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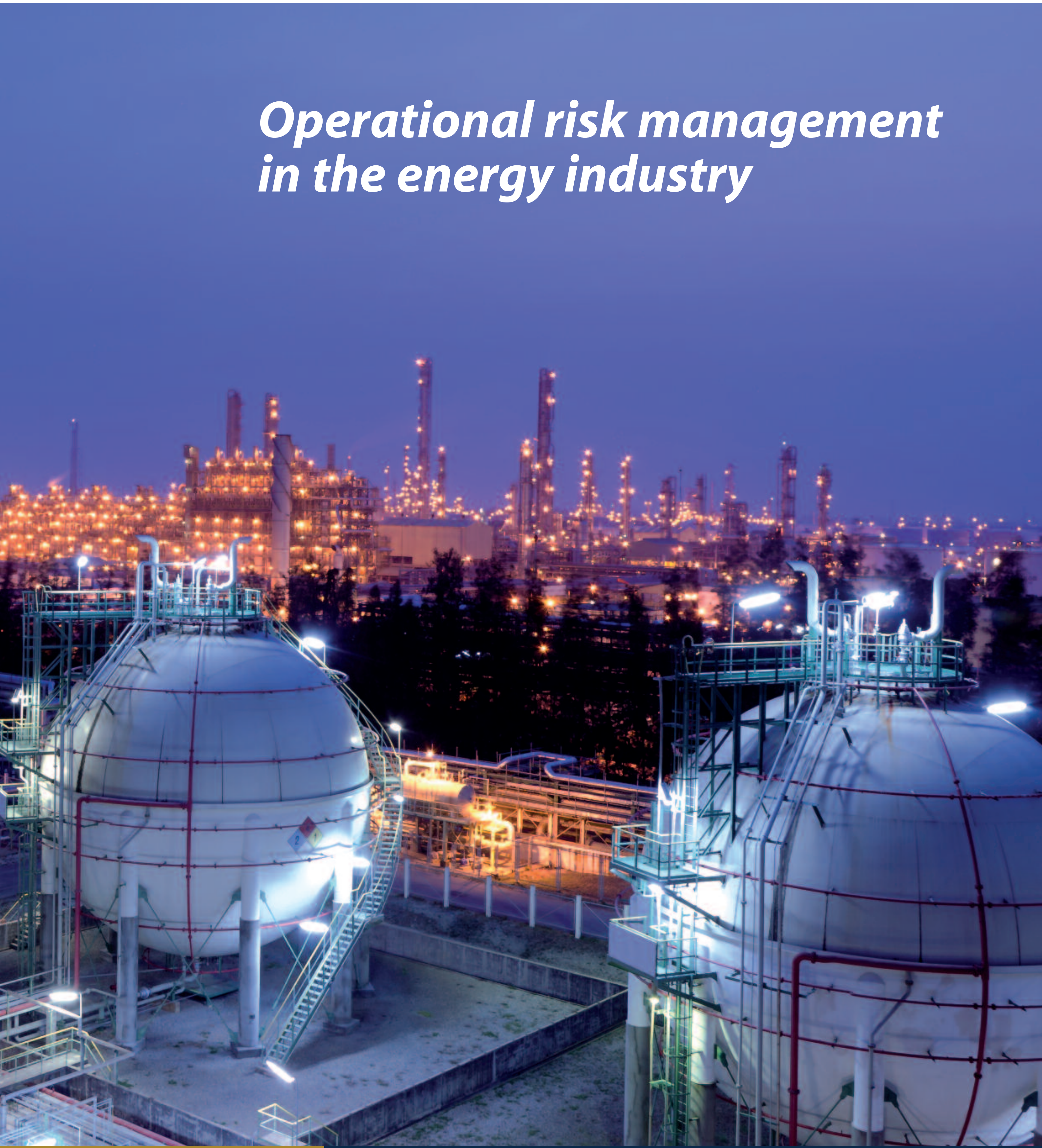
Operational risk management in the energy industry



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Introduction

The increasing complexity of business processes and the materialization of large risk events have significantly increased the risk management activity in recent years, which has led to many reflections, regulations and recommendations on the subject as well as to much work being carried out to enhance risk management in all types of businesses and institutions.

This has gone hand in hand with the growing use of quantitative methods in company and business management, which has been brought about by the need for improved systems in areas as competitive as traditionally regulated energy markets, and further assisted by greater availability of data, technology resources and knowledge.

Against this backdrop, companies have created or developed risk functions and worked on evolving the organization and its governance, policies and models, as well as processes and technology to support the risk management and control activity. Significant improvements have been made in how risk is approached, driven by greater requirements from stakeholders and new regulations, or simply by the added value that developing best market practices provides.

One of the main challenges facing the Risk Function lies in contributing to value generation by integrating the risk model in the business processes to support decision-making and not just as a control tool. It could be argued that the level of effective integration of the risk model in the management process is the most significant differentiating factor when it comes to identifying the maturity of this function in non-financial companies. This maturity, however, tends to vary within the same company depending on the types of risk involved as well as on the company areas and activities.

One of the most significant risks facing businesses in general and energy companies in particular is operational risk, as it affects productive assets that are susceptible to failure and thus to generating economic loss and personal injury or environmental damage, with a potentially significant impact on reputation.

It is precisely because of the potentially fatal consequences it has in terms of economic loss, environmental impact and loss of human life, that operational risk has been traditionally managed through prevention and contingency plans. Operational risk has also been addressed through insurance programs run by specialist departments within the organization that are generally advised by insurance companies and brokers. Although operational risk in general, and insurable[1] operational risk in particular, have a history of being managed by the companies themselves, the use of quantitative techniques has been lower and less uniformly carried out among companies.

This publication is precisely intended to explore the practical application of operational risk models and techniques in the industry, and therefore to serve as an example of how the use of advanced methodologies for operational risk management may contribute to adequate operational risk quantification and improved insurance programs.

To do this, the document first provides an overview of the Risk Function in the broad sense (Enterprise-Wide Risk Management), followed by an explanation of the operational risk management concept and related methodologies, and concludes with a quantitative exercise illustrating the specific application of these methods for optimizing the insurance program of firms in the industrial sector, particularly those in the energy industry.

[1] Insurable operational risk means operational risk that may be insured, and thus be partially or fully transferred to another party, usually in exchange for payment of a premium.

Executive summary

The Risk Function

1. While there are multiple interpretations of the concept of risk, the general consensus is that risk is the possibility of loss occurrence. Depending on the source and nature of this loss, risk may be classified into several domains: financial[2], operational and technology, model, compliance and reputational, strategic and business.

2. In organizations, the Risk Function is responsible for defining and implementing an effective framework for the management and control of all risks in line with the strategic goals of the company.

3. The Risk Function has undergone profound changes over the last few years, particularly in energy companies.

4. In terms of organization and governance, the Risk Function has evolved since it was first developed in the field of financial risk management (sometimes also in the operational and technology risk domains), to achieve an integrated view, sometimes embodied in the role of a Chief Risk Officer or CRO, that is increasingly independent from management or risk-taking roles.

5. Many companies have not only developed but also significantly improved risk maps and policies (including a statement of their risk appetite, partly encouraged by emerging regulatory activity), models and methodologies (especially in traditionally less advanced risk domains) processes and technical support. As regards the latter area, specialist tools are progressively being used, enabling an approach to risk management that is both global and more integrated in the business activity.

6. While a more developed Risk Function is evident in many companies, the level of effective integration of risk data in management is highly variable and sets apart those organizations that are more advanced in terms of risk management and control.

7. The Risk Function necessarily retains its control role and complements it with a support role in the management process. It thus represents an additional mechanism for generating value, as it provides an analytical perspective which is in many cases decisive for supporting business decisions.

8. The analysis includes, for instance, assessing the level of risk in business or investment decisions, measuring risk-adjusted return including the actual or likely costs of risk, determining which resources are sufficient to make business decisions while ensuring business continuity, adjusting the selling price of products and services to reflect a possible transfer or passing of risk to customers, defining action limits for committing company resources in line with the desired risk profile, and other information aspects traditionally not covered.

Operational risk

9. Of the different types of risks mentioned, operational risk is among the most significant and one that has seen much development in recent years in terms of measurement and management. In the financial industry, the formal definition of operational risk is "the risk of loss resulting from inadequate or failed internal processes, people and internal systems, or from external events"[3].

10. Over the last few years, risk measurement methods based on expert information from self-assessments and scenarios have been developed alongside methods based on internal and external historical loss information. These methods make it possible to quantify risk in a simple, understandable and reliable manner as well as measure the expected and unexpected loss that a company may suffer.

11. Methods based on expert information usually rely on two sources: (1) questionnaires developed in order to collect information about the estimated probability or frequency of occurrence and the impact or severity of operational risk events for an average scenario and for a worst-case scenario, as well as about the effectiveness of the control environment; and (2) expert workshops to collectively assess the potential impacts on the company under different risk scenarios.

[2] Included here are the different types of market risk that affect the activity of organizations (mainly exchange rate risk, interest rate risk and commodities risk) as well as credit, counterparty and liquidity risk. Also included here is structural risk, understood as the risk derived from the company's balance sheet structure itself.

[3] See paragraph 644 in the *International Convergence of Capital Measurement and Capital Standards* (Revised Framework) of the Bank for International Settlements (June 2006).

12. This methodology is widely used to assess operational risk because it allows the risk of activities for which there is no history of events to be estimated or a future valuation to be provided based on past events, which means risk metrics can be calculated for events that are less frequent (including the case of extreme events) but have a greater potential impact on the company. Its application can be reduced to asking simple questions in a language that is familiar to experts, but nevertheless requires methodological rigor to standardize answers and ensure they are consistent.

13. Methods based on historical loss information, however, use company or third party operational risk event records. From these records, the probability distribution that best explains the event is estimated using statistical techniques. This requires deciding on clusters of risk events of a similar nature which will be modeled together, which in turn requires striking a balance between statistical rigor (sample sufficiency and statistical distribution adjustment) and business intuition for clustering purposes.

14. These two methods are complementary, and the industry tends to use them in combination so as to integrate the historical view (based on loss data) with the prospective view (contributed by experts). Using them provides information which is generally new and valuable for the company, as it will result in a qualitative leap in the measurement of actual exposure to operational risk.

Applying operational risk measurement methods in the energy industry

15. The methods described are particularly useful to assess operational risk that can be insured (insurable operational risk), as they allow a quantitative assessment to be made of the level of risk or risk profile of companies according to their loss levels. These methods also contribute to approximating the insurance conditions that are most appropriate for each company based on their retention levels and risk appetite, as well as the technical and commercial conditions of the insurance program.

16. Insurance programs in energy companies are critical both in terms of defining the company's risk profile (deciding on the level of risk that the Company wishes to retain and that which is to be transferred) and in terms of efficiency, in so far as insurance premiums and accident costs have a significant impact on the income statement.

17. Many companies are changing and implementing methods to identify and measure operational risk and are making considerable efforts: deployment of risk maps, self-assessments, operational loss data capture, etc. However, most companies and industries have not yet made the most effective use of this information to better manage insurable operational risk and to act on both current losses (cost of premium and claims) and potential losses (level of risk assumed).

18. The study shows that using quantitative methods has a very beneficial impact in terms of risk management, as it allows companies to objectively and independently respond to questions regarding the actual and desired level of risk and the efficiency of the insurance program.

19. The document covers the various steps in the methodology from a theoretical and applied perspective: (1) characterization of the assets concerned, the insurance programs (and their main parameters such as franchise and deductible, individual and overall limits associated with each line or risk and each business activity or asset type) and claims; (2) loss distribution fit; and (3) simulation of the claims outcome to obtain the distribution of net losses from insurance (therefore assumed by the company) by applying the insurance terms to each claim.

