Association of British Insurers

Industry Good Practice for Catastrophe Modelling

A guide to managing catastrophe models as part of an Internal Model under Solvency II

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Background

In July 2011, the UK Financial Services Authority (FSA) convened a meeting, in London, of representatives from insurers and reinsurers, reinsurance brokers and commercial catastrophe model vendors operating in the UK and other European Member States.

The purpose of the meeting was to consider ways of encouraging good practice amongst companies using catastrophe models as part of their supervisory authority-approved Internal Models under the impending Solvency II regime.

From that meeting emerged the idea of a document setting out 'industry good practice' for catastrophe modelling under Solvency II. The document would be written by professionals, for professionals. It would offer technical guidance and suggestions for companies seeking to 'implement Solvency II' for the catastrophe model component of their Internal Models, by describing industry good practice.

The result is this document.

The group members agreed to collaborate on drafting the technical content under the auspices and editorship of the Association of British Insurers (ABI); it is under this badge that this text is published. The views and opinions expressed here are those of the individual authors; not necessarily those of the authors' respective organisations.

The FSA was kept informed throughout the composition stage, but was not responsible for defining or drafting the document. Accordingly, this document does not amount to FSA guidance and does not necessarily represent the FSA's views on this topic.

Good practice, not current practice

The intention of the authors has been to consider what constitutes 'industry good practice' for catastrophe modelling within the framework of the Solvency II requirements, pertaining to the approval and use of an Internal Model.

Therefore, the authors have attempted to describe '*good'* practice, rather than necessarily the '*current'* practices in their own organisations or the wider market. One of the pleasures of this collaborative process for the authors has been realising how much they have to learn from each other. It is in the spirit of sharing their own challenges and aspirations that these thoughts about industry good practice are presented here.

Who are the authors?

The authors all work in areas more or less directly concerned with catastrophe modelling within their respective organisations. A full list of the authors, and their companies, can be found at the front of this document.

Publication date of this document

The world of Solvency II is still very much evolving, with the Directive's requirements not due to be finalised until late 2012. Readers should note, therefore, that the composition and editing of the technical content of this document concluded on **11th October 2011**.

Changes to Solvency II regulations or guidance since then are not taken into account.

The limitations of this document as regulatory guidance

Clearly, everything in this document represents only the collective opinion of the authors. As a group of industry practitioners, they do not have any formal or regulatory status.

Therefore, readers should always bear in mind that the content reflects a best attempt at guidance, based on the authors' own expertise and experience. It does not - in any way - represent the views of any regulatory authority, including the FSA, or any European statutory or regulatory body.

Adopting the suggestions here will not mean, or in any way imply, that an insurance or reinsurance undertaking is necessarily meeting regulatory requirements. Wherever there is any apparent inconsistency between the text of this document and the relevant Solvency II material, the latter must always be regarded as definitive.

In short, *companies need to comply with all legal requirements placed upon them by regulators*. Nothing in this document officially qualifies, limits or extends those requirements.

One size does not fit all

While the authors have done their best in this document to suggest what constitutes 'industry good practice', they are aware that every regulated entity is different, and will have different needs.

Therefore, readers should always test the relevance of these guidelines against the needs of their particular companies. In particular, what is 'proportionate and material' under Solvency II will greatly vary from company to company, and even within different parts of each company's insurance or reinsurance portfolio. A reasonable requirement for one company may not be appropriate for another, and vice versa.

Which Solvency II material is referenced?

The evolving nature of Solvency II is reflected in the available documentation. There is currently a welter of drafts, guidance notes and consultation papers, all in different stages of composition, publication and official adoption.

The authors were keen for this document to reflect, as closely as possible, the latest iteration of Solvency II guidance. The materials used as references during composition and editing were:

Level 1 – formally known as 'The Solvency II Directive 2009/138/EC (Level 1)', which was adopted by the European Parliament and the Council of Ministers and published in the Official Journal of the European Union in 2009.

As at November 2011, this is still the only official Solvency II text. However, the Directive has not yet been implemented. Therefore, the Level 1 document is still subject to revision, and can be considered 'official, but not final'.

Level 2 – the consolidated draft Level 2 measures informally issued in February 2011, which are not official but represented the latest guidance available from the European Commission at the time of this document's creation.

Level 3 – the pre-consultation paper for External Models and Data dated 10th August 2011; drafted by the European Insurance and Occupational Pensions Authority (EIOPA).

We strongly recommend that readers of this document refer to the latest Solvency II documentation when considering what the authors have written here. The reference documents cited above are available from the ABI.

Notes on the text

'Company'
European insurance and reinsurance ventures come in many corporate forms, including mutuals, limited-liability companies and Lloyd's Managing Agents. Solvency II texts refer to these entities captured by the new regime as 'insurance and reinsurance undertakings'. This document uses the term 'company' throughout.

'Catastrophe model vendor'
The term 'catastrophe model vendor' is used throughout this document to represent the *developer and supplier* of a catastrophe model.

Many companies use catastrophe models provided by vendors, or by reinsurance brokers. However, the principles here apply equally to companies that develop their own catastrophe models, in-house. In this case, the term 'vendor' would apply to the internal developer of the model.

Introduction

This document has been written to help insurance and reinsurance professionals understand the implications of Solvency II for the catastrophe modelling component of their company's (or client's) Internal Model. It also suggests business practices that the authors hope will make 'implementing Solvency II' in this area as smooth and efficient as possible.

Few people are likely to be reading a technical document like this one for pleasure. The authors assume, therefore, that most readers will fit the following description:

- you either work for, or are in some capacity assisting (for example as a broker, catastrophe model vendor or third-party service provider), an insurance or reinsurance company that needs to demonstrate compliance with the Solvency II requirements for an Internal Model
- for assessing the catastrophe element of their underwriting risk, the company has decided to use one or more catastrophe models, rather than utilising the Solvency II Standard Formula for catastrophe risk based on premium income
- you want to ensure the most efficient possible use of the company's resources in meeting the challenges of Solvency II for catastrophe modelling in this context

The last point is important. Given unlimited time, energy and funding, ensuring compliance with Solvency II would present few challenges. However, most industry professionals do not work in such a beneficent environment. The task is more likely to involve finding a way to meet the requirements – both now and in future – by leveraging the Solvency II principles in a way that benefits the 'business as usual' processes.

The hope of the authors is that - by adopting appropriate levels of what they consider to be industry good practice - insurance and reinsurance companies will find that they are meeting their Solvency II obligations for catastrophe modelling.

Finally, it is worth remembering that Solvency II does not seek to dictate exactly what companies should do. That is up to individual insurers and reinsurers. From the perspective of this document, the purpose of Solvency II is to ensure that:

- insurance and reinsurance companies have assessed, in a structured fashion and using a risk-based approach, the catastrophe risks they face
- there are appropriate processes in place to manage these risks, taking into account proportionality and materiality
- the processes are being followed and there is adequate evidence that they are

How to read this document

The document is divided into three sections, beginning with the general principles of Solvency II before moving on to operational and, finally, more technical subjects. Each chapter contains the relevant Solvency II text *(see Background)*, except Chapter 9.

Section 1 – General principles

Chapter 1 - Governance describes the responsibilities of senior managers to understand a company's risk exposures, and the high-level controls and processes that should be in place to manage them.

The authors encourage everyone to read this Chapter, since it provides the framework for understanding everything that follows. The general principles established here apply to all other chapters.

Chapter 2 - Third-party service providers describes the principles governing the use of external service providers for catastrophe modelling under Solvency II. These include the requirements to have a formal outsourcing policy, a specific agreement for catastrophe modelling services to be separate from any other service provision (such as reinsurance broking), and the limitations on what can be outsourced.

This Chapter will be of interest primarily to companies who rely on a service provider for all or part of the catastrophe modelling in their Internal Model (e.g. a broker, catastrophe model vendor, or other service provider). It emphasises that companies cannot outsource their understanding of - or responsibility for - any part of the catastrophe modelling process: 'responsibility for all components of an Internal Model lie with the company itself.'

Chapter 3 - Documentation covers the requirement for companies to document every part of the catastrophe modelling process, including model selection, model validation and change management. It also describes some of the documentation that catastrophe model vendors provide.

As with Chapter 1 on governance, the authors recommend that everyone reads this Chapter. Documentation is the main way in which companies can (and must) provide evidence that they are following the governance principles in Chapter 1.

Section 2 – Operational principles

Chapter 4 – Catastrophe model data describes the data commonly used in catastrophe modelling, and how it differs from companies' other data requirements.

Managing data for the catastrophe model component of an Internal Model presents unique challenges. This Chapter assesses what comprises 'accurate, complete and appropriate' data – taking into account proportionality and materiality – and how to manage it.

Chapter 5 – Model selection and model change covers the process whereby companies consider, select and (when appropriate) change their catastrophe model(s). There needs to be a clear policy, and processes that are both robust and evidenced.

This is a significant new challenge presented by Solvency II. Many companies currently delegate the business of model selection and model change to technical specialists, either internally or to their service providers.

Under Solvency II, companies must be able to demonstrate that they have appropriate in-house understanding of model selection and model change, and that the processes for managing them are well defined, properly documented, and evidenced. This responsibility cannot be outsourced, or delegated away.

Chapter 6 – Options and settings of catastrophe models describes the process by which companies decide how catastrophe models are run to provide an appropriate view of risk. This includes understanding what choices are available, and deciding which ones matter when modelling particular sets of exposures.

For the purpose of this document, 'options' and 'settings' are defined as meaning different things, explained here. This may be helpful in distinguishing the different levels of decision-making a company faces, and how assessing proportionality and materiality help in this process.

Chapter 7 – Catastrophe model validation describes companies' obligation to provide evidence that their catastrophe models are 'validated and appropriate to their own portfolio, and if they are not comfortable with the level of validation, they must identify this as a weakness and remedy this according to company strategy.'

This represents another significant new challenge, and is another area where assessing proportionality and materiality is of primary importance.

Section 3 – Technical principles

Chapter 8 – Multi-modelling approaches describes why a company may choose to use more than one catastrophe model in relation to a particular peril and/or region, and some of the consequences of doing so under Solvency II.

There is no requirement under Solvency II to use multiple catastrophe models. This Chapter explores the benefits and challenges of multi-modelling. As always, a company must have a robust, documented, evidenced policy for making the decision to multi-model (or not), and for managing the process.

Chapter 9 – Uncertainty in catastrophe modelling output explains 'how companies may seek to understand, describe, and ultimately mitigate against the uncertainty that is invariably present in catastrophe models.'

Dealing with uncertainty in a defined and evidenced way is perhaps the most technically challenging of requirements for catastrophe modelling. This Chapter describes different types of uncertainty, how they may be considered in a structured way, and possible approaches to their mitigation.

Nil desperandum

The Solvency II requirements for catastrophe modelling as part of an Internal Model can seem dauntingly complex and demanding. Certainly, during the composition and editing of this document, the authors spent hours and days wrestling with the exact meaning of certain clauses, or trying to grasp the underlying intention of this or that general principle.

In the end, however, Solvency II is about routine good governance. There is nothing in the requirements that, ideally, companies should not all be doing anyway.

The process of understanding, selecting and using catastrophe models is sufficiently complex that the industry should welcome the clarity offered by Solvency II. The more certainty companies have about the processes they use, and why they use them, the more confident they can be that the inevitable – and irreducible – uncertainties of catastrophe models themselves are being managed as well as possible.

SECTION 1 – GENERAL PRINCIPLES

Chapter 1 Governance around catastrophe risk modelling

1.1 Introduction

To make informed and prompt risk management decisions, senior management must have a sound understanding of a company's risk exposure and its key drivers.

