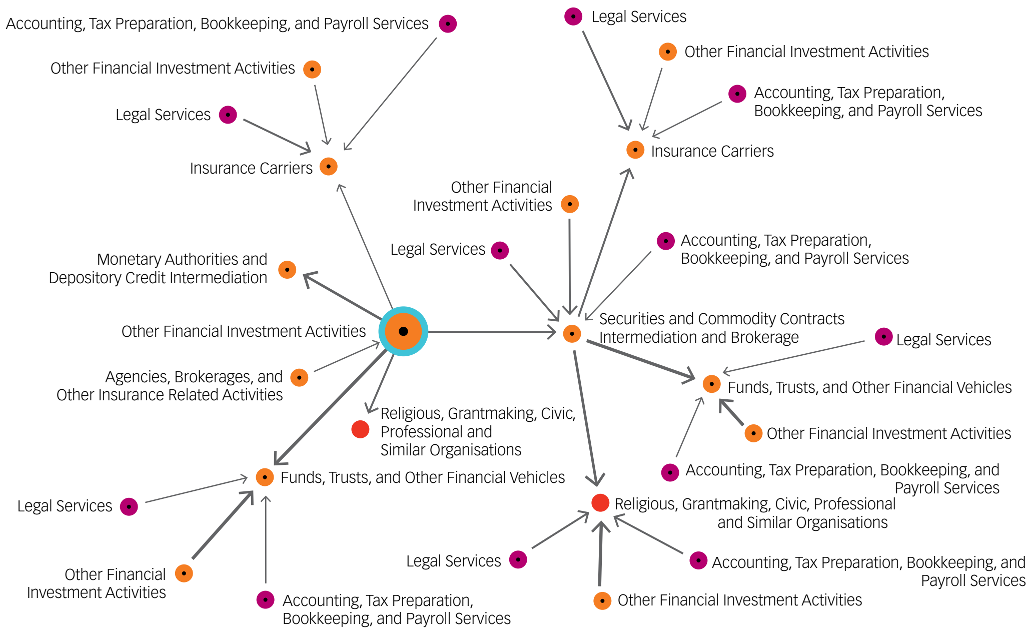
With the event footprint mapped, the next step is to break the event down into its constituent sub-scenarios, which will be aggregated into a single loss event but parameterised separately. While some scenarios cannot or need not be broken down in this way, a Ponzi scheme scenario can be separated into distinct sub-scenarios for the following reasons:

- With the perpetrator insolvent prior to any actions, the lawsuits are taken out against the different deposit takers or investors each with their own set of advisers, rather than against the perpetrator.

- Lawsuits against direct and indirect investors involve different parties – the indirect investors are also able to pursue the respective feeder funds.

- Direct and indirect investors sued may make a third party complaint (if in the US) or additional claim (if in the UK) against their advisers. A different quantum of loss as well as different kinds of advisers may be involved where the investors sit within different industries or operate on different scales. For example, a charity may be advised by a smaller law firm than might usually be expected to advise an insurance company.

Figure 9:



- Shareholders may also claim against the depository banks and the investors for the loss to the share price for either banking misappropriated funds or investing without sufficient due diligence. These claims may be covered under their D&O policies.

Parameterising each sub-scenario

Once the scenario has been broken down into its constituent sub-scenarios, these sub-scenarios can be parameterised – in this exercise, this is done using historical information from the Bernard Madoff securities fraud (see box 3). The publicly available historical data was used to help set a range of losses and the number and nature of institutions involved.

However, the scenario cannot be constructed just from knowing the identity of the insured and the size of the loss. For example, simply knowing that an insurance company had losses in the Madoff Ponzi scheme doesn't inform whether that company was a direct or indirect investor, the extent to which that company recouped losses from their advisers and which advisers paid the most, or whether only medium to large law firms were advising the company. Further data is necessary to parameterise the scenario.

Data needed to parameterise a scenario typically cannot be found in a single place or from a single adviser. For the Ponzi scheme example, data on the losses for Madoff investors are publicly available[17,21], as are the losses to the banks sued for handling the misappropriated funds[15,22], but the two are not always found in the same place – and without constructing the scenario first, it may not be obvious to search for the losses to the depository banks. In this way, it is helpful to have a framework for an entire scenario before trying to parameterise each sub-scenario.