20. From this process, it is also possible to obtain the distribution of transferred losses, the average of which is an approximation to the pure premium that should be expected for that particular insurance program.

21. Next, and to find the optimal insurance terms, the above simulation process is repeated with changes in the program's parameters in order to estimate the impact that changes in the insurance terms would have on retained and transferred losses. The best scenario is the one out of all acceptable scenarios in which the total cost of risk[4] is minimized, consistent with the company's risk appetite.

22. The above process, which is detailed in the document, allows companies to:

    - Quantify the company's operational risk profile (the risk and retention levels) through the expected and unexpected loss (at a certain confidence level).

    - Assess the efficiency of the insurance program, understood as the suitability of the premiums paid in the insurance program relative to the risk transferred to the insurer.

    - Analyze the impact of alternative insurance programs on the total cost of risk and evaluate products or specific clauses such as a stop loss[5] or a cost-benefit analysis of variations in insurance parameters. This analysis is, however, conditioned by the availability of programs with specific parameter levels in the market, as well as by other elements in the insurance premium other than the pure premium (commercial margins, insurer's risk aversion, premium due to recent loss events or to lack of information, etc.).

    - Identify the contribution of the different lines of business or assets to the company's risk profile and therefore to the cost of the premiums, which makes it possible to measure the impact on cost of the risk posed by plans involving maintenance, renovation or technical changes to assets.

    - Contribute to meeting regulatory requirements (e.g. Solvency II), either existing or potential, concerning reporting as well as capital measurement and allocation.

23. Implementing risk profile quantification techniques such as those described provides companies with a useful tool to objectively and independently respond to many questions that form part of the agenda of risk and insurance divisions and generally of all business areas, and for which it is not easy to provide an economically quantified answer: how much risk exposure does the company have?, how much of this risk should be transferred and how much retained?, how much risk does the company assume by implementing insurance cost reduction measures?, what is the most suitable insurance program?, what are the areas that contribute most to the risk and to the cost of insuring this risk?, how should the price of an insurance program be expected to change if certain parameters are changed?, what preventive or maintenance activities is it worth investing in from the point of view of reducing costs and risk?, and other similar questions.

24. Answering the above questions does not require a substantial effort in terms of methodology or systems implementation because methodologies have already been thoroughly tested and the extent to which models are used can be adjusted in order to achieve greater accuracy levels while still gaining a first insight that is usually achievable in the short term.

[4]Total cost of risk is defined as the sum of the cost of insured risk (insurance policy premium) and the cost of uninsured risk (losses borne by the company).
[5]A product that limits the total loss to be borne by the company to a specific amount.

The Risk Function

Concept of risk

In the business context, risk is linked to the possibility of suffering a loss[6], and is defined differently depending on its source. Figure 1 shows some of the most common definitions.

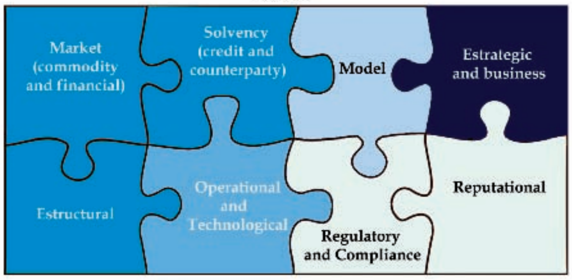
The various definitions of risk can in turn be grouped into domains: financial, operational and technology, model, compliance, reputational, strategic, business, etc. (Fig. 2).

- ***Financial risk:*** includes the different types of market[7] risk affecting the activity of organizations (mainly exchange rate risk, interest rate risk and commodities risk) as well as credit risk, counterparty[8] risk and liquidity risk. This domain also includes structural risk, understood as that derived from a company's balance sheet structure.

- ***Operational and technology risk:*** operational risk is defined as the risk of loss resulting from inadequate or failed processes, people and systems or from external events. This definition includes legal risk, but excludes strategic and reputational risk.

- ***Model risk:*** model risk refers to the potential for adverse consequences from decisions based on incorrect or misused[9] model outputs and reports. Model error may include simplifications, approximations, inaccurate assumptions or an incorrect design process, while model

Figure 2. Risk domains



[6]Other definitions sometimes focus on the probability of not meeting targets rather than on potential losses.
[7]Market risk is defined as the possibility of incurring losses in on and off-balance sheet positions as a result of movements in market prices.
[8]Credit risk is defined as the possibility that a party to a transaction may default on its obligations before the transaction is settled. Economic loss would occur if the transactions or portfolio of transactions with that counterparty would have a positive economic value at the time of default. Furthermore, counterparty risk implies the bilateral risk of loss because the market value of the transaction, which may be positive or negative for both parties, is uncertain and can change over time in line with underlying market factors.
[9]See Management Solutions (2014).

Figure 1. Risk definitions

RISK DEFINITIONS

Source	Definitios	Focus
ISO	Organizations of all types and sizes face internal and external factors that cause uncertainty as to if and when goals will be achieved. The effect of this uncertainty on company objectives is "risk".	Effect of **uncertainty** on the achievement of goals.
FERMA	Risk can be defined as the combination of the likelihood of an event and its consequences.	**Overall** view of **probability** and **impact**, including the **positive** impact.
COSO	Events can have a negative, positive or both a positive and a negative impact. Those that have a negative impact represent risks that can prevent value creation or erode existing value.	Risk is represented by the **events** that have a **negative impact**.
Market consensus	The probability that an event will occur which may cause economic loss over a given time interval.	**Probability** of an **event** occurring that may have a negative economic **impact**.

(1) ISO 31.000:2009. (2) ISO/CEI 73 Guide. (3) Enterprise Risk Management – Integrated Framework Executive Summary. September 2004. (4) Risk Workshop Guide (guide pending approval).

misuse refers to applying models for purposes other than those for which they were designed. Model risk can lead to financial loss, events that may damage a company's reputation or even sanctions.

- ***Regulatory compliance risk and reputational risk:*** includes possible impacts resulting from noncompliance with existing regulations and standards that apply to the industry and the company - and are articulated through internal policies and procedures, with the resulting economic impact (fines and penalties, exclusions, etc.). Also included are the potential impacts resulting from damage to the company's brand image and business[10] reputation, as well as accounting risk. The latter is a very specific type of risk concerning the proper and true economic and financial reflection of the company's reality as well as compliance with all related regulations (IFRS, SOX, etc.).

- ***Strategic and business risk:*** this includes risks related to the wider business environment (the macro-economic situation in the country in which the company operates and the conditions specific to the particular industry or sector), the market and the competition, and medium and long term decision-making that may impact on business continuity and profitability.

Different functions are carried out in order to address the different types of risk, mostly dealing with risk identification and measurement, management (e.g. establishing risk mitigation measures or taking out insurance), control (e.g. through KRI[11] implementation) and reporting (Fig. 3)[12].

The Risk Function

The Risk Function has shifted towards Enterprise Wide Risk Management, which takes a holistic view of risk. This risk function's reference model has several components: mission and general measurement principles, risk management and control, risk map, organization, governance, policies and models, processes and IT support systems.

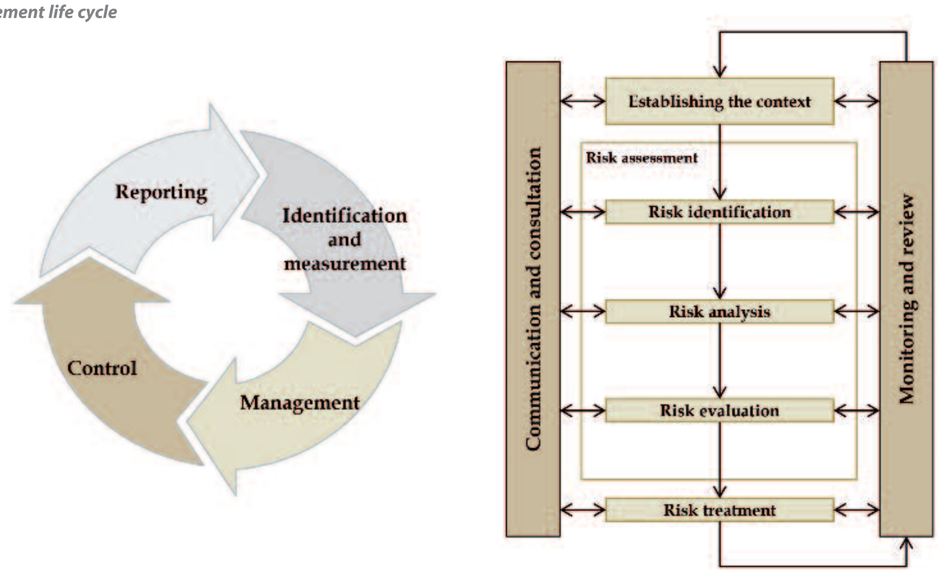
Mission and principles

The main purpose of the Risk Function is to support Senior Management in defining risk appetite and ensuring this appetite is met, as well as to support other strategic objectives and facilitating decision making. A further purpose is to define and implement a framework for action covering all significant risks for the company.

This is achieved through the implementation of basic principles of task segregation (management vs control), oversight and continued involvement of Senior Management, efficiency, quality and changing control environment.

[10]Corporate reputation being understood (according to the Corporate Reputation Forum) as the set of perceptions about a company by the different stakeholders with whom it interacts, both internal and external. It is a result of the company's behavior over time and describes its ability to deliver value to stakeholders.
[11]Key Risk Indicators.
[12]Source: own preparation and *Risk Management – Principles and guidelines*. ISO 31000-2009. Processes on the left relate to those on the right as follows: Identification and measurement corresponds to *Establishing the context and to Risk Assessment (Risk identification, Risk analysis and Risk evaluation)*; Management, to *Risk Treatment*; *Control and Reporting, to Monitoring and review and to Communication and consultation respectively.*

Figure 3. Risk management life cycle



The Risk Function comprises both modeling and control tasks (risk treatment definition –terms of reference–, modeling, overall control and reporting) in addition to functions relating to the integration of risk in the management process (risk policy development and deployment, and policy implementation jointly with risk takers).

Risk map

The Risk Function should afford a comprehensive view and cover all risks that may affect a company. Playing a central role in this view is the risk map, which establishes what risks are significant and determines risk management and control accountabilities.

The risk map, therefore, serves not only to provide a full taxonomy of risks, but is also the starting point to determine the roles and responsibilities of the various participants in the risk management and control process within the organization in relation to each of the risk types identified. It is a basic element of the enterprise-wide risk management model and serves as a basis for developing guidelines for action that are commonplace in the industry (e.g. assurance mapping and combined assurance).

Organization and governance

Risk Function responsibilities under a EWRM (Enterprise Wide Risk Management) model are exercised throughout the company with different objectives and by different areas, roles and authority levels, but the Risk division executive retains ultimate control over the risk function.

Among the factors that determine the Risk Function structure are the risk type involved, the location of specific functions within the company and whether it is local or global in scope. However, the basic risk function tasks should be carried out ensuring there is separation between management and control.

Management and control tasks (and the roles performing these tasks) can be grouped into three lines of defense (Table 1):

- ***First line of defense (Risk Management).*** Responsible for risk identification and assessment, as well as for monitoring and action plan definition. This role is usually carried out by the risk-taking areas themselves, and also by specialist risk management areas.
- ***Second line of defense (Risk Control).*** In its risk control and oversight capacity, this line of defense is responsible for reviewing first line of defense compliance with risk management policies and procedures, as well as for validating the models and methodologies used. This role is usually carried out by a centralized Global Risk Control area led by a Chief Risk Officer (CRO) who is able to provide a comprehensive, cross-cutting and independent view that complements the first line of defense.
- ***Third line of defense (Risk Audit).*** Finally, the third line of defense provides an independent review of processes to ensure the company has an effective risk and control function in place. This role is usually performed by the Internal Audit area.