This Chapter examines good practice to ensure senior managers understand their obligations, how information can best be obtained and communicated among the senior management team, and some controls that can assist in this process.

These good practice recommendations apply if catastrophe risk represents a material portion of the company's insurance risk profile.

1.2 Solvency II text

The following articles from the Solvency II Level 1 text are particularly relevant to governance in this context:

Article 44 (paragraph 5) – Risk management

For insurance and reinsurance undertakings using a partial or full internal model approved in accordance with Articles 112 and 113, the risk-management function shall cover the following additional tasks:

a) *to design and implement the internal model*

b) *to test and validate the internal model*

c) *to document the internal model and any subsequent changes made to it*

d) *to analyse the performance of the internal model and to produce summary reports thereof*

e) *to inform the administrative, management or supervisory body about the performance of the internal model, suggesting areas needing improvement, and up-dating that body on the status of efforts to improve previously identified weaknesses.*

Article 116 (paragraph 2) – Responsibilities of the administrative, management or supervisory bodies

The administrative, management or supervisory body shall have responsibility for putting in place systems which ensure the internal model operates properly on a continuous basis.

Article 120 – Use test

Insurance and reinsurance undertakings shall demonstrate that the internal model is widely used in and plays an important role in their system of governance, referred to in Articles 41 to 50, in particular:

a) their risk-management system as laid down in Article 44 and their decision-making processes

b) their economic and solvency capital assessment and allocation processes, including the assessment referred to in Article 45.

In addition, insurance and reinsurance undertakings shall demonstrate that the frequency of calculation of the Solvency Capital Requirement using the internal model is consistent with the frequency with which they use their internal model for the other purposes covered by the first paragraph.

The administrative, management or supervisory body shall be responsible for ensuring the ongoing appropriateness of the design and operation of the internal model, and that the internal model continues to appropriately reflect the risk profile of the insurance and reinsurance undertakings concerned.

1.3 Senior management

To make proper and timely decisions on risk management issues, senior management must have an overall understanding of where the company is exposed to catastrophe risk, and what its key drivers are. This can be obtained through regular, transparent reports and presentations that highlight changes in exposure and modelling approach.

Examples include:

- exposure reports
- risk trigger reports
- peril-specific exceedance probability curves

An importance ranking of catastrophe scenarios should help senior management to focus on the most important perils and regions.

Senior management should:

- understand the strengths and weaknesses of catastrophe risk models
- be aware of potential gaps and quality differences in the company's catastrophe risk modelling landscape
- actively seek the levels of information and detail it needs to feel comfortable with taking decisions
- ensure that the proper policies and procedures for doing so are in place

At least one senior manager - for example, the Chief Risk Officer - should be responsible for keeping the rest of the senior management team informed and up to date.

Key ‘catastrophe risk specialists’ should have an overall understanding of the building blocks of stochastic catastrophe risk models, such as:

- event set
- hazard
- vulnerability
- financial module

These risk specialists should also understand the main challenges faced in developing each of these components for the perils that are most relevant to the company. This will inform their understanding of the purpose of the model, and help ensure that the modelling approach reflects the nature, scale and complexity of the risks inherent in the company’s business.

Senior managers do not need to have the same level of knowledge about catastrophe risk models as the members of the catastrophe risk management team, but there should be regular, transparent and evidenced exchanges of information between the two groups.

Exactly how this knowledge is transferred between the catastrophe risk management team and senior management is up to the company, but could include, for example:

- management-level technical documentation
- seminars
- workshops

Senior management’s overall understanding should include, for the areas relevant and material to the company, knowledge about:

- general principles of catastrophe modelling and building blocks of stochastic models
- key measures to define the company’s risk appetite: the concept of return period (and, if relevant, Value at Risk – VaR – versus Tail Value at Risk –TVaR), occurrence exceedance probability and annual exceedance probability
- publicly available data about the company’s exposures
- the catastrophe exposures modelled, areas and perils modelled, peak zones of exposures, lines of business (LOB) or products modelled and a view on variability of the models’ results
- the catastrophe exposures *not* modelled:
  - identification of ‘cold spots’, and the reasons for them in terms of areas, perils, model limitations and data limitations
  - how the exposures are assessed
- expected near-term catastrophe model updates and a view on the most significant impacts expected
- sensitivity of the model results with regard to assumptions, parameter calibration, and the quality of underlying input data (portfolio information)

- a view of the models' limitations, including:
  - strengths and weaknesses of the models
  - possible divergence between the catastrophe model outputs and actual loss experience, due, for instance, to model limitations, data limitations and specificities of the risk profile
- how the risk management team gets comfort that the catastrophe model results appropriately reflect the risk profile of the company, such as testing results against experience or real-time event data
- data quality by region and perils, appropriateness, completeness and accuracy

This good practice document contains chapters on data handling and the treatment of uncertainty, as well as policies on model: selection; change; validation; and documentation - all of which should prove helpful in addressing the topics listed above.

1.4 Risk management team

The catastrophe risk management team – those responsible for maintaining, running, and evaluating the catastrophe risk models either in-house or through a third-party service provider such as a reinsurance broker – should be the provider of the information mentioned above.

The catastrophe risk management team, in co-ordination with the risk management function, should regularly review the company's approach to catastrophe risk modelling. They should do this especially for the most relevant perils to ensure that:

- the modelling approach continues to reflect the risks within the company
- adequate changes in the modelling approach are implemented as a result of changes in the scope or nature of the company's business, or any relevant change in the perception of the risk

(See also chapters on model selection (Chapter 5), model change (Chapter 5), and model validation policies (Chapter 7) in this good practice document)

In their training and education, the catastrophe risk management team should be made aware of the importance of data quality, how the results of their modelling may impact the company's Internal Model, and the relationships with other internal steering and risk management processes.

Responsibility for risk and processes should be clearly documented to ensure businesses are confident that the model continues to operate properly. The delegation of responsibilities should take into consideration the skills, experience and qualifications of individuals and teams and should provide for appropriate training and relevant knowledge sharing to maintain suitable skills.

1.5 Processes and controls

The controls in place should include a process for the escalation of issues arising.

There should be clear processes in place so that results from catastrophe risk models are used to inform decision-making and risk management. These might include, for example:

- pricing
- capital allocation
- accumulation control
- setting of risk appetite
- risk transfer mechanisms

Exactly how the results of catastrophe models are incorporated into a company's Internal Model for the determination of their Solvency Capital Requirement (SCR) – the regulatory capital that a company must hold under Solvency II – should be appropriately documented, including outlining the relevant internal auditing and control checks. The process and controls in place should ensure that the model outputs and the reports produced are consistent.

There should be processes in place in relation to model changes, be it an update of an existing model, or a change to a new model.

(See chapters on model change (Chapter 5), validation (Chapter 7), and documentation (Chapter 3) later in this good practice document)

Chapter 2 The use of third-party service providers

2.1 Introduction

Under Solvency II, responsibility for all components of an Internal Model lies with the company to whom its use is granted. This includes the catastrophe model component, and applies even when a company outsources catastrophe modelling to third-parties such as reinsurance brokers or catastrophe model vendors.

This Chapter explains the Solvency II obligations for companies that choose to outsource any functions linked to the catastrophe modelling component of their internal model.

These obligations – including responsibility for model selection, model validation, and model change management – *cannot* be outsourced or delegated, even if some of the actual functions are performed by third-party service providers. It is important to note that, in the context of Solvency II, outsourcing considerations also apply to functions performed outside of the individual company but that remain within the same group of companies.

2.2 Solvency II text

The following text is from the Solvency II Level 1 text and deals with the issues surrounding outsourcing:

Article 49 – Outsourcing

1. Member States shall ensure that insurance and reinsurance undertakings remain fully responsible for discharging all of their obligations under this Directive when they outsource functions or any insurance or reinsurance activities.

2. Outsourcing of critical or important operational functions or activities shall not be undertaken in such a way as to lead to any of the following:

a) *materially impairing the quality of the system of governance of the undertaking concerned*

b) *unduly increasing the operational risk*

c) *impairing the ability of the supervisory authorities to monitor the compliance of the undertaking with its obligations*

d) *undermining continuous and satisfactory service to policy holders.*

3. Insurance and reinsurance undertakings shall, in a timely manner, notify the supervisory authorities prior to the outsourcing of critical or important functions or activities as well as of any subsequent material developments with respect to those functions or activities.

2.3 Outsourcing policy

Under Solvency II, companies are obliged to demonstrate robust governance. The outsourcing of any function connected to a company's Internal Model under Solvency II is subject to such governance arrangements. Specifically, a company that outsources any function is expected to have a dedicated outsourcing policy. Any part of the catastrophe modelling process that may be outsourced to an external service provider must therefore be governed by the company's outsourcing policy.

In the context of catastrophe modelling provided by an external party, the outsourcing policy needs, specifically, to cover the following:

- the selection of a suitable service provider, ensuring that:
  - the service provider has the capacity and resources to perform the outsourced functions in a reliable, correct and punctual manner
  - no conflicts of interest exist that may affect the provision of the outsourced service
- the existence of a formal outsourcing agreement between the company and the service provider, specifically covering the rights and obligations of both the company and the service provider *(see The outsourcing agreement, below)*
- timely notification - to company management, legal and regulatory bodies - that a particular function is to be outsourced, including authorisation to use the nominated service provider and the terms of their specific outsourcing agreement
- provision that local data protection law is complied with under the terms of the outsourcing agreement. Specifically, this should govern information exchange between the company and service provider

In addition, the outsourcing policy should apply to both new and existing outsourcing agreements, meaning any pre-existing arrangement will be expected to be made Solvency II-compliant.

2.4 The outsourcing agreement

The outsourcing agreement is a legal contract between the company and service provider, and should describe the roles and responsibilities of both the service provider and the company.

An outsourcing agreement covering any aspect of catastrophe modelling work should cover the following points:

- a clear description of the receivables, timelines, deliverables, and legal responsibilities of the service provider under the agreement, detailing the responsibilities accepted by the service provider and those retained by the company

- the requirement of the service provider to comply with all applicable laws and any other guidelines designated by the company
- the company's ultimate ownership of the service provider's deliverable, including the company's ability to:
  - provide guidance to the service provider when performing the outsourced function
  - formally approve any assumptions made by the service provider in performing the outsourced function
- lines of communication between the company, service provider(s) and regulatory authorities, including:
  - confidentiality agreements between the service provider and company
  - the contractual obligation of the service provider to assist the company in all regulatory issues relating to the outsourced function, including, but not limited to:
    - direct access to the service provider by the regulatory authority
    - supervised on-site inspections of the service provider by the regulatory authority
- the performance measures agreed between the company and the service provider to ensure the provision of services as detailed above, such as the company conducting regular performance reviews with the service provider
- the obligation of the service provider to inform the company of any change in circumstances that could materially affect the provision of the service as agreed under the outsourcing agreement
- the contingency measures to be taken in the event of the service provider not meeting its performance criteria
- the procedures in place to ensure continuity of outsourcing to the company if termination of the outsourcing agreement is enacted by either the company or service provider, such that either changing service provider or discontinuing the outsourcing of this function (bringing the function in-house) should not materially affect the stability or integrity of the company's Internal Model
- the terms and conditions under which the service provider may itself outsource any aspect of the outsourced functions, including provision that the outsourcing of work by the service provider in no way affects the service provider's responsibilities as described in the outsourcing agreement

2.4.1 Formulating an outsourcing agreement

The following may prove useful in formulating an outsourcing agreement to cover catastrophe modelling.