Where information is not so readily available, a best guess can be used. When the loss is put in the context of the other relevant data – such as the policies exposed, their attachment points and limits – a conclusion can at least be reached as to at what magnitude of overall economic loss the accumulation to that portfolio will exceed the insurer's risk appetite.

Loss allocation

Once each sub-scenario is parameterised, the sub-scenarios can be run together as a single loss event for a portfolio and each parameter can be stress tested, starting with the range of economic losses and re-randomising the pick of implicated insureds. In this context, stress testing is in part a way of exploring the structure of the scenario and how it interacts with the shape of the portfolio and policy terms. It may be that the loss is driven by large economic losses in some scenarios but high policy limits in others, or a portfolio may have exposures in industries that are very unlikely to bear culpability.

NON-FINANCIAL CASE STUDY: E-cigarettes

For the non-financial case study, a scenario was developed based on the potential harm to users and others from e-cigarettes, defined as all types of electronic vaporised nicotine delivery systems which produce a nicotine-containing aerosol.[23] The scope was limited to a 1-in-200-type scenario excluding accidental one-off contamination or problems with lithium batteries or exploding chargers. Andrew Auty, an expert on emerging risks from Re: Liability (Oxford), provided expert input during the design of this scenario.

Event description

The chemicals found within e-cigarettes that potentially cause long-term harm are:[24, 25]

- **Nicotine**
- **Propylene, glycol and glycerine**
- **Flavours**
- **Polycyclic aromatics**
- **Food dyes**
- **Formaldehyde** – this chemical is present in e-cigarettes not as a functional component but as a by-product produced during vaporisation. Its production may therefore be considered a design defect, and advisers who helped design the product may be implicated if the chemical is established to cause harm.

Several loss mechanisms could be implicated with e-cigarettes, including:

- Teenage addiction.
- Toxicity from solvents and mist enhancers.
- Toxicity from contaminants, flavours and dyes.
- Toxicity from nanoparticles.
- Nicotine-related asthma[c, 26, 27] in children.

Mapping the event footprint

The method used to build the footprint for an e-cigarette scenario starts with the e-cigarette manufacturer. As this is not just an emerging risk but an emerging product, and it is included in the cigarette industry, the trades with the chemicals found in e-cigarettes, detailed above, are comparatively faint compared with other supplies to cigarette manufacturing.

Given the relatively weak strength of trades relevant to an e-cigarette scenario within the cigarette industry, a valuable strategy could be to filter out all non-relevant trades, such as from tobacco manufacturers, and also all financial or other non-related trade. Expert input is essential for this stage to ensure the industries retained in the footprint are genuinely relevant to the event being mapped. After filtering, the resulting footprint for the e-cigarette scenario includes:

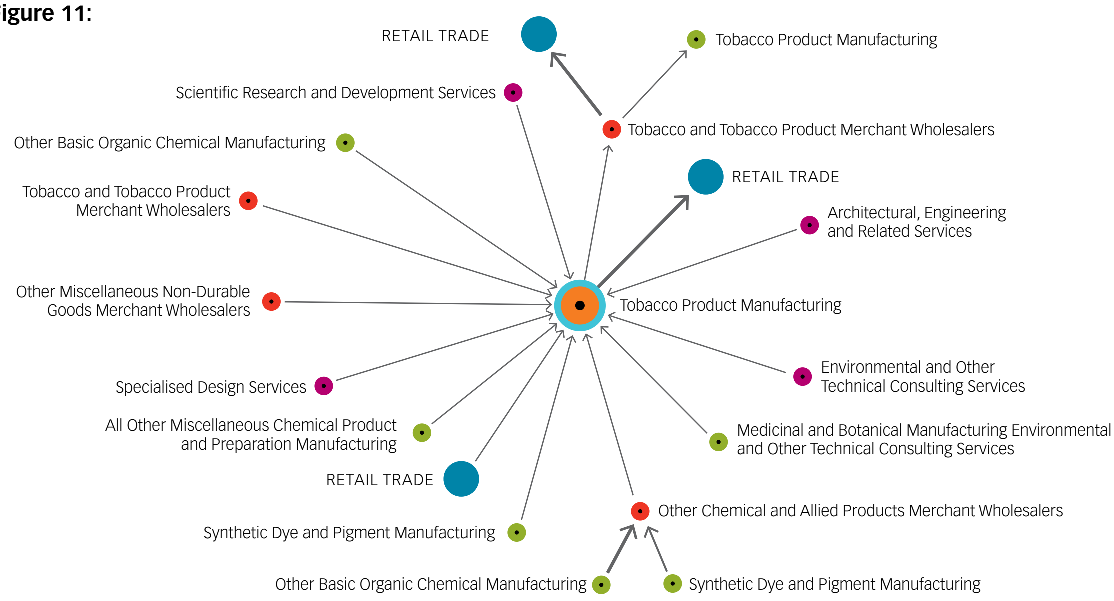
- Cigarette (including electronic cigarette) manufacturers.
- Component chemical manufacturers.
- Retailers.
- Wholesalers, tobacco product wholesalers and chemical wholesalers. Wholesalers responsible for smokers' supplies are also included as they may import e-cigarettes or e-cigarette components.
- Possible technical advisers to the e-cigarette industry – such as chemical consulting, engineering, industrial design, R&D, and graphic design services – that may be implicated for making a potentially hazardous product look attractive.