Table 1. Lines of defense

Risk types	"Domains"	Lines of defense: 1st line	Lines of defense: 2nd line	Lines of defense: 3rd line
Market (Commodity, Interest Rate, FX and Equity)	Financial	Risk Management (Business and Specialist risk)	Risk Control (EWRM / Internal Control)	Risk Audit (Internal Audit)
Solvency (credit, counterparty and concentration)				
Structural (Interest Rate, FX, Commodity and Liquidity)				
Operational	Operational and Technology			
Technology				
Model risk	Model			
Regulatory compliance	Compliance and Reputational			
Reputational				
Strategic	Strategic and business			
Business				
Aggregate Risk (Capital)				

Risk Function governance refers to a company's governing bodies and committee structure with risk management and control responsibilities as well as to the delegated authority structure for decision-making in the area of risk.

In relation to the above, organizations with a more mature risk management often consider having a Board Risk Committee (BRC) that reports directly to the Board and includes the key executive positions involved in risk management (CEO[13], CRO, CFO[14], Audit Committee Chair, etc. Fig. 4) coexist with a number of additional committees with more peripheral participation in risk management[15].

Policies and models

A properly planned Risk Function requires defining a hierarchy of policies based on a risk framework with an integrated approach (which should be approved by the Board of Directors), that is later developed for each specific risk type in lower-level standards (management models, policies and procedures, etc.).

One of the most important components, and a sphere of activity in which companies are investing substantial efforts, is risk appetite, defined as the level of risk that a company wishes to take on in pursuit of profitability and value. It can be expressed through a set of quantitative and qualitative statements that define the desired risk profile. As it is the case with the risk framework, a company's risk appetite must be approved by the Board of Directors and will subsequently be developed into a structure of lower-level limits consistent with the approved appetite.

For measurement and decision-making purposes, the Risk Function is supported by different models and methodologies. The risk framework develops guidelines on the types of models to be used for measuring, managing and controlling risk, as well as for integrating risk into the management process. These methodologies should be documented in detail through procedure manuals, methodology documents, etc., which should be consistent with the different policies and management models in the organization, and should consider any specificities of the geographies or businesses in which the company operates.

IT processes and systems

The Risk Function relies on a set of support IT processes and systems (management tools, calculation engines and information systems). These processes develop the company's principles, goals and high-level policies with the aim of structuring and facilitating the deployment of the risk management, control and monitoring functions.

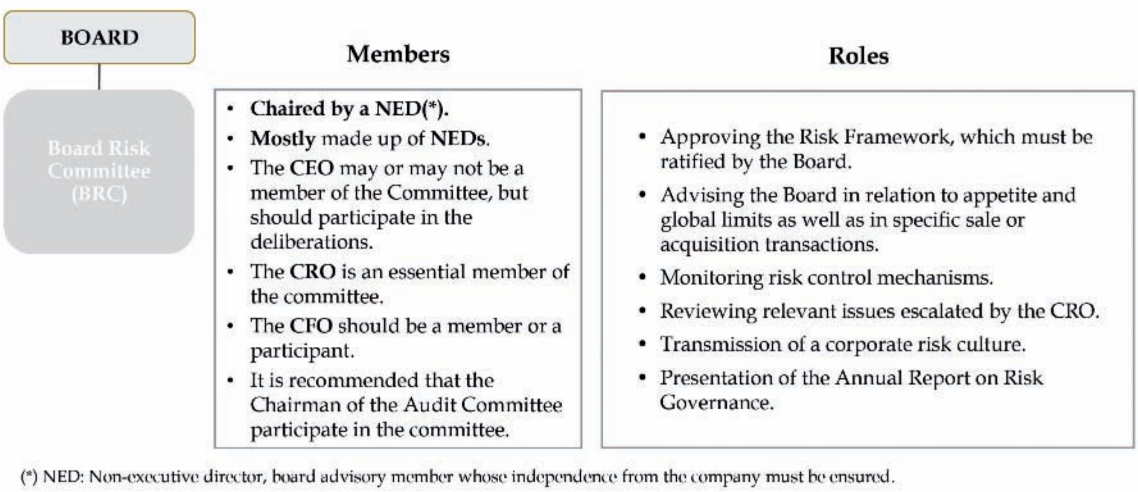
Risk management also relies on an information model supported by systems that are able to capture all material sources of risk necessary to evaluate the effect that changes in risk factors may have on value or on results from an economic and an accounting standpoint. This information should be complete and current to enable the level and nature of the risks to which the company is exposed to be understood.

Based on these premises, the basic Risk Function support architecture requires:

- **Management tools** that support key risk processes (e.g. origination, monitoring, etc.).

[13] Chief Executive Officer.
[14] Chief Financial Officer.
[15] Such as the Audit Committee, the Remuneration Committee, the Appointments and HR Committee and the Compliance and Ethics Committee.

Figure 4. Board Risk Committee characteristics



- **Calculation engines** that facilitate measurement (and later control) in accordance with defined methodology.

- **Data analysis repositories and tools** that support information retrieval processes for decision-making and for risk measurement, follow-up and control. They should cover transactional or operational data (e.g. internal operational risk events) and client or market data (price quotation data used in the market risk valuation process).

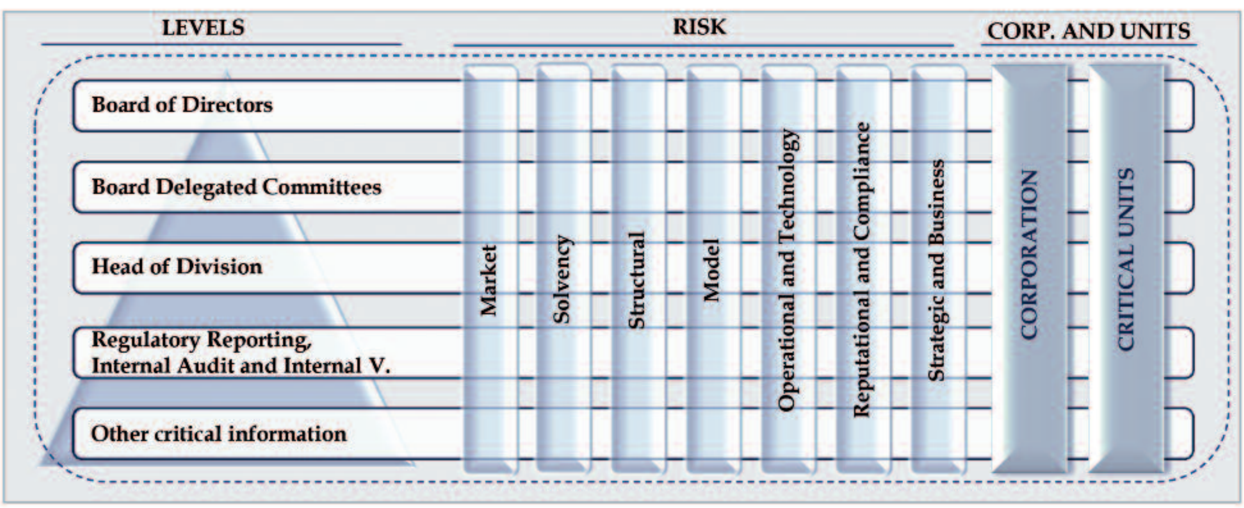
At present, however, there is no one single systems map or global support architecture model for the Risk Function. The market offers both specialist risk management tools and holistic solutions with an enterprise-wide approach that are generally used not only to address risk management, but also to cover the audit, internal control and compliance functions. Sometimes Risk Function architecture models combine market solutions with in-house developments or adaptations on corporate ERPs[16].

This diversity in IT architecture has some drawbacks, especially when it comes to integrating risk into management systems. IT support is therefore beginning to be regulated due to the fact that deficiencies can give rise to integrity problems in risk information. In the financial industry in particular, regulatory publications such as BCBS 239 (RDA&RRF[17]) -Figs. 5 and 6- have been issued requiring companies to review the reporting of risk data the Board and Senior Management.

Figure 6. Principles for risk data aggregation and risk reporting

[16] Enterprise Resource Planning.
[17] *Risk Data Aggregation & Risk Reporting Framework,* in the publication Principles for effective risk data aggregation and risk reporting, BCBS (2013).

Figure 5. RDA&RRF coverage



Changing role of the Risk Function in the energy industry

In the energy industry, the Risk Function has undergone major changes in various areas over the past few years. Organizations are aware of how a mature Risk Function can help them to achieve their objectives in addition to ensuring compliance with increasingly demanding regulatory requirements and enhancing their image with the different internal and external stakeholders.

With regard to **mission and principles,** the practice of defining the Risk Function and making its mission explicit is becoming part of the corporate culture, both internally and for the benefit of stakeholders; in addition, the fundamental principle of control function independence between the management and risk taking functions (e.g. in financial risks) is being increasingly adopted.

As for the **risk map,** companies have made significant progress in this area through the definition of a risk taxonomy that provides them with an overview of the risks affecting their activities, together with the identification of the roles and responsibilities of different areas in the management of the risks involved.

In terms of **organization and government,** the Risk Function has not always been explicit in non-financial sectors and, when it has, it has been located at a second organizational level, usually under Global Economic and Financial[18] Divisions. In this regard, it has been common practice to establish a specific Risk unit around the financial risk domain and sometimes around operational and technology risk.

More recently, progress is being made towards building up the CRO role and developing a global and comprehensive approach to managing all material risks. These recently created units (which carry out the functions pertaining to the second line of defense) are serving as an engine and a catalyst for the development of other risk domains.

In the area of **policy and models,** companies have mainly worked to strengthen risk policies and refine measurement methodologies and control procedures. More recently (driven by increasing regulatory pressure), the definition of risk appetite is also being addressed together with its deployment in the organization.

Finally, as far as **IT processes and support** for the Risk Function are concerned, the energy industry has worked for years to systematize the measurement and control of financial and operational risk, supporting the role of the first line of defense.

Today, the challenge for companies is mainly to enhance IT support for risk control and reporting purposes and to develop less advanced risk areas such as operational risk.

In short, organizations are making efforts in three main areas of action:

- Defining and deploying new risk functions that will further develop the three lines of defense model, and promoting initiatives to foster integrated risk management ensuring that all areas of the company participate and interact (like defining the risk appetite framework).[19]

[18] In the financial industry, the Risk Function in general is located at the first level of the organization (Global Division Executive or VP reporting to chairman or CEO).
[19] The combined assurance model developed from EWRM and focuses on an integrated and coordinated approach by all participants in the risk management process, both internal and external. The main purpose of this model is to optimize risk assurance and integrate all assurance-related information into a single, clear and agreed upon vision of the risk management situation in the company.