In general, under Solvency II, a company must be able to demonstrate that outsourcing any function in no way adds undue operational risk. In the case of catastrophe modelling, the company should demonstrate that outsourcing this work does not impede their ability to:

- maintain understanding and control of all aspects of their Internal Model
- allow the regulator to monitor their compliance with Solvency II obligations
- maintain the stability and integrity of their Internal Model
- demonstrate the ability to measure a service provider's performance
- demonstrate that their service provider has sufficient disaster recovery functions, such that the company's audit obligations, Internal Model, stability, and integrity, cannot be affected by failures of the service provider

Whatever controls are in place to ensure the service provider's performance, outsourcing the catastrophe modelling function does not allow a company to delegate the *responsibility* for any element of its Internal Model to the service provider.

2.5 Catastrophe modelling functions that may be outsourced

Whilst, technically, any aspect of catastrophe modelling may be outsourced, it is important to recognise that the ownership of the modelling process cannot be outsourced. When employing a service provider to perform any catastrophe modelling, responsibility for understanding the model - and key decisions on use and governance - remains with the company.

For example, *ownership* of the model selection *(covered in Chapter 5)* and model validation *(covered in Chapter 7)* processes must remain in-house, with input from third-party service providers where required. A clause in the outsourcing agreement could cover, for example, the circumstance under which a reinsurance broker acting as a service provider could employ a catastrophe modelling vendor to perform any aspect of the outsourcing work.

The following examples show stages of the catastrophe modelling processes that may be outsourced, either individually or in any combination:

- exposure data cleansing
- address geo-coding
- exposure data formatting
- exposure data entry into the catastrophe modelling software
- portfolio analysis within the catastrophe model
- use of catastrophe model output in other simulation tools

It is anticipated that, in most cases, these functions will have been outsourced to either reinsurance brokers or catastrophe model vendor consultancy groups. Reinsurance brokers may be using either licensed vendor models or their own in-house catastrophe models.

2.6 Specific examples and considerations

Under Solvency II, ultimate responsibility for any aspect of an Internal Model always remains with the company, even when components of the Model have been outsourced to third-party service providers. Therefore, recommendations in other chapters apply equally to the company and the service provider performing any function covered.

If an external model is used, the vendor should help the insurance company licensing their model to understand the data underlying the model, and the assumptions used. The greater the risk to the business, the more granular the understanding should be, subject to reasonable expectations of non-expert, third-party understanding.

It is crucial, therefore, for a company to understand the processes and workflow covering outsourced work. A thorough audit trail is essential.

Examples of key checks that could be in place might include:

- when outsourcing data cleansing, ensuring that exposure data from all business entities and underwriting units is included, where available (including agency business)
- when outsourcing stand-alone geo-coding functions, the company should understand address correction algorithms employed by the external service provider. For example, where a street address apparently mismatches a postal code or city, is the same street address in a ‘corrected’ city or postal code used, or is the risk located in a known city or postal code?
- the company should understand how and why its risk classification schemes are mapped to model-specific construction and occupancy codes, particularly where this may deviate from a purely semantic one-to-one mapping

It is recommended that the company’s and service provider’s audit trail includes the implementation of checks and balances at all stages of the catastrophe modelling process:

- before delivery of data to a third-party
- during the outsourced work at the service provider
- as part of the company’s validation of the service provider’s deliverable

Chapter 3 Catastrophe modelling documentation

3.1 Introduction

A company's obligation to document 'the design and operational details of the Internal Model' applies to the use of an external catastrophe model as part of its Internal Model.

This Chapter looks at two different types of documentation:

- the sections of a company's Internal Model documentation that covers the catastrophe model, in accordance with Article 125, pertaining to the Internal Model
- documentation that catastrophe model vendors may provide to help the company understand and use the catastrophe model

3.2 Solvency II text

The following is from the Solvency II Level 1 text and specifically references documentation standards:

Article 125 – Documentation standards

Insurance and reinsurance undertakings shall document the design and operational details of their internal model.

The documentation shall demonstrate compliance with Articles 120 to 124.

The documentation shall provide a detailed outline of the theory, assumptions, and mathematical and empirical bases underlying the internal model.

The documentation shall indicate any circumstances under which the internal model does not work effectively.

Insurance and reinsurance undertakings shall document all major changes to their internal model, as set out in Article 115.

3.3 The company's own documentation

For Solvency II, the company must 'own' their internal documentation in relation to the catastrophe model. Merely referencing the vendor's documentation or passing on information are unlikely to be considered adequate.

The company should document the design and operational details of the catastrophe model, and demonstrate compliance with Solvency II requirements for the Internal Model.

The documentation could be a suite of documents, provided that there is an index or clear reference system. Appropriate controls should be in place, for example, version control. Documentation must be kept up to date.

More than one level of documentation is likely to be needed to address the different audiences within the company, from the catastrophe risk specialists to senior management.

It is important that the documentation should be consistent with the intended use of the model, and its materiality and proportionality to the overall Internal Model.

3.3.1 Demonstrating understanding

The company's documentation should provide evidence of the processes followed to develop an appropriate understanding of the catastrophe model or models prior to selection, validation and use. This may include material such as:

- a list of documents provided by the vendor modelling company
- description of training and conferences attended by individuals within the company and relevant qualifications obtained
- records of meetings held between the company and the vendor modelling company, as well as descriptions of any additional support provided by the vendor modelling company

Actual documentation, e-mails, and any other form of written communication, as well as any training material provided by the vendor modelling company, may be subject to the specific licensing arrangements between the vendor modelling company and the company and/or their outsourced service providers.

3.3.2 Demonstrating operation

Important factors a company should take into account for Solvency II documentation may include the following topics:

- **Access to – and use of – catastrophe models**
  The documentation should include a description of how the catastrophe model is being used, for example, through direct licensing, or through a service provider such as a broker or catastrophe model vendor. It should also include the process for ensuring and validating that the model has been used appropriately.

- **Use of a third-party service provider**
  Where the company uses a third-party provider to operate the catastrophe model, or for related activities such as data cleansing, the Solvency II obligations for the purpose of an Internal Model remain with the company *(see Chapter 2)*. The documentation should include the company outsourcing policy and the current service level agreement.

- **Use and management of catastrophe model data**

  Documentation could include:

  - a directory of the data used in the catastrophe model, specifying source, characteristics and usage
  - a description of the processes for collecting and preparing the data, including a description and justification of any adjustment or correction made
  - a description of the process for updating the data, and the frequency of updates
  - an assessment of data quality
  - an assessment of compliance with the company's data policy

- **Model selection**
  The documentation should include the reason(s) for selecting a particular catastrophe model, and a list of the alternatives considered.

- **Model change**
  The documentation should cover an assessment of changes to the catastrophe model, the effects of a change in an external catastrophe model to the Internal Model and evidence of the company's internal approval process.

- **Model validation**
  The documentation should show why the selected model is valid for the business, and may include:

  - a description of the process to validate the catastrophe model in accordance with the validation policy of the Internal Model
  - a validation report
  - a description of how the findings have been escalated and communicated in the company, and any decision or action taken

  The validation may use documentation provided by the vendor or the service provider, but it should also reflect the company's own validation.

- **Model methodology**
  The company may use documentation provided by the vendor or service provider, and it should include:

  - an explanation of the basic components of the catastrophe model and how such components interrelate, focusing on the aspects and features of the model that are relevant to the particular risk profile of the company
  - which fields of expertise were used in developing the model, and whether the model is based on generally accepted practices within the applicable fields of expertise
  - a description and justification of the assumptions relevant to the particular risk profile of the company

- **Circumstances under which the catastrophe model may not work effectively**
  The documentation may include:
  - risks relevant to the company that are not covered by the catastrophe models
  - an assessment of the nature, degree and sources of uncertainty
  - the sensitivity of the results for the key assumptions
  - any deficiency of data, or lack of data
  - the limitations and risks of the underlying IT system used to support the functioning of the model
- **Governance around catastrophe modelling**
  The documentation may include:
  - policies, controls and procedures for managing the catastrophe model
  - a description of how the catastrophe model is embedded in the business process
  - a description of the role played by the catastrophe model in the decision-making process and risk management system as part of the use test
  - a description of the relationship with vendors and other third-party providers
- **Use and management of outputs**
  The documentation may include:
  - an assessment of any potential inconsistency between the catastrophe model and the Internal Model, such as inconsistent assumptions or granularity of outputs, that can compromise the use of the catastrophe model as a source of data or parameters for the company's Internal Model
  - a description of the process to integrate the catastrophe model output into the Internal Model
  - an explanation and justification of any adjustments made to the outputs of the catastrophe model, such as loading factors
  - blending procedures applied to catastrophe models within a multi-model framework and associated justification of weights

3.4 Vendor documentation

The purpose of vendor documentation is to give companies a sufficient level of understanding of the catastrophe model to help with model selection, usage and validation.

By their very nature, catastrophe models incorporate specialised knowledge outside the expertise of many of the people within a company who will use them. Vendor documentation helps a company to develop an appropriate level of understanding *(see 3.3.1)*. The exact level of knowledge required will vary according to different functions within the company, and the proportionality and materiality of the catastrophe model component of the company's Internal Model.

Documentation, in this context, means any information the vendor provides to help companies understand its products, such as documents, websites, and seminars – not just words on a page.

3.4.1 Restrictions on vendor documentation

The Solvency II obligations to understand a catastrophe model, for the purpose of an Internal Model submission, rest squarely on the company itself.

It should be noted that Solvency II places no obligation on catastrophe model vendors to provide documentation, although many do provide a significant amount of information to their licensees.

Vendors are not obliged to provide documentation to non-licensees. However, where a company does not directly license a catastrophe model, and so has no direct access to vendor documentation or support, the company's obligation to document their use of the catastrophe model remains.

Finally, it should be noted that much detailed vendor documentation is subject to restricted distribution, including regulatory submissions. Unless special provisions apply, a company, whether or not a direct licensee, is not necessarily entitled to pass vendor catastrophe model documentation (including excerpts) to regulators.

3.4.2 Suggested content

In addition to helping the company understand, select and use a catastrophe model, vendor documentation can play a useful role in helping a company discharge the obligations created by the use of an external model in its Internal Model.

Therefore, although *(as noted in 3.4.1)* Solvency II places no obligation on vendors to provide documentation, it would be extremely helpful if vendors addressed some or all of the following:

- **Version control information**
  Companies should know they are looking at current information. Therefore, where relevant, it is important to know the document's provenance and history, including version control, change history and author.

- **Model history**
  Knowledge about the model and/or peril history provides perspective on how long it has been in existence, how many revisions it has undergone, and why.

- **Methodological approach**
  Although a common 'language' is emerging for catastrophe modelling, each vendor employs its own modelling and statistical approach. A summary of the approach taken, including idiosyncrasies the vendor believes are particularly significant, is helpful. For example: 'Numerical weather prediction underpins our approach to European windstorm modelling.'

- **Validation**
  This should explain the validation the vendor has performed on the model. Information could include: the validation approach, different tests and tools used (such as formal peer review and expert judgement) and an explanation of how the validation of the model is independent from its development *(See Chapter 7.3 for examples).*

- **Limitations and weaknesses**
  Knowledge of the catastrophe model's limitations and weaknesses is important for its appropriate and effective use. For example, vulnerability curves tend to relate the percentage of a structure's replacement value that has been damaged to the severity of the hazard at that structure's location. These are calibrated to represent the average behaviour of a collection of structures and may not accurately represent the behaviour of a single structure.