Box 4
Supply chain and trade strength

The distribution of trades between different entities within an industry will typically consist of relatively few large trades and a multitude of much smaller trades. Some of these smaller trades may seem peculiar, and could reflect non-business related purchases – for instance, umbrellas, hats, pens purchased for marketing purposes – or be included in error. However, improbable trades may actually be part of the supply chain, and should not be readily dismissed. For example, a map of the supply and distribution chain for Play-Doh® would include trade from starch manufacturers to toy manufacturers; although this seems an unlikely connection, flour starch is in fact one of the key ingredients used to make Play-Doh®.[28] It is in these seemingly peculiar and relatively small trades in the supply and distribution chain of the cigarette industry that e-cigarette components are found, such as from flavour manufacturers and aerosol can manufacturers to tobacco manufacturers.

[c] *A clear indication of this was provided in the 2006 US Report of the Surgeon General[26], but no mechanism could be decided. A very credible causal mechanism has since been identified in rat experiments[27].*

Figure 11:



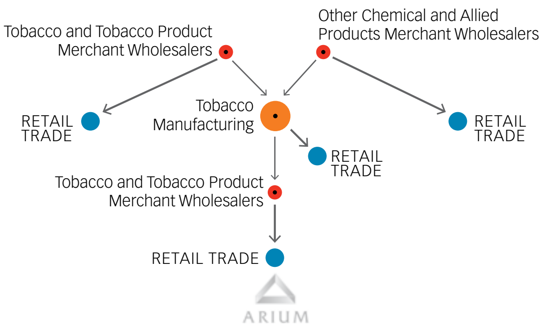
This initial map, shown in figure 11, involves many advisers and chemicals.

For the e-cigarettes case study, only a single mechanism-to-harm was chosen for analysis: the risk of nicotine-related asthma in children. This decision was made on the basis that nicotine can cause an epigenetic change in offspring. Unlike the other suggested loss mechanisms, this leaves strong evidence of specific causation at dose levels that are likely to be encountered in the real world. Asthma is also a very common problem in the offspring of smokers[27]. In other words, generic causation, proximity, specific causation and frequency of harm are lined up to make this arguably the most significant emerging liability risk for e-cigarettes. As such, the scenario does not need to be broken down into sub-scenarios, and instead can be parameterised as a whole.

Current expertise suggests that this particular type of harm caused by e-cigarettes is the result of nicotine, not any of the other chemicals found in e-cigarettes. The map can therefore be adjusted accordingly, on the basis that the advisers and suppliers of any chemicals beside nicotine are not considered responsible for the harm in the scenario. Finally, the map can be filtered on the basis that product liability (and possibly general liability and employer's liability in certain circumstances) are the lines of insurance most likely to be affected by claims under this scenario, so other lines can reasonably be filtered out.

The reduced map corresponding to this scenario is shown in figure 12[d].