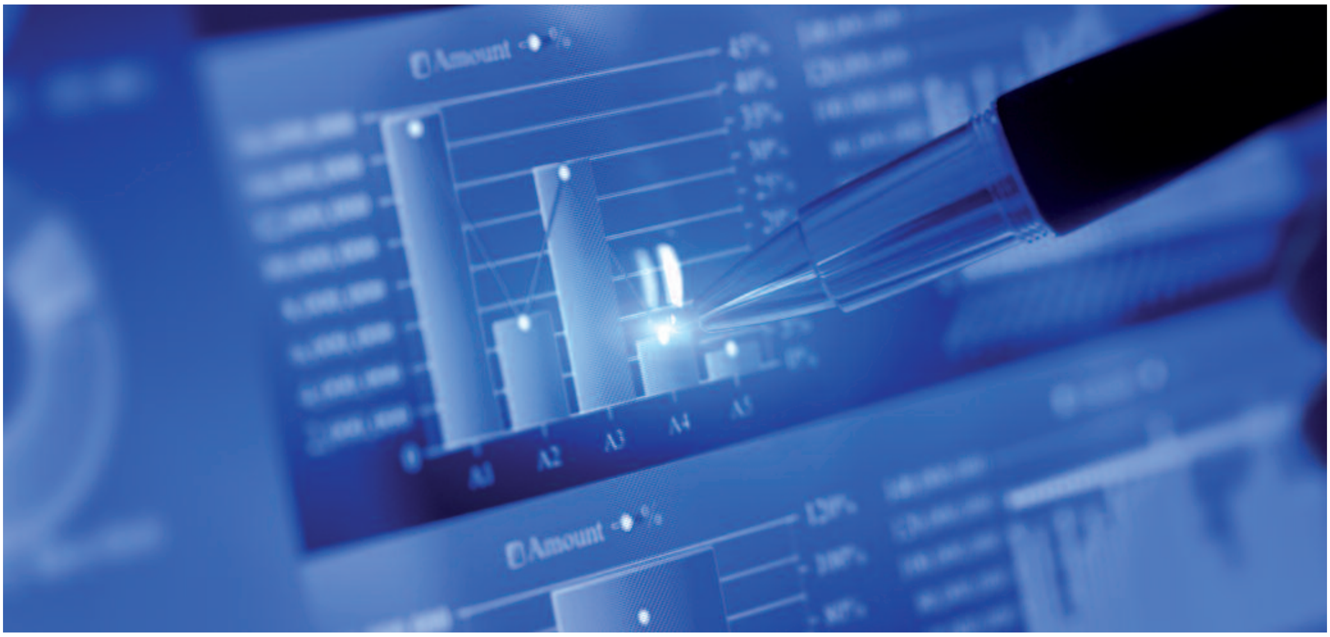


Table 2. Relevant publications

Body	Scope	Publication	Key aspects
BCBS (BIS)	Worldwide	*Principles for Enhancing Corporate Governance (2010)*	• Governance (Board committees) and organization • Remuneration
COSO	Worldwide	*Enterprise Risk Management -- Integrated Framework (2004) (COSO II)*	• Corporate risk management and Internal control
IIF	Worldwide	*Implemementing robust risk appetite frameworks to strengthen financial institutions (2011)*	• Risk appetite • Stress and scenario testing
ISO	Worldwide	*Risk Management – Principles and guidelines. ISO 31000-2009*	• Guidelines for implementing risk management processes
EBA	Europe	*Guidelines on Internal Governance (GL-44) (2011)*	• Lines of defense • CRO, Internal Control, Compliance and Audit
European Commission (Liikanen)	Europe	*High-level Expert Group on reforming the structure of the EU banking sector (2012)*	• Ring-fencing • Corporate governance
Senior Supervisors Group	Europe	*Observations on Developments in Risk Appetite Frameworks and IT Infrastructures(2010)*	• Risk appetite: governance, scope and follow-up
ESMA / U.S.A.	Europe/USA	*European Market Infrastructure Regulation / Dodd–Frank Act*	• Reporting of operations to a trade repository • Potential obligations regarding clearing and the adoption of risk mitigations techniques
Independent Commission on Banking (Walker)	UK	*A review of corporate governance in UK banks and other financial industry entities (2009-ongoing)*	• Board Risk Committee (BRC) • CRO • NEDs
PRA (ant. FSA)	UK	*Effective corporate governance* (CP 10/3 and PS 10/15) (2010)	• Implementation of the Walker Review • Significant Influence Functions (SIFs)

- Integrating the Risk Function in the business process so as to give it a more central role in decisions that are either strategic or have a potentially significant impact on business.

- Developing risk domains that are traditionally less advanced in terms of risk measurement and management. In this regard, it is worth noting that there are highly sophisticated methods for commercial credit and counterparty risk (and their interaction with market risk), as well as for environmental risk, compliance risk, model risk and operational risk, which is discussed further later in the document.

Regulatory context

The development of the Risk Function in organizations is largely encouraged, and in some aspects regulated, by both supranational organizations and local regulators, as well as agreements reached by company groups and associations, the academic world and independent institutions (e.g. COSO).

The position adopted by all these bodies is convergent and points towards further development of the Risk Function. Table 2 provides a non-exhaustive overview of some of the key publications and regulations affecting the industry, including a specific reference to financial sector regulations given their particular stage of development.

Operational risk

Operational risk concept

Operational risk definitions vary from broad views that include in this category everything that cannot be considered as business risk, to more restrictive views that only include the risk of loss resulting from inadequate or failed internal processes, people, systems or external events.

In the financial industry, a commonly accepted definition is contained in the Basel II accord: "the risk of loss resulting from inadequate or failed internal processes, people or internal systems or from external events". This definition is significant because it is often used as a reference due to a lack of adapted and widely accepted definitions in other industries.

Operational risk losses are usually understood to mean all additional costs resulting from events that would not have been incurred had such events not occurred. Loss calculations generally include losses, legal contingencies and refunds and non-financial industries usually also include opportunity cost and lost profits.

The amount of the loss can be reduced by partial or full recovery. Recoveries are usually classified into direct (caused by action taken by the company) and indirect (usually brought about by insurance).

Operational risk classification and identification

The Basel II Accord is particularly useful for classifying operational risk in the industry, as its proposed classification into seven types of operational risk is often used as a reference point in industries where operational risk management is not as heavily regulated:

- ***Internal fraud:*** losses due to acts intended to defraud, misappropriate property or circumvent regulations, the law or company policy, in which at least one internal party is involved for their own benefit.
- ***External fraud:*** losses due to acts intended to defraud, misappropriate property or circumvent regulations, by a third party.
- ***Employment Practices & Workplace Safety:*** losses arising from acts inconsistent with employment, health & safety laws or agreements, from payment of personal injury claims, or from diversity/discrimination events.
- ***Clients, Products & Business Practices:*** fines, compensation and costs arising from regulation infringements by the company, and from claims from customers that have suffered an economic loss or consider themselves to have been adversely affected by the company.
- ***Damage to Physical Assets:*** damage to physical assets from natural disasters or other events.
- ***Business Disruption & System Failure:*** direct losses arising from failure of systems supporting the business activity.
- ***Execution, Delivery & Process Management:*** losses from failed transaction processing or process management, from relationships with trade counterparties and vendors.

In the specific case of the energy industry, operational risk classifications are often similar to the above, since they are usually based on the source of the risk, i.e. there are categories for risk relating to individuals (e.g. health and safety), processes (e.g. productive asset management), systems (e.g. information security) and external events (e.g. environment). It is common for organizations to include compliance risk, as well as ethics and conduct risk, within the operational risk domain.

Within the framework of insurable operational risk, the subject of this document, it is common for risk categories to be linked with insurance lines: property damage and loss of profit, civil liability, political risk, freight, etc.

Having established a classification for operational risk, companies try to identify the specific risks to which they are exposed in their business activities, for which there are different approaches:

- ***Bottom-up approach:*** used to identify all company risks. It entails a detailed review of processes, which often results in thousands of risks being revealed. Under this approach, risk identification often goes hand in hand with the identification of controls in place for each process for risk mitigation purposes. An example of this approach are the control models derived from the Sarbanes-Oxley Act. It has the advantage of being highly comprehensive and thorough, and the disadvantage of requiring many organizational resources.

- ***Top-down approach:*** aimed at identifying major company risks. It requires identifying the most common risks in each category and mapping these risks to business lines in order to determine their applicability, which tends to reveal hundreds of risks. An example of this approach is the risk estimation effort carried out by internal audit areas as part of their planning activity. It has the advantage that it allows companies to focus efforts on managing key risks and the disadvantage that some risks may be overlooked.

The techniques described below are valid irrespective of the risk classification and identification approach chosen.

Operational risk assessment methods

Once operational risks have been identified and classified, it is necessary to assess their materiality. Different approaches and methodologies may be used for this purpose.

Assessment methodologies may be classified according to the data provisioning sources that support them. Based on this premise, a distinction can be made between those using expert information, such as scenario analysis methodology, and those based on historical operational loss event data, such as the loss distribution approach (LDA) methodology (Table 3).

Although this classification is useful for informative purposes, in practice data from the different sources available is used for all methodologies described.

Methodologies based on expert information

Methodologies based on expert information are those used in operational risk assessment through the estimates provided by organization staff ("experts") that have better knowledge and information on the risks to be assessed, based on previously established criteria.

Different techniques are available to assess operational risk on the basis of expert information, self-assessment questionnaires and scenario analysis being those that are most widely used:

- ***Self-assessment questionnaires:*** techniques based on information collected by experts through questionnaires designed to gather information on the impact and frequency of the identified risks, the effectiveness of existing controls and the possibility of setting up additional controls, and the follow-up of ongoing improvement plans.

[20] As may be the case in extreme weather events such as "El Niño", which is is characterized, among other physical and atmospheric elements, for rising water temperatures in the central and eastern tropical Pacific, leading to disastrous climate changes (heavy rains, cyclones, droughts, erosion, waves, etc.).

Table 3. Main information sources

Information sources	Characteristics	Advantages	Disadvantages
Expert information	Usual evaluation methods - Questionnaires: used to gather information on risk evaluation and controls by those responsible for business activities. - Scenario analysis: working sessions during which experts analyze material risks in depth.	- Operational risk can be estimated in respect of activitivies for which there is no history of past events (particularly useful for high impact, low frequency risks). - Provides insight into how risk might develop going forward (considers changes occurred in assets, processes, the control environment, etc.).	- It can be difficult to unify the evaluation critaria among the different evaluators. - It requires a strict approach by the evaluator as well as capacity for abstract thinking in order to picture hypothetical scenarios.
Incident and internal loss databases	- List of company losses and incidents in previous stages that may not necessarily result in losses. - Basic information: - Date of occurrence. - Cause. - Gross loss. - Net loss. - Risk and line of business.	- Provide detailed information on the company's internal events. - It is a key input for insurers to determine the price of an insurance program.	- It requires internal data capture systems and processes usually not available in non-financial industries except where reported accidents are concerned. - There are usually few low frequency, high impact events.
External loss databases	- Public databases that contain information provided by suppliers. - Databases from entity groups (local or international).	- Allow the inclusion of events that could eventually take place in the company.	- They often lack information on events (e.g. date of the event, cause, etc.). - Require the use of scaling factors and criteria to adjust to company size and characteristics.
Indicators (KRI))	- Metrics and ratios that contribute information about the level of operational risk.	- Warn on changes that might be indicative of unfavorable developments in terms of risk exposure. - Can be used to set limits that will trigger actions.	- Require internal information capture systems and procedures.