  Vendor documentation should also discuss the specific limitations of the particular catastrophe model *(see Chapter 7.3 for more examples)*. These may include:

  - limitations and weaknesses in modelling particular exposures
  - weaknesses and assumptions in the financial calculations. For example, reinstatements or policy structures that cannot be modelled, and the means of accounting for this (if any)
  - non-modelled perils or sub-perils such as tsunamis, landslides, or volcanic eruptions

- **Uncertainty**
  Information about the nature, degree and sources of uncertainty should help identify circumstances under which the model may not perform effectively.

- **Geographical information, including geo-coding**
  This should be a list of areas and regions covered by the model, as well as particular regions not covered, such as off-flood plain areas (if relevant for a flood model). Other documentation may include levels of geographical resolution accepted by the model to geo-code the exposures data, as well as the related resolution of analysis of the geo-coded data.

- **Hazard information**
  This should explain how the particular physical peril is represented within the model. An example in a windstorm model could be three-second peak gusts versus 10-minute sustained winds. It may include a description of often-spatial information incorporated within the calculation of hazards, such as geological, hydrological, geo-morphologic, soil, climate, land use, and anthropogenic parameters, and the data sources used.

- **Vulnerability information**
  This should explain how a particular hazard translates to the actual damage caused at specific geographical locations in the model, and describe how vulnerability curves are developed, together with the data sources and expertise utilised in this process.

- **Construction, occupancy, and LOB**
  These are lists of construction, occupancy and other risk-specific information - for example, roof type and age - accepted by the model, and containing sufficient detail in order for companies to relate their own exposure sets to the available options. This also applies to LOB and other exposure variables. Additional documentation on what impact the different available options may have on the risk assessment or model outputs is of interest.

- **Financial information**
  This should explain what policy and financial structures, including reinsurance, can be modelled and how such modelling may be carried out.

- **Options and settings**
  This documentation should list possible options and settings, and their meanings. The reason for any default or recommended settings should be made clear *(see Chapter 6)*.

- **Access to and – and use of – system/software**
  The documentation should set any technical requirements and recommendations regarding the installation and use of the supporting system and software. There should be full database schemas, with each field explicitly identified.

- **Model change**
  This should identify and describe any changes made to the catastrophe model, identifying the main drivers of change and the impact on the output at industry level or benchmark portfolios, together with validation of the new model results.

SECTION 2 – OPERATIONAL PRINCIPLES

Chapter 4 Use and management of catastrophe models data

4.1 Introduction

Under Solvency II, catastrophe modelling and modelling data should reflect a company's risk profile and characteristics, so that those with greater catastrophe exposure have a more detailed understanding of the models being used.

This Chapter examines the specifics of catastrophe modelling data, common industry practices, and recommendations in relation to Solvency II and looks at the use of:

- catastrophe models (business data)
- developer building models (model development data)
- catastrophe modelling and a company's Internal Model

Data commonly used in catastrophe modelling can differ significantly from other areas of the insurance industry. A key challenge for companies using a catastrophe model is gathering accurate and detailed data about the risks insured, especially if it is supplied through third-parties, and is based on various databases and models.

4.2 Solvency II text

The following excerpt from the Solvency II Level 1 text is of particular relevance to catastrophe modelling data:

Article 121 (paragraph 3) - Statistical quality standards

Data used for the internal model shall be accurate, complete and appropriate. Insurance and reinsurance undertakings shall update the data sets used in the calculation of the probability distribution forecast at least annually.

4.3 Key considerations

Key points of consideration for companies using a catastrophe model include:

- understanding that the impact of data quality in the development and use of catastrophe models should be directly related to the materiality of the catastrophe-exposed business in comparison to the rest of the insurance portfolio
- the accuracy and appropriateness of catastrophe models is highly dependent on the data used to build the model
- any company using the models should try to get as accurate, complete and appropriate data to feed into the model as possible

- this activity should focus on the perils and geographic regions that present the greatest risks to the business
- monitoring in-house data quality regularly and having defined, accepted and manageable data standards is recommended good practice

4.4 Business data

Gathering detailed and accurate data on risks can be challenging for companies using a catastrophe model, especially if it is supplied by a third-party.

For building-related risks, characteristics including age and construction type, as well as the sums insured and any policy structures in place, are commonly captured.

For other risks, including life and workers' compensation, motor, aviation and marine risks, there are additional challenges related to the issues of time-variable value, location, as well as specific risk themes relevant to those types of risks and their vulnerability.

For catastrophe modelling focussing on property data, the issue of risk materiality is a primary consideration in terms of relative importance of particular exposure data attributes. Here, the relative materiality is influenced by the model design and calculation approach as well as the availability and ease of initial data collection.

Of particular relevance to many perils will be the geo-location of risks relative to the hazards being modelled. Other factors may include the limits and deductibles of the policy attaching to the location, as well as the specific characteristics of the catastrophe model. The company should be able to demonstrate awareness of the locations and characteristics that are likely to impact their loss results most significantly for their book of business.

Exposure data represents the risks taken by the company. For example, in relation to property risks:

- detailed location data:
  - sum insured
  - location address information
  - primary and secondary modifiers
- aggregate exposure data

Policy conditions typically contain the financial structure of the insurance contract. For example:

- deductibles
- limits
- shares/participation
- rate on line/premium
- reinstatements
- inception/expiry date

The third class of data used in insurance companies is operational data. Each contract could include information such as:

- broker
- underwriter name
- historical claims data
- premium in previous years

4.4.1 Using a third-party service provider

Companies using reinsurance brokers for their catastrophe modelling, or other outsourced service, should demonstrate knowledge of any data quality testing conducted by the broker, and any manipulations made to the data to improve either the accuracy, completeness or appropriateness, compared to the data provided by the original supplier.

4.4.2 Data accuracy

The company is responsible for deciding how to monitor and potentially improve data accuracy. There are several options for achieving this, including commercial tools. Companies should be aware: data that is complete but inaccurate can generate more risk than incomplete data.

Analytical tools and techniques adopted by the company can also highlight the characteristics and locations that have the biggest impact on the model output, through data quality scoring. However, it is important to note that this is only one way of checking data quality, and a more comprehensive approach would be to apply a range of data quality assessments that, taken together, provide a coherent assessment of spatial, temporal and thematic data quality relative to the company's portfolio and business processes.

4.4.3 Aggregate data

In some cases, aggregate data, where thematic attributes including value are combined and/or spatial resolution reduced, might be the most readily available, or appropriate data for use in modelling.

Reasons to use aggregate data could include situations where:

- no detailed model exists from the model vendor
- no detailed data is available from the client
- aggregate data provides a cross-territorial or cross-peril consistency of data quality
- the aggregate model is simply judged to be the best fit for the business being modelled

This reflects the general requirement for the data used to be of appropriate accuracy and precision for the model and its calibration. In many cases, the aggregate level of data supplied will dictate the most appropriate thematic (attribute) characteristics applied in the model. For example, if data is supplied at CRESTA level, certain policy or other conditions affecting absolute values may be inapplicable at aggregate level.

Aggregated data should be treated with a similar level of care as detailed data. Because of the data processing chain, which will have led to the final form of aggregate data being made available to the modeller, there are a number of common issues relating to aggregate data. An example of a common error could be where erroneous currencies and values are represented in multiples such as thousands but are interpreted as absolute values. Care should be taken to capture and refer to information reflecting a database's source, quality and construction when applying it for modelling or aggregate management.

4.4.4 More accurate data versus lower loss estimates

More complete or accurate data does not necessarily mean lower loss estimates.

The models often translate missing information into an average value for the relevant area, in order to produce a reasonable approximation of loss for the company. For example, an unknown construction type input by the company might be interpreted by the model as the average construction type in the city where the building is located. The impact of missing information on the loss estimates is model-dependent and needs to be understood by the people using the catastrophe model. Sensitivity testing of incomplete data is advised, with most appropriate tests likely to be specific to the model being used.

Those using the catastrophe model should also be aware of the connection between the modelled results and common underwriting practice. More uncertainty in the results in general implies a higher price, but may require a commensurately conservative view on capital allocation.

4.4.5 Check for accuracy

Often, it is difficult to check how accurate the information actually is. Examples of techniques to check and improve accuracy might include the use of:

- comparisons of a company's own data to industry databases, although it is important to understand the quality and provenance of the comparison dataset in order to ensure that appropriate benchmarking is carried out
- geo-browsers to check high value locations individually, although caution should be exercised when using secondary sources of information such as aerial or ground imagery, as interpretive mistakes can create additional error
- sense checks based on logical interdependency checks. For example, a 50-storey wood frame building is highly unlikely to be a correct representation of the actual construction
- more detailed validation rules based on additional knowledge of local conditions. For example, a location that conflicts with local building regulations or common construction practices is unlikely to be correct

- a strong audit trail and assigned ‘data champions’ to ensure that the data process pathways that manipulate and modify data are fully recorded and understood
- training for third-party providers of data, and close communication in-house between data stakeholders. Also, the use of third-party data augmentation tools to enhance company-provided data
- comparisons of recorded building valuation-to-valuation model results
- completeness and accuracy scoring metrics that are linked to catastrophe models and their outputs

4.4.6 Data appropriateness

Data quantity does not necessarily mean data quality. Quality refers to all aspects of accuracy, consistency and completeness.

Data relevance (a key attribute of appropriateness) is thus key to quality, and is dependent on the requirements of the model, which is, in turn, a function of the type of hazard being modelled and the method of calibration.

For example, address-level geo-coding accuracy might be of lower importance to modelled European wind exposure - depending on the model used - than to flood or earthquake risks. It is also important to know the resolution of the underlying model (for example, wind speed computed to a one-kilometre grid) compared with the resolution of the underlying exposure, in order to understand the impact of improvements in data quality on the accuracy of loss results.

Some primary modifiers might be critical for one peril, but be less relevant for another. There is a symbiotic relationship between the model itself and the data used. Demonstrating an understanding of such relationships helps build a robust case for any assumptions made in relation to the data.

The company using the catastrophe model should also be aware of how appropriate the data is for the task. For example, data could be accurate for a contract but out of date and may therefore not reflect the risk correctly anymore. Using data in inappropriate ways can lead to false confidence and be a risk to the business.

4.4.7 Data completeness

Nowadays, there is generally a drive to build more and more detailed location information into catastrophe models, and it can be quite difficult to check how complete the current data is.

Examples of queries in this regard (in relation to building risk) could be:

- what percentage of locations contains the full street address?
- how many buildings have number of storeys given?
- how many locations have unknown square footage?
- how old is the data collected?

The users of the catastrophe model should also consider if all sources of risk have been included, and work closely with external departments and underwriting units to ensure all appropriate data is captured.

A check for completeness of data could cover, for example:

- data from known exposures, such as instance data capture for LOB identified as exposed to catastrophe risk
- potential additional data that could be impacted by a catastrophe event, such as LOB that may be impacted

4.4.8 How to treat missing or incorrect data

If exposure data is missing or incorrect, which could mean, for example, an unknown occupancy type for a house or a location with high value missing from a schedule, then the company's reaction should be proportional to the potential risk posed. It is important, therefore, that the company understands the main risk areas to the business and the impact – on the modelled results – of missing information.

The company should have guidelines on how to handle data that the catastrophe model users deem to be potentially incorrect, and there should be clear responsibilities regarding the data control. The company should decide who is responsible for the data.