Figure 12:



Parameterising the scenario

Losses

For a scenario based on the risk of nicotine-related asthma in children in the UK, the economic losses are estimated as follows[d]:

- Present conditions: hypothetical total loss (including defence costs) from £26m to £130m per annum
- Foreseeable conditions: hypothetical total loss from £200m to £440m per annum

[d] *Based on the current proportion of fertile women who vape, the frequency of childhood asthma, reported odds ratios in tobacco smokers and the nicotine content of cigarettes, the frequency of currently attributable injury ranges from 535 to 2,350 per year in the UK.*

Culpability

It is anticipated that most (60%) of the liability for the harm in this scenario would lie with the e-cigarette manufacturers, and the remainder (40%) with the liquid manufacturers. However, this estimation is made on the basis that all manufacturing of e-cigarettes takes place within the EU. In reality, the majority of e-cigarettes are imported into the EU from China,[29] and estimations of culpability must be adjusted to account for this. In this scenario, importers may bear liability for the products they import[30] – although they may subsequently pursue the overseas manufacturers to recoup any damages and costs they incur. In addition to this, claimants are likely to pursue retailers in the absence of a known and present manufacturer, and these retailers may have strict liability if their records of who imported the e-cigarettes or e-liquids are not accurate or available.[31] The distribution of culpability for this scenario therefore needs to take account of these factors, redistributing some of the liability to importers and to a lesser extent retailers.

Stochastic modelling

Box 5
Stochastic modelling is a method of financial modelling in which one or more variables within the model are random. The purpose of stochastic modelling is to estimate the probability of outcomes within a forecast, to predict what conditions might be like under different situations. The random variables are usually constrained by historical data, such as past market returns.[32]

Where possible, modern exposure management for property insurance and reinsurance relies on event-based stochastic modelling. These models have become such a standard tool that their outputs now form a central part of the Solvency II regulatory framework. It is thus natural to ask whether a similar concept can be implemented in principle for the liability sphere and, if so, how it can be done. It is also important to consider how credible such an approach would be, and what the uncertainty would be in any figures generated.

Historical analysis and its limitations

Modern actuarial science utilises a large set of tools to extract information from historical events. Probabilistic models for property insurance are routinely fitted to historical loss data to derive a description for the peril at hand as it relates to the insurer's business. In some cases, a catalogue of events is stochastically generated from presumed underlying distributions fitted to the historical occurrences of catastrophe frequency, severity and location. More modern catastrophe loss models generally eschew the old statistical approach, and instead use 'genesis' models to re-create historical events based on underlying geophysical science.

This approach is most suitable for perils whose properties can be assumed to be relatively stable over the course of time; while this assumption may be theoretically false, the error that arises can be negligible for perils that only change slowly. This is the case for the majority of property exposures, as the atmospheric and geological conditions that shape natural hazards typically change slowly – albeit with some short-term variation driven by periodic cycles such as the El Niño Southern Oscillation – and because improvements to building infrastructure, such as to prevent fires, are often only developed and implemented gradually.

By contrast, liability scenarios are characterised by sudden step changes, driven by two factors. First, once a systemic liability case has surfaced and resulted in losses, agents in the economy would be expected to react to the event – the event may alter the regulatory environment; insurers may limit their exposure; manufacturers may alter their products – and, as a result, the event will rarely be expected to repeat in the same form. Second, changes in legislation can have dramatic effects on the severity and occurrence of losses.

As with most other catastrophic perils, the number of observed events in the liability sphere is usually relatively low. Therefore, approximating the tail of a distribution purely from historical data can prove difficult. As with property catastrophe, scenario-based models seem the appropriate course of action.

Stochastic modelling from first principles

In view of the limitations of historical modelling for liability catastrophe, the natural next step is arguably to think about stochastic modelling from first principles.

The current generation of stochastic models – natural catastrophe or otherwise – could be described as a collection of scenarios for the peril at hand, each tied to a frequency variable modelling the annual occurrence probability. In principle, there is in theory no reason why this approach cannot be transferred to other types of liabilities. In practice, however, there are some obstacles:

- In order to cover a sufficient amount of the universe of all liabilities, a large number of scenarios are needed. This is very similar to property catastrophe modelling, when any geographic area needs to be covered by a sufficient number of events. In the absence of a general understanding of the dynamics of liability, it is hard to see how to come up with a stochastic algorithm to generate the required number of scenarios.
- Determining probabilities of occurrence and severity for liability scenarios is a daunting task, particularly because historical analysis is often less appropriate than in the context of property.