Figure 7. Assessment scales example

Example of expected loss severity intervals

- Null impact
- Very low (under 300 €)
- Low (300 – 3,000 €)
- Medium (3,000 – 6,000 €)
- Medium high (6,000 – 30,000 €)
- High (30,000 – 60,000 €)
- Very high (60,000 – 300,000 €)
- Critical (300,000 – 600,000 €)
- Highly critical (600,000 – 1,000,000 €)
- Catastrophic (over 1,000,000 €)

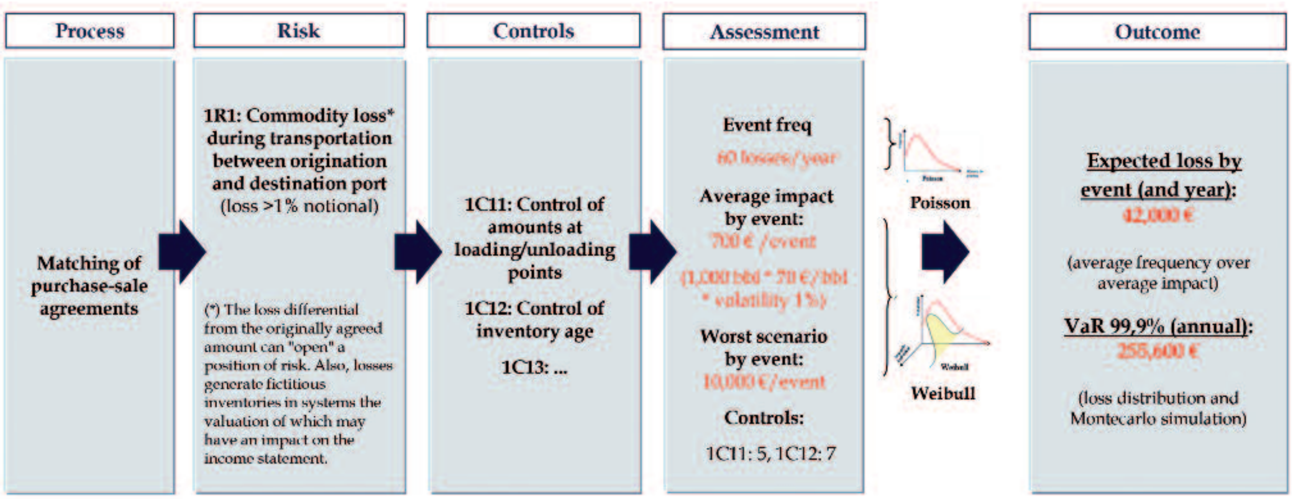
Example of intervals within controls

- Criticality
  - Desirable
  - Convenient
  - Necessary
  - Essential
- Coverage
  - Non-existent
  - Exists and is not applied
  - It is applied occasionally
  - It is applied frequently
  - It is always applied

British Bankers Association scale for the assessment of reputational impacts

- No external effect
- No media coverage, slight increase in customer complaints
- Local or financial sector media coverage, increase in customer complaints, potential loss of some customer accounts
- National media coverage, sharp increase in customer complaints, some loss of customers, information requests from the regulator (informal), possible involvement of Bank directors
- Strong media coverage at national level and moderate at the international level, serious loss of customers, formal investigation by the regulator, involvement of Bank directors
- Strong national and international media coverage, loss of customers on a large scale, deep involvement of the Bank's most senior management

Figure 8. Modeling example based on average frequency, average impact and worst case scenario



The outcome from the questionnaires is the result of a subjective assessment by operational managers. The company should ensure properly defined criteria are used in the assessment as well as a rigorous and impartial approach during the completion process.

Impacts other than purely economic ones, such as reputational, compliance or goal achievement-related impacts are often also recognized and assessed using qualitative scales (Fig. 7).

From these assessments it is possible to approximate risk metrics such as expected loss (qualitative) and maximum potential loss (qualitative VaR) given a specific confidence level[21] and time horizon[22] (Fig. 8).

Finally, both recurrent loss data (expected loss) and data on potential exposure (unexpected loss) can be converted to a qualitative scale that will be used to present the results.

Thus, companies often refer to low, medium, high and very high potential exposure and recurrent losses.

The final step is to evaluate the controls associated with the different risks and to determine the existence of any related reputational risk and its significance.

[21] Usually 99,9%.
[22] 1 year frecuency.

- ***Scenario analysis:*** the scenario analysis methodology is based on the definition of hypothetical operational risk-based scenarios, which are analyzed by expert groups in order to:

  - Identify and assess the most complex and significant risks for the company.

  - Advance the risk management culture through the involvement of executives from different areas of the organization.

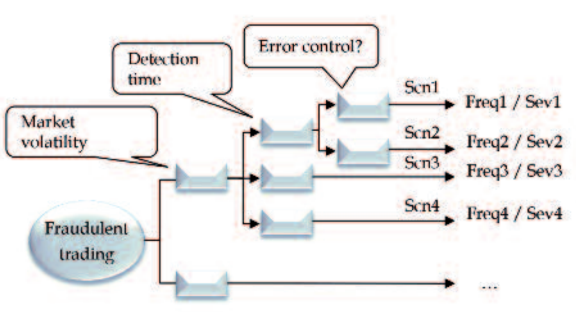
  - Establish prevention or mitigation actions that should be triggered quickly in response to an operational event.

Scenario analysis is usually carried out through workshops involving different professionals from the organization who contribute their knowledge of business processes, (e.g. business areas), of the control environment for each risk (e.g. internal control or risk management areas), of internal and external conditions that may have an impact on risk assessment (e.g. systems areas), etc., coordinated by an operational risk expert who provides a method as well as guidelines.

This method is based on defining a hypothetical risk situation considered to be plausible for the company and proposing different what if hypotheses that will result in different outcomes in terms of probability and impact (Fig. 9).

Probability distributions of frequency and severity are fit to the above data and are convoluted in order to produce the loss distribution, from which the expected and unexpected loss is obtained.

Figure 9. Scenario analysis



Methodologies based on historical operational loss event data

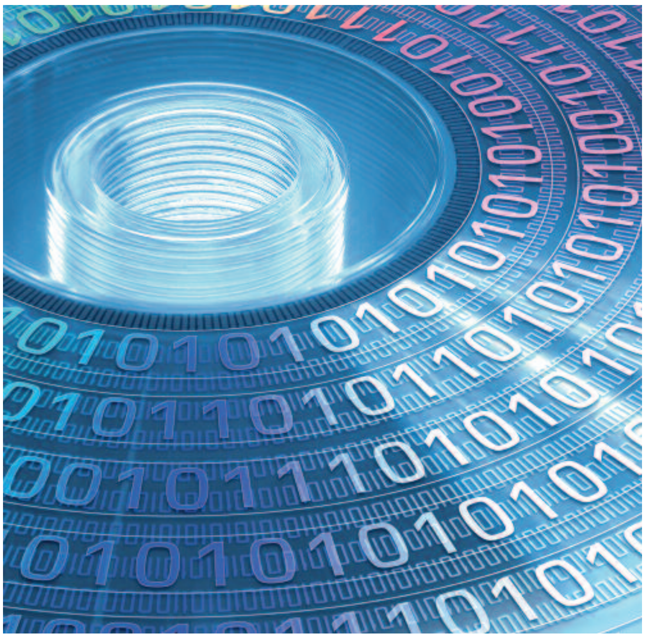
Quantitative data-based methodologies rely on a previous stage of operational risk event loss collection and analysis. In the financial industry, banks often have events collected either internally or externally. However, in companies operating in the energy industry, internal loss event databases are rarely available (except for reported claims), neither is this type of data available from external sources. For this reason, the first step for the use of these methodologies is to prepare and structure information that will feed the risk measurement process.

There are two types of operational risk event loss databases:

Internal loss event database. A key piece to support quantitative data-based methodologies. It should help companies to better understand their operational risk and it should make it easier to establish corrective measures to improve control, to compare between qualitative and quantitative results and to lay the foundations for the implementation of methodologies that are based on the company's own history of losses.

External loss event database. Basel II takes the view that companies' internal loss databases are not deep or reliable enough for modeling operational risk if advanced models (AMA[23]) are used and therefore requires them to be supplemented by using external loss databases.

[23] Advanced Measurement Approach.



Scenario analysis

Scenario analysis makes it possible to determine loss distribution characteristics for a particular operational risk through:

- Estimating *n* loss scenarios considered to be plausible, in terms of their frequency and severity (usually expressed as: an event amounting to *s* euros occurs once every *d* years).
- Fitting the best loss severity distribution from the standard statistical distribution range for operational risk (Weibull, gamma, lognormal, etc.).
- Estimating a loss distribution from the data provided.

Two different techniques are typically used depending on whether or not the average case scenario is identified[24]. (Fig. 10).

The main characteristics of each method are described in Fig. 11.

Any of the above techniques solves the operational risk quantification problem based on expert scenario simulation by means of statistical distribution fitting. If the average case scenario is provided, however, the approach is valid for any number of scenarios.

One of the advantages of scenario analysis is that it is based on simple sentences for the evaluator (*y* euros are lost every *x* years) and provides an objective criterion for choosing the best distribution among a range of possibilities. In addition, the mathematical formulation can be supported by a calculation engine in a way that is virtually transparent for the user (does not require statistical knowledge).

Both methodologies can be used to obtain an estimate of risk and can be supplemented by methods that rely on quantitative information sources.

Operational risk classes

Registering an ORC is an iterative process in which, based on already established combinations (ORC base), candidate ORCs (or event combinations) which could form part of a specific group due to having a similar risk profile are examined.

Using techniques for the analysis of descriptive variables (central tendency or location indices, variability or dispersion indices, shape indices[25], position indices[26], box-plots, histograms, etc.) and for exploratory analysis (mid-summary, p-sigma, etc.), data samples can be examined in order to identify any matching patterns in the candidate series against the base series and decide on their aggregation.

Operational risk classes add consistency to the calculation process, for the following reasons:

- Operational risk source processes are standardized.
- Events may be grouped to produce a number that is sufficient for modeling purposes.
- Provide statistical uniformity to samples (sets of indicators and statistical graphs for descriptive and exploratory analysis as well as for the analysis of model assumptions).
- Provide a statistical basis that can be transferred to other sources: external and built from expert judgment scenarios.

Figure 11. Main characteristics of scenario analysis techniques

Without average case scenario

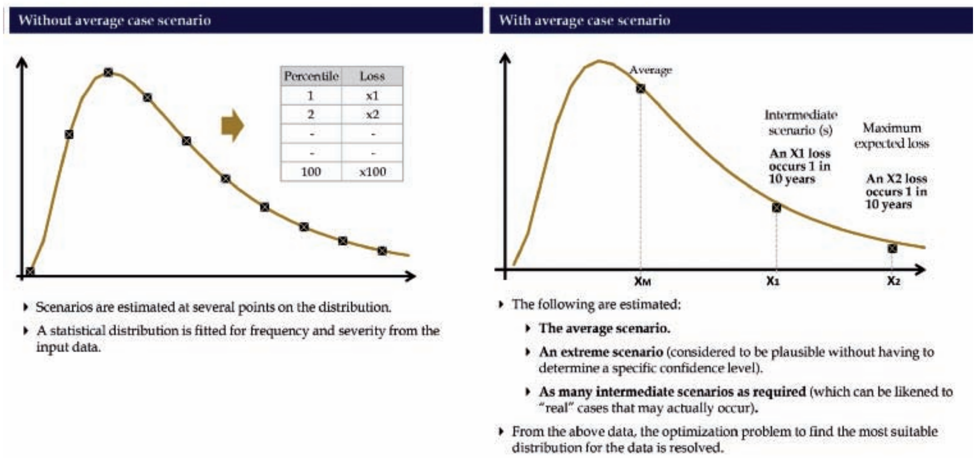
- Methodologically, it is difficult to find distributions that are a good fit for all scenarios.
- The evaluator needs to estimate scenarios that are representative of the different parts of the severity distribution.

With average case scenario

- It is easier to find distributions that fit all scenarios well.
- The expected loss can be obtained directly from the average scenario without the need to make statistical adjustments.
- A good fit for the body and tail of the distribution can be obtained from a few scenarios.

[24]This methodology would also apply if the evaluator estimated the scenario that occurs more often rather than the average case scenario, i.e. the mode instead of the mean.
[25]Skewness and kurtosis
[26]Quartiles and percentiles.

Figure 10. Examples of scenario analysis with and without an average case scenario



Although this type of information is not yet available for the energy business, in the financial industry there are currently two types of external databases:

- Publicly available databases: they collect information provided by vendors such as consulting firms or insurance companies, and typically provide information on events with a very high loss threshold.

- Databases owned by consortiums of entities: they are either local or international. These consortiums provide a way for member institutions to exchange operational risk loss information while preserving the confidentiality of the data. The reporting threshold is much lower than in the public databases. Some of the best examples are ORX (Operational Risk Data Exchange Association), GOLD (Global Operational Loss Database), DIPO (Database Italiano Perdite Operativo) and ABA (American Bankers Association).