If it is not possible to receive updated, corrected data then several approaches can be taken. For example:

Missing data:

- reflect in the capture rate and potentially apply loading factors to the modelled results
- use industry information to estimate values

Incorrect data:

- try to find the correct values through external tools or databases, for example, geo-browsers such as Google Earth (subject to appropriate licence agreements)
- use conservative or mean values. For example, average number of storeys in the area and model using appropriate methods for that data quality
- sensitivity checks of the portfolio using the most or least conservative estimators

The proportionality principle should be applied when selecting the approach and may take into account how the specific data records and their representation of those risks could impact the overall result for the portfolio.

4.4.9 Reinsurance

Reinsurance poses specific challenges to data quality. Reinsurers often receive large amounts of data, including data that represents the property business of the insured cedant. Whilst a direct insurer has one portfolio of locations and contracts to maintain, a reinsurer potentially has hundreds of portfolios of varying levels of quality and provenance.

A reinsurer arguably has less ability to improve the accuracy of a cedant's portfolio, at least directly, but there are several ways of mitigating risk through potentially inaccurate data received. For example:

- conducting their own tests on data completeness and accuracy of the cedant's exposure data, including valuation
- using other sources to enhance data, where appropriate
- carrying out sensitivity testing on selected portfolios, in order to understand the impact of data quality issues
- reflecting data quality in the pricing decision and capital allocation
- working closely with brokers and clients to improve data quality

4.5 Model development data

Any company using a catastrophe model - whether developed in-house or externally - should be aware of the data sets employed in the construction, calibration and validation of that model and the process employed by the model developer, in order to make a quality assessment of the data.

The company should also be aware of any major adjustments made by the model developer in order to take into account changes in event probabilities or severities compared to the historical record. The level of knowledge required should be proportionate to the type of model, its application and the level of knowledge deemed appropriate to provide a reasonable level of confidence in the model and its construction.

As catastrophe models produce loss estimates based on the underlying data used during development, a model could potentially be inappropriate for a specific portfolio. For example, there may be no vulnerability curves provided for the modelled LOB.

Examples of data used for the development data might include:

- a catalogue of historical events
- historical event data and loss experience
- geographical data sets
- scientific research data

4.5.1 Materiality and proportionality

For both model developers and companies using the model, the materiality of the data is essential and the principal focus should always be on the most critical areas. For example, a company with a large exposure on the Florida coast with high hurricane risk, and another set of exposures in an area of significantly lower catastrophe risk, should focus first on improving the accuracy and completeness of the Florida-related data.

4.6 Catastrophe modelling and Internal Models

One major use of catastrophe models is in a company's Internal Model and, therefore, in the calculation of capital requirements.

For larger companies exposed to catastrophe risk, the catastrophe modelling function will often be separated from the capital modelling team, and data must be passed between the two. In other cases, the teams may be combined, or the catastrophe losses directly embedded inside the Internal Model.

Where data is passed from catastrophe modelling to the Internal Model, it is essential that there is good communication and agreed data standards between the relevant groups. The following questions should be answered and documented:

- how will catastrophe loss data be passed to the Internal Model (a common solution could be to pass event loss or year loss tables directly to the Internal Model)?
- which perils and territories are included in the catastrophe data?
- what is the level of detail included? For instance, by major business units or by LOB?
- what is the frequency of updates?
- what is the financial perspective from specific assumptions? For instance, on gross loss, or net loss?
- assumptions for a particular update:
    - what are the capture rates?
    - what currencies and rates have been used?
    - what is the source of the modelling (vendor model and version) and what are the options and settings applied?
    - have adjustment factors - loading or other - been applied?
    - what exposure point in time is captured?
- how is uncertainty around event losses captured, if at all?

The data format passed on between reporting periods should be consistent, if possible. Meta-data should also be produced, for example, in the form of a 'data dictionary' providing onwards use of that data with confidence; particularly where that data is combined with others from varying sources.

A feedback loop between the team operating and developing the Internal Model and the catastrophe modelling team is very important to ensure that the calculation applied to the catastrophe-modelled data (for instance, aggregation or attribution to major business) is consistent with the data provided.

4.7 Solvency II and data quality

Poor data quality will ultimately affect the results of the Internal Model, so companies should decide how to take incomplete data into account and justify the methods applied and assumptions made. One example could be scaling exposure to compensate for non-geo-coded data. There are several viable options to achieve appropriate modelling of gross exposures.

For example, the company could:

- decide to use 'percentage captured' based on premium income, and load catastrophe data accordingly, per peril
- use more sophisticated techniques, depending on the level of confidence in the existing data and its level of overall completeness

It is not likely to be possible to develop a single methodology and each company is responsible for understanding the method used and justifying the assumptions made.

It is good practice to monitor in-house data quality - most likely by client or account - on a regular basis, ensuring the process reflects key data manipulation stages and through defined roles within the organisation, with appropriate lines of communication and problem escalation.

For example, scoring an account's data quality on an annual basis would help to recognise improvements and allow a quick reaction if data standards should deteriorate for parts of the book.

A company with significant catastrophe exposure should have in-house data standard policies and standards of data exchange to ensure everyone in the modelling team treats data in a similar fashion.

4.8 Management of catastrophe data

A company should have documentation to describe how data is used in-house, so that a trained catastrophe modeller should, in principle, be able to reproduce the work done.

The following documentation is recommended:

- workflows describing how data is handled inside the company
- documents describing where data is stored and recovery procedures
- data quality analysis. For instance, data quality scores describing the judged quality of data received. For example, a high score for detailed US hurricane data on the reinsurance side and a lower score for aggregate data use in a minor peril
- documents providing guidelines on how to interpret data and how to handle missing or incorrect data
- a data policy that should also include the frequency of data updates for all relevant areas

Chapter 5 Model selection and model change policy

5.1 Introduction

Under Solvency II, companies must fully understand the catastrophe models they use. This applies to the initial selection of a catastrophe model, and the process of managing how changes in a catastrophe model are assessed and implemented within the company.

This Chapter describes how companies should manage model selection and model change under Solvency II.

As discussed in Chapter 2, companies' responsibilities apply regardless of whether they license catastrophe models directly from a vendor, or use the services of reinsurance brokers or other third-party service providers.

5.2 Solvency II text

The following articles and excerpts from articles in the Solvency II Level 1 text are relevant to this Chapter:

Article 126 – External models and data

The use of a model or data obtained from a third party shall not be considered to be a justification for exemption from any of the requirements for the internal model set out in articles 120 to 125.

Article 115 – Policy for changing the full and partial internal models

As part of the initial approval process of an internal model, the supervisory authorities shall approve the policy for changing the model of the insurance or reinsurance undertaking […]

Article 121 (paragraph 2) – Statistical quality standards

The methods used to calculate the probability distribution forecast shall be based on adequate, applicable and relevant actuarial and statistical techniques […]

The methods used to calculate the probability distribution forecast shall be based upon current and credible information and realistic assumptions.

Insurance and reinsurance undertakings shall be able to justify the assumptions underlying their internal model to the supervisory authorities.

Article 120 – Use test

[…] The administrative, management or supervisory body shall be responsible for ensuring the ongoing appropriateness of the design and operations of the internal model, and that the internal model continues to

appropriately reflect the risk profile of the insurance and reinsurance undertakings concerned.

5.3 Model selection criteria

The first criterion for selecting a catastrophe model or models is the materiality of risk exposure involved. Where there are high concentrations of exposure and risk, it is advisable to use a catastrophe model. However, some catastrophe models do not cover every peril in every part of the world, which may limit their use, depending on the business written by a particular company.

Secondly, catastrophe models may be available in both aggregate and detailed versions. The choice of one or the other should be proportionate, reflect the company's risk profile, and take into account the availability of exposure data on the risk a company insures.

Once a company has decided to use a catastrophe model, the following points may be relevant when choosing the most appropriate one:

- the adequacy of the model for the company's risk profile, including the company's ability to collect the appropriate data required in order to run the model effectively
- whether the model has passed an objective and unbiased validation process in line with the company's own validation process, which may include certain adjustments to the model to comply with the company's book of business
- the expertise and experience of the model developer
- the level of support and transparency the company receives as it develops an understanding of the theory and assumptions applied to the model
- the experience of the company's staff with both the model and its provider, either directly or through an outsourced service provider such as a reinsurance broker
- if licensed directly, the usability and fit within the company's workflow and business processes, and integration into their Internal Model
- an analysis of the strengths, weaknesses and limitations arising from the use of a particular model, as well as any potential restrictions to the on-going fulfilment of the Solvency II requirements

It is advisable to review the model selection criteria regularly, in order to ensure that it remains appropriate for the business. New information, such as a major event or new alternatives coming to the market, may also trigger a review of the model.

5.4 Changes in catastrophe model output

Catastrophe model developers frequently validate and update their models, and publish documentation on the scientific drivers of any change in output, and the impact at an industry level.

Catastrophe modellers need to bring the most up to date view of risk possible to their intended audience. New research or events such as the 2011 Japanese earthquake and tsunami, can reveal the potential for unexpected events, and lead to a shift in the perception of risk. Other changes are more incremental, such as annual updates to event rates.

The magnitude of change will vary by LOB and location, and it is difficult to predict the precise impact of a catastrophe model change on any individual portfolio without actually running the new model.

Companies, or their third-party service providers, may be able to conduct stress tests on catastrophe model output to determine what magnitude of change to the model output - and to which perils or regions - may have a significant impact on their risk profile.

Companies should be aware of model update plans in advance, so that they can start to react and adjust their view of risk before the model release. Model development companies are encouraged to give insight into upcoming model changes, and their potential impacts.

After release, companies should ensure that they understand the drivers of the model changes, either directly or through their service provider.

It is good practice for companies to develop an understanding of the model or models by:

- engaging with the developers
- asking questions
- studying the documentation and attending relevant conferences
- conducting their own validation processes either in-house or in partnership with an outsourced service provider, such as a reinsurance broker

5.5 Timelines for adopting a new model version

Developers will, from time to time, release updates to their catastrophe models as a result of:

- new scientific research
- learning from past events
- the release of new data

When this happens, companies using a catastrophe model should be familiar with the reasons for the update, the new information and data used, and how the vendor has validated the updated version of the model.

Companies should also allow for adjustments to vendor output. This means the impact of a single external catastrophe model change that can change an individual company's internal view of risk. Companies are expected to have suitable programmes in place to alter their Internal Models in light of changes to any of the component risks, including catastrophe.

Each company will have its own timelines for testing and developing the new model. Companies should consider the time of year when the new model is released relative to their own business processes, when deciding when to adopt the new version.

Upon receiving the updated model, companies will again go through their own validation process, taking into account proportionality and materiality. This may result in an updated set of adjustment factors. Unless the new version fails the company's own validation process, it may not be necessary to re-assess all the possible alternatives.

If the overall modelling process is systematised or semi-automated, there should be demonstration of a revision of the process when model version changes introduce new modifier codes for inputs, such as change to the applicability of insurance terms and conditions.

After completing the validation process, a company may find the previous model continues to be the most appropriate version for their business.

5.6 Switching to a different catastrophe model

When reviewing their catastrophe model or models, companies may decide to switch to a different model, possibly from a different provider. The decision can follow a validation or assessment process of the existing model, or other reasons that could include:

- adopting a consistent approach within a company or a group, especially following a merger or acquisition
- a more appropriate solution becomes available

Regardless of the model chosen, the company must always be able to explain the rationale behind their selection decision.

Chapter 6 Options and settings of catastrophe models

6.1 Introduction

Almost all catastrophe models have options and settings that allow their users to calibrate the outputs. Companies using a catastrophe model should have an appropriate level of familiarity with the available options and settings, and any vendor recommendations concerning their use.