Box 6
Broadly speaking, statisticians typically fall into one of two categories[33]:
- For **Bayesian statisticians**, probabilities are fundamentally related to our own knowledge about an event. A Bayesian approach defines an event's probability as to the prior probability distribution known from existing data (such as from historical events), adjusted in light of any new data elicited from trials.
- For **frequentist statisticians**, probabilities are fundamentally related to frequencies of events. A frequentist approach defines an event's probability as the limit of its relative frequency in a large number of trials.

One possible solution to the problem of modelling liability could be to adopt a Bayesian rather than frequentist approach, based on making subjective assessments of event scope, likelihood and severity and building up a sufficiently large event catalogue to encompass the full range of events that can lead to liability losses. Using a Bayesian approach means that these views of chance can be updated based on improved evidence and data. Given the subtleties inherent in defining liability scenarios, this approach would need to tap into expert opinion, involving some form of resource pooling within an organisation or with outside experts. This kind of collaborative approach could achieve the required scale of catalogue for liability events and represent many varieties of valid opinion. Distilling these different scenarios into a single view – such as by employing the Delphi method – is unlikely to be practical given the variety of individual liability events that would constitute the event catalogue, although this does not mean that each event and scenario should not be subjected to rigorous critique. Under this approach, the probability of occurrence would become the principal Bayesian parameter to the model. In its most basic form, this would mean that a catalogue of deterministic scenarios would be coupled with occurrence probabilities to yield the stochastic event set.

Alternatively, many parts of the methodology described for deterministic losses could be retained in a stochastic algorithm, albeit in a parameterised form reflecting uncertainty. Through this approach, it could be possible to give a probabilistic picture of:

- **The form and shape of the supply chain**, whether it is a central supplier branching out to many companies, or a straight supply chain going from one company to the next.

- **The economic loss**, which can be written as the average financial damage to each afflicted person multiplied by the number of people affected. Both variables can be modelled stochastically. Although they will be less clear, similar attempts can be made at non-economic loss and defence cost.

- **The number of companies,** which can be made a stochastic variable.

- **Shares of culpability,** which can be perturbed stochastically.

Because the uncertainty is so large in many parts of this approach, an additional mechanism could be to assume a very large value or even to numerically maximise among a number of choices. Numerically maximising means that instead of letting the scenario designer set a parameter to a specific value, they can also instruct the computer to maximise overall values of that parameter. For example, the ground-up loss could be algorithmically increased until all policies are completely destroyed.

Thus, there are three options for every link in the chain of mechanisms that constitute the event:

1. Make it deterministic.

2. Find a probability distribution and parameterise it.

3. Numerically maximise over a set of choices.

The resulting framework is flexible and highly conducive towards stress testing, as desired.

Conclusion

This report has considered two key questions arising in the area of emerging liability risks: firstly, what the causes and conditions of catastrophic accumulation risk for liability insurance are in general, and secondly, to what extent the methodology could help to understand and start to quantify these risks.

A structured analysis of trading relationships in supply chains is fundamental to understanding potential liability catastrophe risk, and the legal system within which the economy functions must be included as part of this assessment. Further to this, there must also be some way of mapping actual exposures within these economic and legal frameworks. This is a challenging task. In this context, the framework implemented by Arium is a promising step towards improving insurers' understanding of emerging liability risks.

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Appendix

Making use of expertise: What to ask the expert

This outline guidance has been prepared by Dr Andrew Auty of Re: Liability (Oxford) Ltd. This material has been produced for general information purposes only; all opinions are the author's own.

This section provides a structured series of questions that may be valuable to ask product liability experts when designing scenarios relating to product liability in the UK. A similar approach could be appropriate for other claims, such as those for negligent service and/or financial loss.

The aims of expert support include:

- To assist with scenario building.
- To inform judgement.
- To inform risk management actions.

Liability cases can often be resolved using a mixture of purist and pragmatic considerations. The balance between these depends on jurisdiction, but to follow a structured approach it is arguably reasonable to begin with a purist view and then bring other issues into play. A liability analysis typically begins with establishing who owes a duty to whom, then whether the agent in question could have caused harm of the kind being thought about, and finally whether this harm has been caused by the agent and, if it has been, whether this can be proven. Some examples of useful sensitivity analyses are also provided, which could be run by the expert or the user.