Data from external databases are mainly used in two ways: in scenario analysis as supplementary information to assess exposure to high-severity loss events, and to provide extreme events in the loss distribution tail.

They also serve as a tool to benchmark against other institutions in the industry, as they allow companies to compare capital charge relative to gross income, losses over time and loss distribution by business line, as well as information on severe loss events.

Loss distribution methodology

The loss distribution approach (LDA) or loss distribution methodology is the most commonly used method for measuring operational risk from quantitative events.

This method is used to model a company's operational risk and produce a loss distribution for each of the identified risks. Also, if insurable risk is being assessed, it can be used to determine the optimal coverage scenario, linking the economic impact to the income statement through the insurance program.

This method requires the availability of operational loss event data which are then classified according to their nature in order to be modeled jointly and for the distributions to be fitted. Typically, different sources are combined, usually internal and external loss databases, or internal loss databases and information obtained through subjective loss scenario assessment.

The two main steps in this methodology are data analysis and processing, and gross loss modeling, which in turn can be broken down into five stages (Fig. 12).

Risk analysis and data processing. First, it is necessary to verify the quality of the data available for the calculation process and detect records that will not be used by performing a series of validations. Some of these records are: data outside the defined time window, anomalous and erroneous data, or atypical data.

Also, the risks to be assessed need to be identified and classified in order to group operational risk events with a similar behavior. Risks are then classified into uniform classes or categories (ORC - Operational Risk Class) both from a statistical and an insurance standpoint.

It should be noted that the Basel accords establish uniform risk categories based on two classification criteria: line of business and risk category. Basel also defines second-level categories for each of these criteria, leaving it at the entities' discretion to add additional levels if necessary. In the case of non-financial corporates, there is no closed definition regarding the classification criteria.

Figure 12. LDA methodology – Stages of the loss distribution calculation process

	Operational risk-based costs definition	Distribution fitting	External and qualitative data integration	Loss distribution calculation	Sensitivity analysis
AIM	Data analysis (internal, external and qualitative data). Selection of Operational Risk Classes (ORC).	Fitting of frequency and severity distributions to each ORC.	Completing series with expert information and external data. Integrated frequency and severity distributions.	Integrated loss distribution generation. Expected loss and VaR calculation.	Stability techniques. Sensitivity: impact of calculation decisions on results.
KEY ASPECTS	Internal data: data completeness and absence of anomalous / erroneous data. External data: relevance and scaling. Expert information: lack of consistency in scenarios (model input and output data).	Samples: lack of data in some ORCs. Distribution catalogue: wide range of severity distributions to consider. Distributions: need to fit fat tails.	Integration: rule and mixtures to be applied. Extreme events: consider them, though limiting their 'weight' in the calculation. Expert assessments from the last self-assessment exercise.	Correlation: robustness of correlation estimators. Estimation at Group level and for each Unit: diversification effect.	Knowledge of factors with the greatest impact on the results achieved. Active management and consideration of action lines that support the Group's interests.

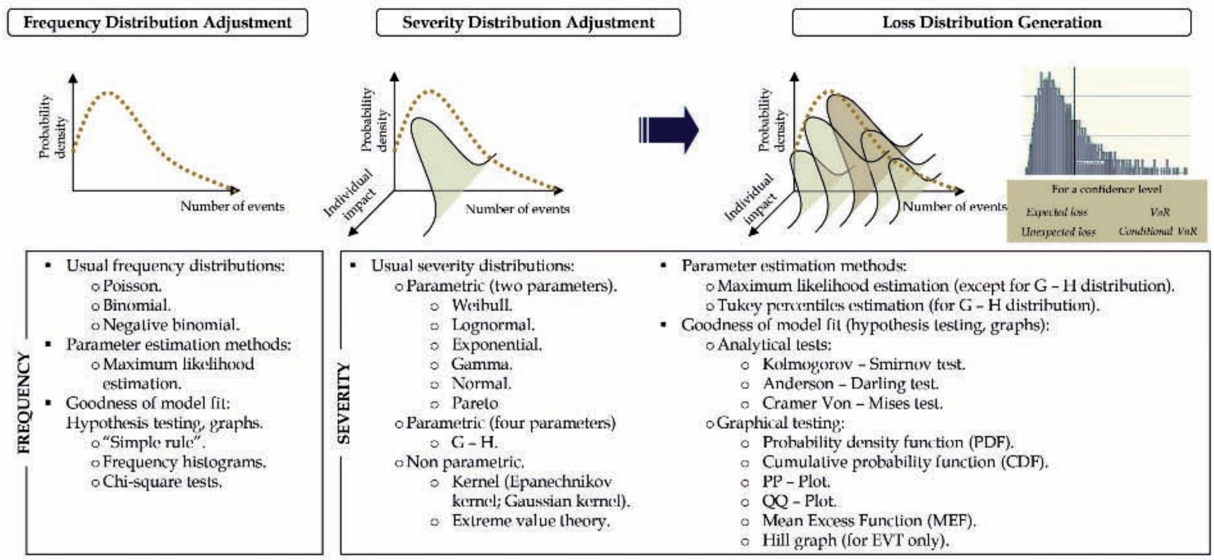
Distribution fitting

Parametric distributions are typically used in distribution fitting processes for the estimation of severity. Bi-parametric distributions (e.g. Weibull, lognormal) are often used, as are distributions of more than two parameters that are sensitive to skewness and kurtosis patterns (e.g. generalized hyperbolic distribution).

However, sometimes parametric distributions do not provide a sufficiently good fit to operational event sample data. This insufficient fit is most evident in data clusters with fat tails or, where this is the case, with outliers that should not be deleted based on business considerations. In such cases, it is possible to undertake the fitting process using semi-parametric distributions (e.g. kernel).

Typically, the chosen severity distributions do not take negative values because a negative loss could be considered again, which would not make sense.

Figure 13. LDA methodology



The last step requires verifying that the LDA methodology premises are met: independence between frequency and severity[27] (by examining seasonality, trends and frequency-severity correlation, etc.) and absence of serial autocorrelation in frequency and severity[28] (through the autocorrelation function and Durbin-Watson, Ljung-Box and runs tests) for each ORC.

The Operational Risk Category (ORC) groupings, ready to be used in modeling, are the output from the risk analysis and data treatment process.

Fitting of distributions. Once events have been grouped according to their nature, the loss distribution for each ORC is determined by fitting a frequency distribution and a severity distribution. This is done by conducting a number of statistical tests on a range of commonly used distributions and selecting the pair that provides the best fit. Integrating the loss distributions obtained for each group allows you to obtain an aggregate loss distribution, which should be built taking into account the diversification effect across groupings through the correlation matrix.

[27]The frequency of an ORC should not determine the amount of its severity.
[28]Verifying that both severity and frequency at a given time are independent from severity and frequency in the preceding time.

Severity distributions used to estimate losses should reflect a reality in which high frequency, low impact events coexist with low frequency, very high impact events. This situation requires distributions to have sufficiently wide tails to contain high severity events.

However, in some cases, the body and the tail of the sample can be fitted with two separate distributions. When this is the case, Extreme Value Theory[29] is used, as it focuses on improving the fit for high losses through a mixture of distributions in which the body follows one distribution and the tail follows another distribution: a General Pareto Distribution (GPD) or an exponential distribution.

External and qualitative data integration. There are different methods for integrating data from expert assessments or from external databases into the loss distribution calculation.

The most common methods are the Credibility Theory-based method to integrate data on frequency and the Dutta and Babbel[30] method to integrate data on severity, which basically consists of adding data to the historical sample shown in those sections where the sample is underrepresented.

Loss distribution calculation. Once the frequency and severity distributions have been fitted, the loss distribution for each ORC in the data sample and also for the totality needs to be obtained. This requires the frequency and severity distributions to be convoluted using Monte Carlo simulations.

Several representative measures can be obtained from the loss distribution:

- Expected Loss (EL): arithmetic mean of the simulated loss.
- Value at Risk (VaR): maximum expected potential loss given a specific confidence interval and time horizon.
- Unexpected Loss (UL): difference between the expected loss and value at risk (VaR).
- Conditional VaR (CVaR) o expected shortfall: average of all losses greater than VaR for a specific time horizon.

The different insurance policy plans available can be applied to the resulting loss distribution in order to mitigate the outcome and adapt it to the true underlying reality.

As a last step in the process, the previously described measures may be calculated taking into account the diversification effect. This is done by performing a Monte Carlo simulation using a random number generation process in which the initial correlation matrix is preserved (Lurie-Goldberg simulation model).

Validation. The quantitative model obtained should be compared with different techniques and studies on a regular basis to ensure its validity. Some aspects to be considered are the sensitivity of results to changes in the model variables, the stability of the calculations to variations due to both intrinsic causes (operational loss distribution dependent on the randomness of the simulation process) and outside causes (reduced size of the loss data sample and loss data variability, such as fat tails), and model backtesting (comparing the estimated operational loss to the actual loss for the calculation period).

[29]If the distribution of the losses exceeding a threshold converges to a limit distribution when the threshold increases, then this distribution is either an exponential distribution or a generalized Pareto distribution.
[30]*Scenario Analysis in the Measurement of Operational Risk Capital: A Change of Measure Approach.*

Figura 15. Loss distribution measures

Goodnes of fit tests

Once the various candidate distributions have been fitted, they should be tested and compared in terms of their suitability. This can be done through a number of goodness of fit tests that can be either analytical or graphical:

Analytical testing: using tests to observe the differences between the empirical distribution (F) and the selected theoretical distribution (F_0). These tests calculate the maximum distance between the two distributions and decide based on this distance whether the null hypothesis (H_0:F= F_0) is to be accepted; i.e. whether the empirical distribution provides a good fit to the chosen theoretical distribution, or if this hypothesis is to be rejected in favor of the alternative hypothesis (H_1:$F_1 \neq F_0$) is accepted.

Some commonly used tests are the Kolmogorov-Smirnov, the Cramer-von Mises and the Anderson-Darling tests. Their inputs are the loss variable from the ORC (x) and the level of accepted significance (α).

- **Kolmogorov-Smirnov test.** Checks the maximum difference between the empirical distribution and the chosen statistical distribution. It can be applied generally to all distributions, as its critical values do not depend on the specific distribution being tested.

  This statistic is expressed in the following way:

  $D_n=\max\{\max_{(1\leq i\leq n)}[F_n(x_i)-F_0(x_i)],\max_{(1\leq i\leq n)}[F_n(x_i)-F_0(x_{i-1})]\}$

  where

  - n is the number of observations in the sample.
  - F_n is the value of the empirical distribution function for a given x_i.
  - F_0 is the value of the theoretical distribution function for a given x_i.

  The values of the distribution function for this statistic are tabulated based on the level of statistical significance (α) and the sample size (n).

- **Cramer-von Mises test.** It has the same applications as the Kolmogorov-Smirnov test, but greater sensitivity to irregular points in the sample (or aberrant points).

  This test is based on a statistic that measures the sum of the squared maximum distance between the empirical and the theoretical distributions, and needs to be calculated taking into account the distribution being considered:

  $$W^2 = \frac{1}{12n} + \sum_{i=1}^{n}\left(Z_i - \frac{2i-1}{2n}\right)^2$$

  where:

  - n is the number of observations in the sample
  - $Z = F\,(x\,;\theta)$ is the vector of probabilities for the distribution function considered F and the vector of estimated parameters θ.

  The W^2 statistic should then be fitted based on the distribution being considered.

  The p-value will need to be calculated to obtain the test result, using a different procedure for each distribution.