This Chapter examines the various choices in the context of Solvency II including:

- the difference between 'options' and 'settings' in the context of this document
- how to ensure that options and settings are used appropriately
- examples of common choices, including:
  - replacement value versus sum insured
  - adjustment of results
  - geo-coding

6.2 Solvency II text

The following articles and excerpts from articles in the Solvency II Level 1 text are relevant to this Chapter.

Article 121 (paragraph 2) – Statistical quality standards

See Chapter 5 of this good practice document.

Article 121 (paragraph 4) – Statistical quality standards

[…] The internal model shall cover all of the material risks to which insurance and reinsurance undertakings are exposed. Internal models shall cover at least the risks set out in Article 101(4)

Article 121 (paragraph 5) – Statistical quality standards

As regards diversification effects, insurance and reinsurance undertakings may take account in their internal model of dependencies within and across risk categories, provided that supervisory authorities are satisfied that the system used for measuring those diversification effects is adequate.

6.3 Definition of 'options' and 'settings'

For the purpose of this document, 'options' and 'settings' are defined as follows:

- an **'option'** is defined as the choice a company makes when deciding how best to approach the overall modelling of its exposure. For example, whether to use detailed or aggregate modelling
- a **'setting'** is defined as a choice provided by the vendor modelling company that allows users to decide how a model is run. For example, ticking certain boxes in the analysis options at the time when the model is run

6.4 Key considerations

The use of individual options and settings may be highly interdependent, and all choices made in the modelling process should be regarded as part of a holistic modelling approach rather than the choice of individual and independent options or settings. This should be documented as part of the model validation and model selection policies and, when appropriate, for model change policies as well.

Those individuals within a company that have defined technical responsibilities for model use and interpretation under the risk management function should be aware of, and understand:

- the options and settings available for the territory and peril under consideration
- what causes of loss and risk processes these represent
- any recommendations made by the vendor modelling company regarding their use, the context of these recommendations in relation to the company's own risk profile, and any implications for loss results

The company can achieve this from documentation or through communication with their vendor or third-party responsible for outsourced catastrophe modelling, as well as by testing to understand the impact of the different choices.

6.4.1 Vendor recommendations

Where a vendor makes a clear recommendation for an option or setting, the company needs to understand this view and its applicability to their business.

A company may disagree with a vendor's recommendation, when applied to their own portfolio, and take a different view. In all cases, a company should be able to demonstrate the rationale for arriving at their decision on the settings used, and the validation process employed to validate the choice made. For example, a company might have their own view on the existence of demand surge for parts of their portfolio in a particular region, typically derived from their own claims experience, which may be different to the model's default options and/or settings.

Where the vendor company does not make any formal recommendations, an understanding of the use of a particular setting is fundamental to the company making an informed decision of whether it should be used, and when.

If a company does not license a model directly but obtains model output from a third-party such as a reinsurance broker, the above considerations still apply. Companies must decide which options and settings should be used by their third-party provider.

6.4.2 Ensuring choices are appropriate

Model developers produce their view of the risk posed by natural catastrophes based on combining knowledge of independent published research, their own research, and analysis of claims data (from both public and company-specific sources) to which they have access. Calibrating the catastrophe model, and validating from such data, results in an 'industry' view of the risk that might be different to the company's internal view of the risk; tailored to their business. It is important to understand the information used by the vendor in calibrating the model itself and the settings that the vendors have provided. This knowledge should enable companies to inform their own internal view of the risk and, hence, the agreed settings for reporting analysis results.

6.5 Options

Options are choices about the overall approach that a company may take to modelling all or part of its portfolio. These are likely to be concerned with the high-level characteristics of both the model and the portfolio.

6.5.1 Detailed versus aggregate modelling

Some data available to modellers may not be of sufficient resolution to be modelled in a detailed manner, and an aggregate model may be more appropriate. The principle of proportionality is often taken into account when deciding whether detailed modelling is essential for the final results of the modelling exercise. In some cases, where the company chooses to use a vendor model exposure database, adjustments to the results from aggregate models may need to be performed. An example could be where the assumptions used by the vendor model to compute aggregate losses are not completely correlated to the company's book of business.

6.5.2 Replacement value versus sum insured

Catastrophe models are often designed - and calibrated - under the assumption that replacement values will be used as an input into the model. For example, the sums insured that are available may effectively be limits, in which case they should be entered as such, and true replacement values sought or calculated independently.

6.5.3 Geo-coding options

Many geo-coding options are available, based on varying methods and source datasets. Vendor models allow for different levels of geo-coding and, in some instances, will have their own proprietary geo-coding databases, providing varying levels of geo-spatial resolution.

Companies using a catastrophe model may also want to consider alternative, third-party sources of geo-coding, where these can provide - in some cases - a higher geo-spatial resolution and additional information related to ambiguous geo-locations: for example, additional means to assess ambiguous address possibilities. The type, level and accuracy of geo-coding can have a large impact on the results, and due to the ambiguous nature of some geo-coding solutions, the choices made should be fully assessed and recorded.

6.5.4 Coding options

The term 'coding', in this context, is best described as choices that companies make when assigning appropriate construction and occupancy type attributes (among others) to the modelled risks. It is important to decide on the appropriate codes to best represent risks, particularly if this information is not clear and has to be deduced. The impact of coding options on loss results can be quite significant and it is, therefore, highly important that companies' coding choices are fully justified in relation to the available data and portfolio character.

6.5.5 Policy conditions

Policy conditions represent the provision of insurance terms that mitigate a company's loss exposure, such as deductibles and limits. Where possible, the most detailed policy conditions should be inputted to obtain the most accurate estimates of loss to the company. If the model being used does not represent certain policy or location-specific conditions in their entirety, or if the information provided to the company is not complete, assumptions can be applied based on knowledge of the portfolio. As with coding options, the company should justify this alternative approach.

6.5.6 Adjustment of results

The options for non-modelled perils and exposures are important towards obtaining a more comprehensive view of risk. For example, possible ways of accounting for non-modelled exposures may be by inflating country-wide exposures or by inflating modelled losses. Again, any decisions on model adjustment should be made with knowledge of model coverage, and limitations, to reduce the potential for double-counting or other errors of commission.

6.5.7 Types and use of loss results

Vendor catastrophe model results are frequently used as an input into capital modelling tools, and several options may be available in this regard. One way could be to include losses net of location terms, but gross of pre-layer terms and, therefore, model policy conditions in the Internal Model. Another option may be to use losses net of all policy conditions in the vendor model as input into the Internal Model.

Irrespective of the loss perspective output from the vendor model, assumptions on the loss output can then be made depending on the vendor model used. For example, the distribution of the number of events in a year, clustering of events (as typical in European winter storms), and distribution of events by month, can be investigated and altered if necessary. Decisions to expand the number of simulated years in the stochastic catalogue can also be made through re-simulation from the output of the catastrophe model. The reasoning behind any such actions should be explained and documented by the company.

6.6 Settings

Settings are choices - using box-ticking, switching or adjusting dials - provided by the vendor modelling companies and sometimes referred to as ‘switches’, which can affect modelled results.

Settings typically vary by peril or region, and also between different catastrophe model vendors. This can be confusing. Even for the same peril, settings can be referred to by different names. Furthermore, some settings may be present in some models but not in others, for example ‘secondary uncertainty’ and ‘average properties’. Even if the settings are the same between different catastrophe model vendors, the recommendations for their use may vary. Companies need to understand how the settings in the analysis options have been developed, what they represent, and what information and data have been used in their derivation.

6.6.1 Analysis settings, which represent different sources of loss within a peril

Turning these on or off may add or remove the impact of these loss drivers to the overall portfolio loss. Some are common across multiple vendors. An example of a common category of settings is ‘secondary perils.’

A ‘secondary peril’ may be fire-following-earthquake, sprinkler leakage, storm surge, precipitation-driven flood; or some form of loss inflation, such as demand surge, or post-event loss amplification.

The existence of these settings helps companies understand how much each of these factors contributes to their overall risk profile. Typically, companies should assess the potential of loss from all sources that the model vendor has provided, unless they can demonstrate their particular business is not at all exposed, such as through exclusions.

6.6.2 Alternative settings, aimed at providing alternative choices to the core model

A good example of this is the provision of alternative event-catalogues, reflecting the fact that risk can change with time. For hurricane risk, the main modelling companies provide a ‘near/medium-term’ or climate-conditioned view, to account for cycles and changes in hurricane frequency levels over time. This attempts to reflect the phenomenon known as non-stationarity in activity levels. Some vendors explicitly recommend this near-term view of North Atlantic Hurricane risk, whilst others do not offer an explicit recommendation.

Similarly, some vendors provide alternative earthquake catalogues reflecting ‘time dependent’ or ‘time independent’ views.

6.6.3 Settings to allow model sensitivity testing

An example of this would be settings used to vary the multiple ground-motion attenuation relationships released by the U.S. Geological Survey in 2008. Other sensitivity testing can cover varying correlation percentage in vendor models, where possible.

6.7 Using options and settings for sensitivity testing of exposure data

Apart from settings provided by vendor models, modifications to the company's exposure data can be made relatively easily for sensitivity testing. For example, loss results for a portfolio with unknown occupancies can be compared with loss results for the same portfolio where those unknown occupancies were set to a defined occupancy, such as commercial occupancy. Another example could be the setting of all secondary modifiers to 'unknown.'

Chapter 7 Catastrophe model validation

7.1 Introduction

Under Solvency II, a company must 'own' the validation of their external catastrophe models, regardless of whether they license them directly, or use brokers or third-party service providers to run them.

This Chapter examines good practice in model validation. Companies need to decide the most appropriate validation methods for themselves, considering their underlying business and the proportionality and materiality of the relevant risks.

There are two main types of catastrophe model validation:

- model vendor validation to ensure that results are appropriate for the specific peril at a country-wide level
- individual company validation that the model is suitable for its actual portfolio

Companies must provide evidence that their catastrophe models are validated and appropriate to their own portfolio, and if they are not comfortable with the level of validation, they should identify this as a weakness and remedy this according to company strategy.

7.2 Solvency II text

The following article from the Solvency II Level 1 text is relevant to this Chapter.

Article 124 – Validation standards

Insurance and reinsurance undertakings shall have a regular cycle of model validation which includes monitoring the performance of the internal model, reviewing the ongoing appropriateness of its specification, and testing its results against experience.

The model validation process shall include an effective statistical process for validating the internal model which enables the insurance and reinsurance undertakings to demonstrate to their supervisory authorities that the resulting capital requirements are appropriate.

The statistical methods applied shall test the appropriateness of the probability distribution forecast compared not only to loss experience but also to all material new data and information relating thereto.

The model validation process shall include an analysis of the stability of the internal model and in particular the testing of the sensitivity of the results of the internal model to changes in key underlying assumptions. It shall also include an assessment of the accuracy, completeness and appropriateness of the data used by the internal model.

Companies must apply the above requirements to any third party models, as required by Article 126 in the Solvency II Level 1 text.

7.3 Vendor validation and its limitations for Solvency II

Companies must ensure they have confidence in the model validation undertaken by model vendors, and demonstrate an awareness of the methods used in this process.

The willingness of the vendors to share knowledge on how they have validated the models is extremely important. Companies can face potentially significant challenges when trying to validate catastrophe models due to the proprietary nature of some catastrophe modelling components. Ideally, vendors should provide enough information about their models to ensure all licensees can gain the required level of confidence in the strengths and limitations of the models. However *(see 3.4.1)*, they are typically not *obliged* to do so.