The expert should provide verifiable sources. Where a judgment is adopted, the expert should state what would change their mind – and, if possible, they should add where to look for that factor going forward.

Hazard scenario

The most basic question is:

Q: ***Which parties were involved in the design, production, importation or supply of this hazard?***

> Those parties not previously or not currently involved at any level may reasonably be deleted from the scenario.
>
> An exposure sensitivity analysis at this stage informs judgements related to, for example, market positioning.

Generic causation

Given that strict liability is the norm, it makes sense to make the first liability refinement using an expert view of generic causation. Without a causal link the analysis of the given scenario should be relatively brief.

Products often present more than one kind of hazard, so an appropriate question to ask could be:

Q: ***Under what circumstances could the product cause harm, and what kind of harm could this be?***

> This is designed to address the objective defects: manufacturing defects, design defects and marketing defects (failure to warn).
>
> For example, e-cigarettes could be thought to present risk of harm arising from addiction (design defect), traditional toxins (manufacturing defect and design defect) and nano-toxins (design defect).

If the expert advises that there is no mechanism by which the product could be found to be objectively defective then the question moves to what potentially insurable issues (harms) remain, such as a subjective defect, legal friction costs or a business commercial risk. A thorough understanding of the wordings used in each market segment would also be needed.

Where there are causally plausible defect and harm combinations (sub-scenarios), then a sensitivity analysis of the various causal mechanisms and wordings combinations could illuminate the effect of changes in knowledge or understanding of the causal mechanism for each combination.

For each sub-scenario where there is a potential defect:

Q: ***By what route are third parties being exposed?***

> This is designed to identify the party(ies) to the supply chain – for Arium's Casualty Analytics Platform, this is specified as a list of NAICS codes. This forms the highest sensitivity scenario, identifying the vast majority of, if not all potential legal parties for each causally plausible defect/harm pairing.

Proximity

Q: Which parties contributed to the causal mechanism?

Besides importers, supply chain participants who passed on the defective product 'as is' are unlikely to be found liable.

Of those remaining parties:

Q: Which parties are most proximal?

Courts often want to assign liability to the proximal cause of the defect but may be persuaded to cast the net more widely. Sensitivity analysis can help form a view of what could be at stake if proximity is varied for 'access to justice' reasons.

Specific causation

The next level of refinement is specific causation:

Q: In what settings would specific causation be provable?

This is designed to take into account the potency of the hazard, vulnerable third parties and the distinction between 'but for' causation and material contribution.

It often is the case that specific causation cannot be substantially evidenced. Those NAICS code groups where evidence will not be forthcoming may reasonably be deleted or sensitivity analysed.

The list thus far is hierarchical in nature; if there is no causation, the analysis can usually end there. If causation is possible, then proximity can provide a useful way to edit the scenario. More difficult to judge is provability, so by making it the third consideration the risk of wasted analysis can be reduced. However, if it is easy to recognise that provability is very low or negligible this could be used as the 'yes or no' metric.

Damage

Damage can vary from one jurisdiction to the next.

Q: What is the total damage (and likely range) by jurisdiction?

A range of damage severities and incidence rates is likely for each defect/harm pairing. Latency may also vary by factors such as severity or exposure mechanism.

Various models of damage may be presented. Each can be assessed for sensitivity to information error and for sensitivity to model error.

Probabilistic conditioning factors can often include dose-response estimates, numbers of third parties, vulnerability effects and probability of specificity of evidence, among others. These can vary for each defect/harm pairing. For very small exposures, the analysis could end here.

Q: As a function of harm severity, what legal costs might be anticipated for each defect/harm pairing?

Q: Is there a reasonable precedent for punitive damages?

Correlation

Analyses of this kind might suggest the involvement of other insurance products.

Culpability

The concept of culpability is used here to identify where the courts might be expected to apportion liability. There is a fairly internationally agreed approach to this, based on generic causation, specific causation and proximity and breach of duty (including foreseeability); this is the purist approach. A more pragmatic approach may then be applied by the courts if they decide that justice is not served when culpability is determined according to the purist approach.

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