- **Anderson-Darling test.** Used to test whether a data sample comes from a population that follows a specific distribution. This test gives more weight to the distribution tails than the previous two tests and uses the specific distribution being tested to calculate critical values. It has the advantage of allowing more sensitive testing and the disadvantage that critical values have to be calculated for each distribution being tested.

  The Anderson-Darling statistic is defined as:

  $$A^2 = -n - \frac{1}{n}\sum_{i=1}^{n}[(2i-1)logZ_i + (2n+1-2i)\log(1-Z_i)]$$

  where:

  - n is the number of observations in the sample.
  - $Z = F\,(x\,;\theta)$ is the vector of probabilities for the distribution function considered F and the vector of estimated parameters θ.

  The A^2 statistic should be then fitted based on the distribution being considered.

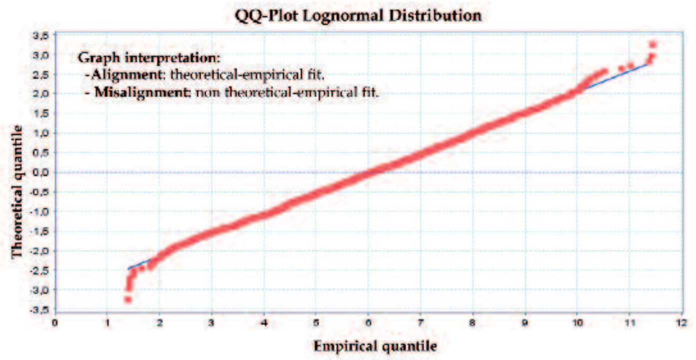
  As in the Cramer-von Mises test, in order to obtain the test result, the p-value will need to be calculated using a different procedure for each distribution.

Graphical tests: goodness of fit tests provide a general measure of how the theoretical distribution fits the empirical distribution. Thus, it may well be that the distribution passes the test because the overall fit is good while the fit for the tails is not appropriate.

Using graphical tests to supplement analytical tests can determine how appropriate this fit is:

- Mean excess graph: allows you to distinguish between light-tailed and heavy-tailed models by comparing the shape of the theoretical and empirical mean excess functions.
- GQQ-plot and PP-plot[31] graphs: these graphs plot the empirical distribution against the theoretical distribution to determine whether the theoretical distribution is a good fit to the sample data. The difference between the QQ-plot and PP-plot is that the first compares parametric families of distributions, i.e. does not consider parameter estimates, while the second compares a single distribution that is completely specified through parameter estimates.

Figure 14. QQ-plot showing the fit of a lognormal distribution



[31]Quantile-Quantile Plot and Probability-Probability Plot.

Key Risk Indicators (KRI)

Finally, a series of indicators are necessary to monitor the operational risk management model. Key Risk Indicators (KRI) are statistics or parameters which are used to anticipate changes in the risk exposure of companies (Fig. 16). These indicators are typically checked on a regular basis to be used as alerts about changes that may reveal negative patterns in risk exposure.

The main KRI methodology goals are:

- Provide information on the company's level of operational risk and identify the main causes of any changes.

- Set warning levels and limits for decision-making by those responsible.

- Identify and measure the effectiveness of controls and any improvements made.

- Identify KRI correlations with operating losses.

The level of detail of the KRI information is different for each area of management and should be suited to the level of those involved in each operational risk management committee.

Figura 16. Example of key risk indicators (KRIs)

KRIs Loss-oriented	KRIs Risk-oriented	KRIs Control-oriented
Product losses in the transport of goods	Investment projects with unavailable funds	Average frequency in updating firewalls to protect access
Losses incurred in assets and related amounts	Purchase orders issued without authorization	Number of hits on the trading rooms
Number of disciplinary proceedings initiated with employees	Number of people with rights of access to invoice return and the master ledger	Number of days with incidents in the data backup (or days without backup)

Operational risk and regulatory capital

Regulations on the calculation of regulatory capital in financial institutions now include operational risk (along with credit risk and market risk) as part of the information on capital adequacy that needs to be individually reported under Pillar 1 of Basel II, where three methods are established for the calculation of regulatory capital for operational risk (Fig. 17):

Basic indicator approach: calculation of regulatory capital through the application of a percentage (15%) on adjusted gross income. This method is aimed at small institutions with a simple business activity structure.

Standardized approach: a step ahead of the basic indicator approach that divides the firm's activity into predefined units and business lines, and calculates capital as a percentage (which varies depending on each line of business) of gross income for each specific line.

Advanced measurement approach (AMA): based on estimating the operational risk loss distribution using loss frequency and severity distributions. These loss frequency and severity distributions can be estimated for each business line and risk type combination. Regulatory capital is based on the calculation of the expected and unexpected loss at a 99.9% confidence level and a one-year time horizon.

The use of advanced methodologies for measuring regulatory capital has led to improvements and developments in other areas, both within financial institutions (e.g. the measurement of economic capital) and in companies operating in other industries (e.g. for negotiating the insurance program). While the loss distribution parameters analyzed in a loss distribution may vary depending on the needs of the analysis, the methodology will be similar to that used in this domain.

Figure 17. Regulatory Capital calculation methods (Basel II)

	BASIC INDICATOR	STANDARDIZED	ADVANCED (LOSS DISTRIBUTION)
QUANTITATIVE REQUIREMENTS	Capital based on ordinary adjusted margin (15%). Aimed at small institutions with a simple business activity structure.	Institution's activity is divided into predefined units and business lines. Capital based on ordinary adjusted margin for each business line (calibrated at 13%). - Retail banking (ß = 12%) - Retail intermediation (ß= 12%) - Asset management (ß=12%) - Commercial banking (ß = 15%) - Agency services (ß = 15%) - Sales and marketing (ß = 18%) - Corporate finance (ß = 18%) - Payments and settlements (ß = 18%)	Institution's activity is divided into business lines and risk types. Capital based on the calculation of expected and unexpected loss (99.9% confidence level over a 1-year horizon). Two distribution functions are used (Severity and Frequency) from which the Operational Risk loss distribution function (VaR) is derived. Insurance is recognized as a mitigating factor up to a 20% limit.

Lower complexity – +
Greater complexity
Lower capital requirements

Use of operational risk measurement methodologies in the energy industry

Background

In recent years, the energy industry has experienced an increase in both the number and magnitude of events that have given rise to claims. Examples such as the oil spill in the Gulf of Mexico from the sinking of BP's Deepwater Horizon platform and the nuclear disaster in Japan in 2011 show the economic and environmental impact that a single operational risk event can have on the energy industry.

During that time, the insurance industry has had to take significant losses that have contributed to higher insurance costs and to heightened pressure on insured companies to retain more risk. Against this backdrop, both insurance and reinsurance companies and regulators, shareholders and stakeholders as a whole require organizations to allocate resources to improve their operational risk management systems.

Recent trends reveal two areas for improvement in operational risk management in the energy industry:

- Improved prevention and mitigation in order to prevent accidents and to minimize damage in the event of occurrence. For instance, more rigorous and frequent inspections of critical assets.

- Improved measurement to better typify and estimate the risks assumed by the company as a result of its business activity and minimize the related cost.

A case study on the implementation of operational risk assessment methodologies in relation to the second area will be provided in this section.

Insurable operational risk management

Transferring risk through insurance is a widely used operational risk management tool. Although different insurance management models are used by companies in the energy business, the most commonly used among large corporations is based on captive insurance.

Under this model, the risk of an organization, usually multinational, is concentrated in a group company that provides insurance for the organization's activities. This model makes it possible to determine the level of risk to be retained in the captive company, and means the organization as a whole has access to the reinsurance market, which gives it greater bargaining power and thus results in lower costs.

The methodology described below answers some of the questions that companies need to consider in order to improve their operational risk management systems:

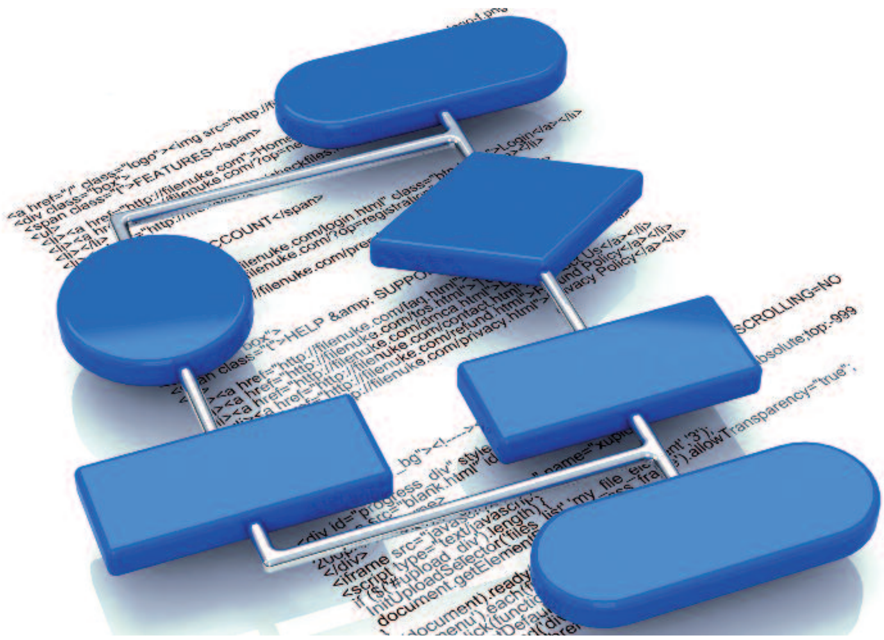
- What is the risk assumed by the company in each of its activities or business lines?

- What is the reasonable cost of the premium for a particular insurance program?

- What is the total cost of risk?

- How does risk vary with changes in company size?

- How is the risk retained by the group distributed between activities or business lines?



Insurance program optimization methodology

The optimization methodology described in this section, which is based on the previously described LDA methodology, consists of seven stages (Fig. 18).

Risk analysis and data processing

The risk analysis and data processing methodology used in this case is similar to that described in relation to the LDA methodology, with the particularity that the sources of information used are usually:

- **Loss data base:** the company's historical claims database is used.
- **Expert information:** the model often incorporates, as a subjective input, the maximum probable loss and maximum possible loss estimates that are usually produced for the most critical assets using methodologies based on expert information.
- **Industry information:** as a supplement to the previous two sources, based on incidents occurred in the industry which, due to their characteristics, are thought to be likely to occur in the company.

Operational risk-based costs definition

One of the goals pursued by the use of this methodology is to minimize the total cost of operational risk (TCOR) for the company. Total cost of operational risk is defined as the sum of the losses caused by the realization of operational risk plus the costs associated with managing this risk. According to this definition, the following key TCOR components have been identified:

- **Transfer costs:** costs relating primarily to the acquisition of insurance (premium, brokerage, intermediation costs, etc.).
- **Retention costs:** cost relating to the realization of uninsured risk or costs outside the insurance thresholds (events below the franchise or above the insured limit).
- **Management costs:** costs relating to risk identification, assessment, monitoring, risk prevention plans, risk mitigation and risk control.
- **Other costs:** in some cases, other components such as the cost of capital or the cost of internal resources needed to tackle risk are included in the definition of total cost.

For the purposes of this study, the total cost of risk is made up of two summands:

- Cost of insured risk (CostIR): corresponds to the insurance policy premium.
- Cost of uninsured risk (CostUR): loss borne by the company.

$$TCOR=CostIR+CostUR$$

Both components will be defined by both the retention levels ("R" – loss levels below which losses are borne by the company) and the insured limit[32] ("L" – maximum loss covered) of the insurance scenario[33]:

$$TCOR=CostIR(R,L)+CostUR(R,L)$$

[32]The insured limit is usually defined in terms of limit per occurrence and aggregate limit.
[33]This characterization has been simplified for the purposes of illustrating the methodology. In practice other variables are considered, including the operating deductible or limits such as the stop loss, which put a limit on the loss that can be borne by a company.