Vendors traditionally use a variety of sources of information to validate and calibrate their model. Their documentation may include information on model components as well as the total output from the model, such as:

- validation of model event frequency rates: for example, relative to the known historical catalogue, and any adjusted event catalogues to account for time-dependency or non-stationarity in the historical record
- validation of the hazard model: for example, through reconstruction of historical event footprints where possible
- evidence of scientific basis used to determine physical conditions of events such as wind speed, wind tracks, and climate science
- use of claims data to validate vulnerability
- use of historical market-wide data to validate the overall model against wider industry losses
- expert judgement and independent peer review of whether individual components and whole model outputs - particularly at longer return periods and in the absence of historical information - are robust and sensible
- application of policy conditions
- documentation validating changes to the model calibration and output, together with an explanation of why these are necessary
- known model limitations, covered perils, and known sources of non-modelled losses
- data sources used in the model development

7.4 Validation by the company

A company must validate the appropriateness of the catastrophe model to their portfolio. The validation process requires a detailed understanding of the company's own data and how the catastrophe model or models have

been built. It should also consider what the model does not allow for, and use sensitivity testing to support the validation process.

Companies may have past claims data that can be used to help validate high-frequency catastrophe losses, but for low-frequency events, they should ensure they are comfortable with the vendor's model validation, potentially using a variety of models and expert judgement.

The following paragraphs list types of validation that can be carried out. These lists are not exhaustive, and the most appropriate choice of tests will vary for each company based on the underlying portfolio and proportionality and materiality of the risks to which the company is exposed.

7.4.1 Data validation

The company should be able to validate that the exposure data used in the models is representative of their actual exposures. This can be done through the use of reports (supported by appropriate governance) that describe the exposures used in the models.

Where a company relies on exposure data provided by third-parties - for example, industry exposure and loss-curves provided by model vendors - they should ensure that this data is validated against any appropriate historic losses. Where historic loss information is unavailable, the company should have a process for agreeing the use of these curves, for perils based on the materiality of the risk.

7.4.2 Model validation

A company must gain an appropriate understanding of how the model applies to their own portfolio, which may require investigating one or more of the model's modules, such as hazard, data handling, vulnerability and the financial module. These tests should be pre-defined and also include basic hazard testing such as Annual Average Loss (loss cost) maps, and performance regarding historical key events.

Companies should compare the quality of their own data to the key data items required by the model. For example:

- validation of selected distribution of exposure data where no location is given: for example, country-wide values
- unknown or limited exposure data versus vendor model industry data or market data
- unknown secondary modifier data – so, using vendor view on LOB, structure type, and occupancy

Companies should understand how the model has been built to ensure it is appropriate for their portfolio. For example:

- the materiality of the peril to the company's business
- LOB that are allowed for in the catastrophe model

Where available, companies should use their own claims data to validate the catastrophe model output for high-frequency catastrophe events. For example, what perils does the model cover? Is it tsunami following earthquake?

Other questions that may be addressed include:

- data handling with respect to aggregation or disaggregation
- ex-ante and ex-post testing, where major change drivers should be identified

7.4.3 Sensitivity tests

A number of sensitivity tests can be carried out, although companies should be careful not to under-estimate the resource-heavy and data-intensive nature of much sensitivity testing. Tests might include:

- varying the granularity of data used: for example aggregate versus detailed (yet only to the degree of available portfolio data)
- testing if the available geographical data resolution is adequately reflected in the model
- reviewing the impact of the various options and settings such as loss amplification in the model, and the validity for the portfolio being modelled versus vendor guidance
- results from different vendor models, if available: either in-house or through a third-party such as reinsurance broker. Companies should bear in mind the use of catastrophe results from multiple models as different models may better represent events in different parts of the curve
- reconciling changes in year-on-year model results by identifying changes due to their own portfolio, and those due to the model

7.4.4 Non-modelled perils and biases

Model validation will highlight to companies any areas where the model may not be adequate for their risk, for example: non-modelled perils, coverage, exposure data, model biases, and planned portfolio changes. The company should decide the most appropriate way to deal with any validation issues taking into account the uncertainty, materiality and proportionality of the relevant risks.

7.5 Documentation and process

Companies should fully document the validation process, and clearly demonstrate the reasoning behind why they feel that the model they have chosen is appropriate for their business portfolio. Companies should be able to demonstrate the independence and impartiality of the validation process, and prove that robust challenge exists in relation to the validation of the model. The uncertainty in the model, limitations and required future developments should also be documented.

Companies would also be expected to clearly set out the frequency of model validation, and allow for modifications when a vendor releases a new version. There should also be a clear internal governance procedure to ensure model validation is appropriate.

7.6 The limitations on validations for individual companies

Catastrophe models are predominantly required by insurance and reinsurance companies to estimate extreme natural catastrophe losses, because they do not have past data to model the risk adequately.

To simulate extreme losses, catastrophe modelling vendors employ significant scientific expertise and build models to recreate the underlying physical processes. However, there is a limit to how far an individual company can validate low-frequency, high-severity events without replicating the scientific knowledge required to build the original model. For extreme events, companies should focus on satisfying themselves that the validation undertaken by vendors is robust, and consistent with currently accepted scientific knowledge. However, key assumptions and methods should be understood and documented.

SECTION 3 - TECHNICAL CONSIDERATIONS

Chapter 8 Multi-modelling approaches

8.1 Introduction

Under Solvency II, companies may use one or more catastrophe model(s) to produce parameters for input into their Internal Models. Companies are required to explain why they might consider the use of external models or information preferable to internal ones, to list the alternatives considered, and to explain why they have chosen a particular external model or data.

This Chapter addresses the needs and obligations of companies that are using – or thinking about using – multiple catastrophe models.

Provided that companies meet their obligations, there is no requirement under Solvency II to use more than one catastrophe model in order to derive the relevant parameters. The overriding consideration is for the company to form their own view of their catastrophe risk, using whatever methods are appropriate for the portfolio and business. This may be a single model or a multi-model approach. *There is no single correct approach*.

8.2 Solvency II text

The following article from the Solvency II Level 1 text is relevant to this Chapter.

Article 121 (paragraph 2) – Statistical quality standards **(see Chapter 5)**

Also relevant, is the following text from the Committee of European Insurance and Occupational Supervisors' (CEIOPS) Advice for Level 2 Implementing Measures on Solvency II: Articles 120 to 126, Tests and Standards for Internal Model Approval (former consultation paper CP56):

10.20. Undertakings shall be also able to explain the reasons for preferring external models or data to internal ones. They shall also be able to list the alternatives considered and explain the decision for a particular external model or data.

8.3 Current practice

In the insurance industry, it is common – but by no means universal – practice for companies to run several catastrophe models for a given portfolio. This has arisen partly through reinsurance brokers providing results from all available models, including their own proprietary models; partly through companies who licence one model wanting a second opinion on their risks.

There are two main reasons for this practice: (1) model benchmarking; and (2) blending results from different models.

For model benchmarking, output from the second, third or even fourth model can be used to calibrate the output from the first model. In this case, the additional results are not used further in the business process. Demonstrating that some kind of model comparison has been carried out may allay regulatory concerns about over-reliance on a single external model, although this is not a requirement.

In terms of blending results, companies may seek to combine two or more model outputs into a single output: that is, actual multi-modelling.

However multi-models are being used, the process should continue to follow good practice on model selection *(covered in Chapter 5)* and model validation *(covered in Chapter 7)*.

8.4 Practical considerations

There are a number of practical considerations for companies selecting and using multiple models, including:

- ensuring that output selected from the range of multiple models should not be used to cherry-pick a commercially desirable outcome
- the cost of ownership and resource requirements for multiple model runs

Although a number of reinsurance brokers do provide modelling output, it should be recognised that some companies will have difficulty accessing multiple models and, therefore, may not be able to make informed choices between models as required.

Additionally, there are consequences for applying the use and validation tests, and some potential incompatibility with rating agency approaches.

The use of multiple models is sometimes seen as one way to reduce uncertainty by providing several informed estimates of loss, though it can be better seen as a way to reduce the risk of model incompleteness or bias. However, if the models represent risk poorly, then the use of multiple models can compound this risk or lead to a lesser understanding of uncertainty. In CEIOPS' documentation, there is concern that external models or data can cause deficiencies in the Internal Model, or actually increase the risk that a company assumes.

8.5 Multi-modelling techniques

For a company that has decided to use multiple model output, there are a variety of approaches available. For example:

- a simple comparison of the alternative outputs
- blended use of output to form a bespoke loss probability distribution

These approaches may vary across the company. For example, in some cases, a single model might be used for underwriting and portfolio management, but several models could be used for capital management.

The term 'multi-modelling' necessarily implies use of more than one catastrophe model. It also covers processes using both a standard output from a single model and a *variation* of that output. For example, recalibrating the output of a catastrophe model to specific entity loss experience, or loadings for model incompleteness, could both be termed 'multi-modelling'.

8.6 Guidelines

The following guidelines may assist companies using, or thinking of using, multiple models:

- the objective should be to produce an independent view of risk, specific to the company's own portfolio
- materiality and proportionality are important, and it is appropriate for the key catastrophe risk in a portfolio to be modelled, even if the remainder of the portfolio is not. However, this multiple model output could be used as a benchmark - not necessarily as a combined output - if the comparison process is clearly documented
- the choice of single or multiple models used as inputs to the independent view of catastrophe risk should be closely related to good practice on model validation and model selection
- it may be useful for the company to describe the circumstances in which they feel it may be necessary to look at more than one model to help calculate their SCR
- the company should show that they are aware of the available alternative models
- if multiple model outputs are to be used in combination, the company should document both their own understanding of the individual models used and the process used to blend or combine their outputs
- if a second (or third or fourth) model is used as a benchmark, the company should ensure that the model selection good practice guidelines *(see Chapter 5)* are followed and documented clearly
- documentation should set out the criteria used to select the models *(see Chapter 3.3);* these criteria should, in turn, be used to set out the methods used to combine the model outputs, in terms of choice of weights, blending method, selection of data such as loss experience or other scientific data. This should also demonstrate the fundamental compatibility of the models used
- exposure data consistency is important across the models used, and the method used to capture and report exposure data should be demonstrated to be appropriate to all models used

- model set-up should be consistent, where possible. For example, treatment of unrecognised data, any methods used for disaggregation of exposure data, or where there are differences, such as different approaches to economic demand surge. These should be documented in the model blending methodology with reasons given for the differences
- process management should be consistent across the models used; the same level of checks and review applied to the data, model imports and model output
- when selecting weights, companies should use technical considerations based on an understanding of the underlying models, breaking them down by module and component and supplemented by wider considerations, such as:
  - age
  - type and frequency of model revision
  - vendor documentation
  - external scrutiny – for example, peer review
  - ranking of output
  - risk appetite

8.7 Examples of typical approaches

The following is a range of approaches that could be taken by companies using multi-modelling:

- **single model with assumptions and/or data** – assumptions and data should be shown to be appropriate for the portfolio and the model
- **simple weights, common approach** - this can use a weighted average of model outputs, although it assumes that the underlying models are calibrated to the same extent at the stage of model output. The choice of weights is based on high level assumptions, rather than model detail, and weights can be applied to the output severity distributions or the frequency distributions
- **simple weights, alternative approach** - this is based on event loss table data and applies weights to the event rates. Simulation methods can be used to take account of models with year loss tables. This approach preserves event sets with physical events and footprints, and is a probability-weighted model that can enable correlation between portfolios
- **model decomposition** - this approach weights different components of models differently, which can help with sensitivity testing of specific components and take advantage of the perceived specific strengths of different models. A blended model run might include per portfolio or country marginals, such as a blend of models with other adjustments and loss calibration, correlations between countries, and clustering

- **variable weight blending** - this isolates a component of a model and applies a distribution of weights. For example, a revised event rate distribution that gives model A the same event relationship as model B, and can be based on vintage of data, and new research
- **'shoehorning'** refers to the need to incorporate output from two or more models in an accumulation or dynamic financial analysis platform, based on the format of output from one model. It takes account of grouping across different models appropriate for different portfolios, where the portfolios cannot all be run in the same model

  This uses transformation functions that return losses with the same return period from the multiple models and applies a distribution to enable the event loss table from one model to give the results in the same format as another. For example, this can be used where the model selected for scientific credibility does not enable policy terms and conditions to be applied correctly, and the output from the first model can be run with those applied in the second. The transformation function can be statistical or physical, or based on a proxy portfolio.

Chapter 9 Treatment of uncertainty in catastrophe modelling output

9.1 Introduction

Under Solvency II, companies should be able to demonstrate a reasonable understanding of uncertainty and the sources of uncertainty associated with catastrophe models. In particular, companies must understand the effect that modelled uncertainty may have on their Internal Model and how capital is assessed.

This Chapter describes how companies may seek to understand, describe, and ultimately mitigate against uncertainty that is present in catastrophe models.

The following topics are considered:

- uncertainty as a fundamental notion in catastrophe modelling
- companies' understanding of implications of uncertainty in key loss estimates
- different sources of uncertainty in catastrophe modelling
- the role of more accurate data and company processes in reducing overall uncertainty
- communicating modelling uncertainty to non-experts
- approaches for embedding catastrophe modelling uncertainty in the risk management function of companies

9.2 Uncertainty as a fundamental notion in catastrophe modelling

Uncertainty can be described as the imperfect knowledge of a process or system and is a natural consequence of any complex process such as natural or anthropogenic hazards.

This means that 'prediction' of events is impossible.

Uncertainty underpins the concepts of probabilistic and stochastic modelling and, if properly understood, is a positive factor in improving risk assessment above and beyond deterministic approaches. All risk assessment is inherently uncertain, and catastrophe models provide methods to treat risk uncertainty through stochastic means. As such, models are a useful way of characterising the type of high-severity, low-frequency events that may not exist in a company's own claim history.

While catastrophe model vendors try to reduce uncertainty in their models, these models themselves are simplifications of complex physical phenomena. This simplification, the sparsity of data, and incomplete understanding, may introduce material sources of uncertainty into the models. It is important to understand that although some of the uncertainty in the modelled results are characterised in current catastrophe models, many sources of uncertainty are not fully represented or understood. As

such, relying on the results without reference to the uncertainties, can lead to a material misrepresentation of risk.

This is particularly relevant in Solvency II, where catastrophe risk is a material risk that may be measured by a company's Internal Model.

These uncertainties about how well the model reflects reality can introduce bias, where the systematic skewing of results is not representative of the portfolio being considered. Companies should seek to identify material biases that may exist in how the model adequately represents their portfolio. Subject to appropriate governance, modelled results should be adjusted to minimise any identified biases.

9.3 Companies' understanding of uncertainty in key loss estimates

Typically, uncertainty is handled in the stochastic event set and resultant exceedance probability (EP) curve, where the EP curve represents the range of losses that could be experienced for the modelled peril. It is important to note that when looking at a single point in an EP curve, uncertainty becomes significant; probably more so than might be imagined.

It is critical that companies resist pressure to focus on individual points on the EP curve as this encourages optimisation of portfolios around weaknesses in the model.

Biases relate to systematic mis-statements of the risk by a model, and are of particular concern where only one model is used in all risk management decisions. For example, a company may use one model, without reference to additional risk measures, for all risk decisions from pricing to capital management. That model may understate vulnerability of an occupancy type as no claims data is available, and frequency of events in a location as there are limited observational records in the area.

As the model may favour these occupancy types or regions, there is a reasonable likelihood the resultant portfolio is skewed towards accounts with these characteristics. If the same model is then used to assess the amount of reinsurance to purchase, these deficiencies will not be identified, and the suggested level of reinsurance protection may be inadequate.

Typical sources of bias include:

- non-modelled perils, coverages and LOB
- by geography
- by peril
- as a consequence of building characteristics
- financial policy structure

9.4 Different sources of uncertainty in catastrophe modelling

There are three broad classes of uncertainty:

- uncertainty that is inherent in any model
- known uncertainty in the model
- unknown uncertainty in the model

9.4.1 Types of uncertainty

'Aleatory uncertainty' refers to inherent uncertainty due to the random nature of a physical or financial process such as a fault that generates earthquakes on average once every 10 years. This means that even if the physical nature of the fault is perfectly understood, it will still not be possible to predict when the next earthquake will occur. This uncertainty is also found in the apparent randomness in damage suffered by similar properties exposed to the same level of hazard.

'Epistemic uncertainty' arises as a result of an incomplete or inaccurate knowledge of the underlying system or process. A range of equations and parameters may be thought to describe a physical process; however science has not evolved sufficiently to know for sure. As the understanding of physical processes increases and more empirical data becomes available, epistemic uncertainty might be expected to reduce.

Catastrophe models often also describe uncertainty in terms of primary and secondary uncertainty, although this is not the case for all models:

'Primary uncertainty' relates to uncertainties in defining event and hazard characteristics. These are typically epistemic and arise from a lack of understanding, so are difficult to measure. As this uncertainty affects the event or hazard, it is often heavily correlated across an entire portfolio. For example, if event frequency is incorrect by a factor of two, losses may double.

'Secondary uncertainty' relates to the uncertainty in loss given that an event has occurred. Typically, this relates to the precise local intensity of the hazard, and the vulnerability of a property to this hazard. As much of this uncertainty is random (aleatory) in nature, it is not heavily correlated within a portfolio, and as such, does not introduce a significant amount of variation in loss results. Most of the uncertainty represented in the modelled results is secondary uncertainty.

9.4.2 Uncertainty within the catastrophe model

Uncertainties within catastrophe models can be divided into a number of categories, including:

- event generation
- local intensity
- vulnerability
- exposure
- financial modules

9.4.3 Parameter uncertainty

There is uncertainty in the parameterisation of probability distributions used to build the stochastic catalogue and in the choice of the model used to represent the process. There is also uncertainty in whether the size of the stochastic event set wholly accounts for the uncertainties present in the expected realisation of the modelled hazard. In addition, uncertainty in past data due to implied deficiencies in the historic record, and under-reporting of both small events as well as significant events manifests itself in recorded history. Therefore, both tails of the probability distribution, and thus the parameters that govern the distribution, are affected by this deficiency.

To address parameter uncertainty, multiple sources of data may be used, supplemented with geo-physical data such as GPS observations, where available. In addition, historical data may be non-stationary; that is, the record of a time-varying process such as water height or wind speed is affected over time by shifts in the measurement baseline.

9.4.4 Model uncertainty

Model uncertainty refers to, for example, the use of multiple catalogues for certain models, such as the standard and climate-conditioned catalogues for the US hurricane model.

Uncertainty is also associated with the structural damage to physical risks, locations and facilities. Secondary uncertainty incorporates sources such as variations in model choice, intrinsic variability in damage given that an event has occurred, and uncertainty in the exposure data provided by the company.

Uncertainty may exist in the local intensity - for example ground motion or wind speed - of an event at a given location. Depending on underlying assumptions, parameters, and data used, different equations - alternative models - for calculating local intensity are possible, and the choice of which model or models to use is a source of secondary uncertainty; that is, uncertainty in the size of the loss. This is related to variabilities in potential loss to specific risks from a given event magnitude, from both aleatory and epistemic sources.

9.4.5 Vulnerability module

This secondary uncertainty is captured within the vulnerability module, which translates local intensity to building performance or other response to the damage-causing event. Because actual damage data is scarce, especially for the most severe events, statistical techniques alone are inadequate for estimating building performance.

As a result, catastrophe modelling companies construct damage functions based on a combination of:

- historical data
- engineering analyses
- claims data
- post-disaster surveys
- information on the evolution of building codes

Model outputs will reflect uncertainty due to the model's secondary uncertainty, through statistical measures of standard deviation and coefficient of variation. The exact influence will vary with peril, exposure data quality and resolution as well as the distribution of exposures and their likely correlation.

9.4.6 Financial module

In the financial module, there is parameter risk with regard to the inclusion of further characteristics via options and settings (*see Chapter 6*).

Another source of epistemic uncertainty is non-modelled risk and is related to the materiality and proportionality considerations of the Solvency II process. For example, models may not include certain loss-causing factors or parameters in their construction, such as storm surge around all coastlines, or specific loss functions such as vulnerability functions for automobiles. The impact of such loss additions should, within reason, be assessed during the analytical process, and taken into account if they have a material contribution to the total risk.

Uncertainty also exists in relation to cross-peril and multi-location correlations that may not be captured in the models, and whose causal processes are not understood to the level that they may be incorporated with confidence into the models. Again, the materiality of the uncertainty on the overall risk assessment should be considered.

Risk management functions should take account of model uncertainty within the decision-making process in as effective a way as possible; recognising that all models will include uncertainty within their structure.

9.5 The role of more accurate data and company processes in reducing overall uncertainty

Catastrophe models cannot faithfully represent risk if inaccurate exposure data is used. Companies should strive to obtain the best data available to describe their risks. This includes, for example, trying to understand the potential effects of mis-stated property values, and demonstrating how building values are assessed before their use in catastrophe models.

Detailed data can also introduce uncertainties into the model when the data used is more refined than the resolution of claims information used to develop the model. In this case, modelled results may have increased precision, but less accuracy, as the model responds to data based on aggregated data and not detailed data.

There are numerous options when performing catastrophe risk modelling and the choice of approach or settings will have a material impact on results, even if carried out within the same catastrophe model. It should also be borne in mind that companies themselves can introduce uncertainty into the process.

Companies should demonstrate that standards for data usage and modelling process are in place, supported by documentation.

9.6 Communicating modelling uncertainty to non-experts

It is crucial that companies are able to demonstrate the key elements of uncertainty and how this has been communicated within the organisation. Companies should be able to demonstrate that an appropriate individual is able to describe the key uncertainties, and how they affect the metrics that are used to run their business.

It is important that these uncertainties are presented in a way that does not devalue the modelled results. Rather, decisions should be taken with reference to the fact that the tools used have material uncertainties, and should always be considered with this in mind.

9.7 Approaches for embedding catastrophe modelling uncertainty in a company's risk management function

Modelled results should be adjusted to account for identified biases. Companies need not necessarily load the models because of uncertainty, as this can manifest itself in both directions. Companies should, however, have a clearly defined view on uncertainty in models and how its effects are mitigated in the risk management function. Less complex models than catastrophe models may calculate risk statistically and describe it by error bars around the distribution of results. Some - but not all - vendor catastrophe models do this.

Companies can, however, investigate relative uncertainties by:

- peril
- region
- LOB

Companies should, for material perils, be able to demonstrate how their understanding of these uncertainties is incorporated into their risk management approach. Generally, perils and regions that have experienced frequent or recent events are expected to have less uncertainty than those that have not.

To mitigate against the effects of uncertainty in models, companies can employ a suite of risk measures beyond the results from one model. For example:

- use of multiple models
- control of total limits exposed or deterministic measures, such as Lloyd's Realistic Disaster Scenarios

Companies may also adopt tolerances to a range of metrics beyond those required by regulators and ratings agencies, including measures such as TVaR, and points higher in the EP curve than the one-in-200 years' stress.

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