Figure 18. Stages of the insurance program optimization process

Risk analysis and data processing	Operational risk-based costs definition	Frequency and severity modeling	Loss modeling with insurance	Pure premium calculation	Acceptable region and efficient frontier definition	Optimal scenario definition
Definition of uniform groups of losses for insurance modeling and mapping purposes. Analysis of data quality, depth and consistency. Analysis of information sources. Scoping.	Definition of 'cost of insured risk' concept. Definition of 'cost of uninsured risk' concept.	Adjustment of frequency and severity distributions for each portfolio of insurable assets. Review of goodness of fit (and use of expert criteria as a complement). Gross loss distribution outcome (calculation of expected loss, VaR and Conditional VaR).	Allocation of policies to assets according to the line of insurance. Standardization of calculation parameters (franchise, stop loss, limit, etc.). Loss distribution outcome after insurance (retained and transferred). Characterization of losses retained by the business and the captive	Definition of pure premium based on the retained level and insured limit. Analysis of premium components (expected loss -EL-, safety factor, cost and business margin). Comparison of premiums and expected losses and identification of potential savings.	Definition of the total operational risk cost function. Definition of the region of acceptable insurance scenarios for different confidence levels. Definition of the efficient frontier (theoretical optimal premium for each level of risk). Definition of insurable risk appetite policies.	Definition of maximum acceptable loss and related confidence level. Definition of minimum cost function and selection of optimal retention level.

Fig. 19 illustrates the concepts of insured risk (IR) and uninsured risk (UR), as well as the retention level (R) and the insured limit (L). These concepts can be expressed graphically using the loss severity distribution of a single risk.

CostIR may be calculated as the pure premium or expected loss borne by the insurance policy ($EL_{Reinsurance}$). This value will differ from the actual premium payable for such coverage, which includes other costs unrelated to the risk borne by the insurance company (administration costs, commercial premium, tax, brokerage, etc.). However, it is considered to be an acceptable proxy for the purpose of finding the optimum coverage level.

$$CostIR = EL_{Reinsurance}$$

CostUR may be calculated as the sum of the expected loss for the group (EL_{Group}) and the unexpected loss for the group at a confidence level α (UL_{Group}). The values given to α are typically chosen from the high loss distribution percentiles (between 95% and 99.9%) when considering adverse loss realization scenarios[34].

$$CostUR = EL_{Group} + UL_{Group}\ (\alpha)$$

Thus, the total cost of risk is defined as:

$$TCOR = EL_{Reinsurance} + EL_{Group} + UL_{Group}\ (\alpha)$$

This definition of total cost of risk does not account for management costs as defined above. For the purposes of applying this methodology, these costs can be considered to be constant and, therefore, would have no impact on the optimization calculations.

Sometimes companies want to add the cost of capital to the definition of total cost of risk. In this case, the TCOR formula may be adapted as follows:

- Adding WACC (weighted average cost of capital): weigh the unexpected loss by the average cost of capital[35].

- TCOR = p + expected loss+ unexpected loss

$$TCOR = EL_{Reinsurance} + EL_{Group} + UL_{Group}\ (\alpha) * WAC$$

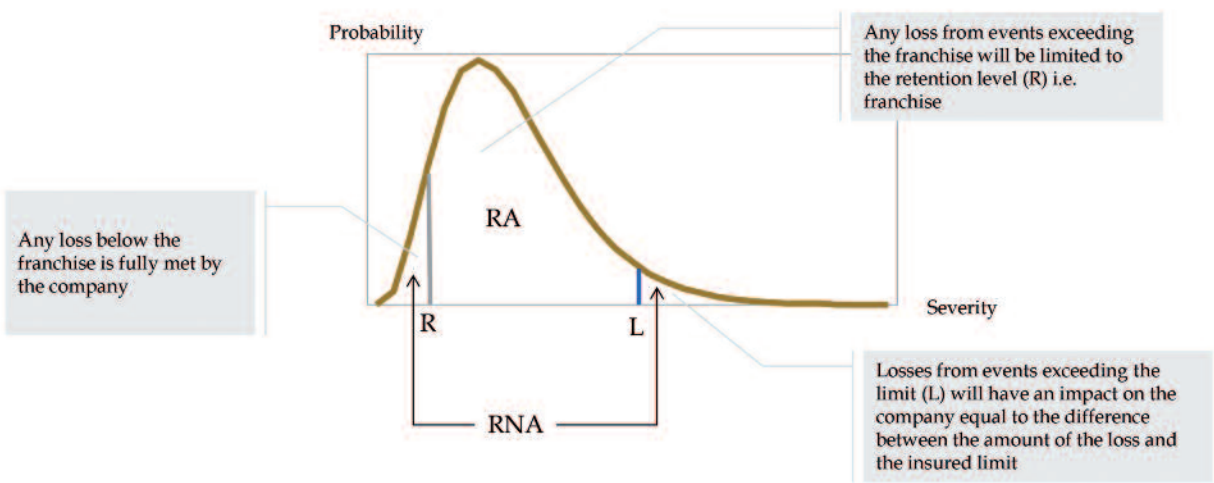
It should be noted that this expression represents a linear behavior of the cost of insurance to movements in retention levels. However, the reality of the insurance market shows that: (a) it is not possible to obtain quotations for all insurance scenarios and (b) increasing retention levels do not result in a proportional reduction in the premium. To reflect this fact, a loading factor (LF) on the pure premium can be included in the TCOR formula, to reflect the fact that the variation in the premium quoted does not respond linearly to changes in the level of retention or stop loss.

$$TCOR = EL_{Reinsurance} * (1+FL) + EL_{Group} + UL_{Group}\ (\alpha) * WACC$$

[34] α of 95% would be equivalent to including in the TCOR value all unexpected group losses below the distribution's 95th percentile, i.e. excluding the loss suffered by the company 5% of all years (1 in 20 years). Similarly, α of 99.9% would be equivalent to including in the TCOR value all losses below the 99.9% percentile, i.e. excluding those occurring 0.1% of all years (1 in 1000 years). It should be mentioned that a year is the usual scale for calculating loss distributions due to being similar to the period of validity of the insurance.

[35] Some companies, mainly in the financial sector, include in the total cost of risk the weighted average cost of capital needed to meet unexpected losses.

Figure 19. Cost of insured risk and uninsured risk



Frequency and severity modeling

This section aims to determine the frequency and severity distributions that best fit the data relating to gross loss, defined as the realized loss without considering the mitigating effect of insurance. The methodology used is similar to that described in section 4 of this document.

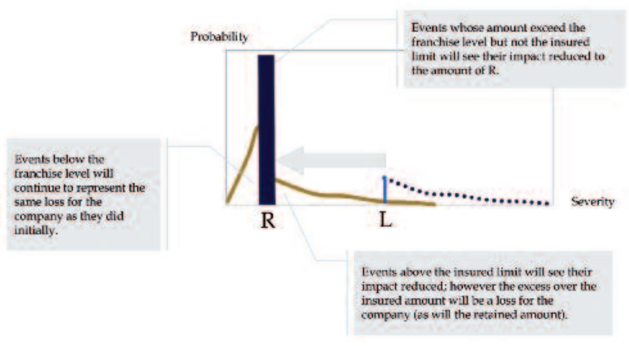
Loss modeling with insurance

Once a gross loss distribution has been obtained, the next step in the methodology is to determine the mitigating effect that an insurance program has on that loss.

Figure 20 shows that using insurance allows companies to shift the loss severity distribution to the extent that such insurance transfers losses between R and L.

The method used to obtain the loss after insurance is to simulate events and apply the existing coverage conditions.

Figure 20. Loss distribution with insurance



Thus, for each event we obtain:

- **Amount of the loss retained by the group:** depending on the characteristics of the insurance program and the focus of the analysis, this data can in turn be divided into the loss borne by the business and the loss borne by the captive insurer.

- **Amount of the loss borne by the insurer:** corresponding to the gross loss arising from the event less the amount retained.

Pure premium calculation

From the application of a given insurance program on the gross loss scenarios, it is possible to characterize the distribution of losses borne by the insurance and, specifically, to obtain the expected loss or pure premium and the loss associated with a given percentile.

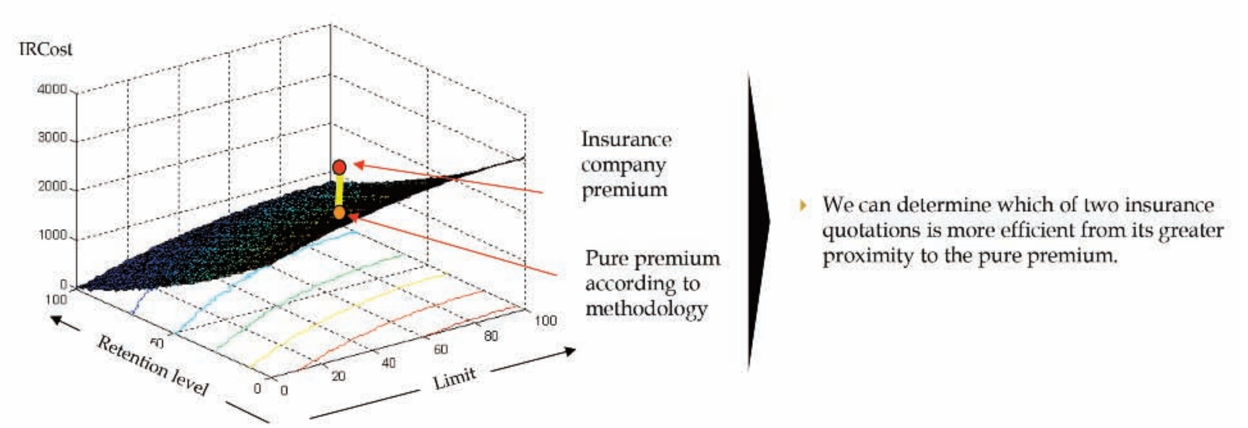
$$\text{Pure Premium} = \text{CostIR} = EL_{Reinsurance}$$

As already mentioned, the pure premium does not match the quoted premium because of the different surcharges that need to be added to the first to achieve the second. However, by calculating the loss distribution borne by the insurance, we are able find out:

- The efficiency of the insurance program: by comparing the pure premium calculated with the quoted premium we can determine how efficient the program is (Fig. 21).

- The percentile for the quoted premium: it is possible to identify which loss distribution percentile the premium requested for a particular insurance policy corresponds to and how far it is from the mean.

Figure 21. Insurance program efficiency



Acceptable region and efficient frontier definition

Not all insurance scenarios represent a tolerable risk situation for a company. Tolerable risk is determined by the company's risk appetite, which in practical terms is usually expressed as the maximum acceptable loss at a given confidence level, i.e. a α confidence level means that there is an α probability that losses will be under the acceptable limit. Equivalently, losses above the acceptable limit will occur with a probability not exceeding $1 - \alpha$.

The risk appetite levels allow a company to rule out insurance scenarios that do not maintain group losses below the maximum acceptable loss at a specific confidence level α. The remaining scenarios are referred to as the acceptable region.

Within the set of insurance scenarios in the acceptable region, those that minimize the total cost of risk represent the efficient frontier.

To illustrate this, the surface shown in (Fig. 22) represents full risk aversion. For retention and limit combinations for which high probability losses are below the acceptable loss (3.2 million euros in this case), total cost is the cost of the premium. Thus, the pure premium will be at its minimum on the efficient frontier of acceptable scenarios.

Optimal scenario definition

Using a basic insurance program as a basis, progressive changes in franchise and limit conditions are simulated to obtain a distribution of the losses retained by the group and transferred to the insurer.

From this simulation of the insurance conditions, we can find:

- The program that minimizes total cost of risk.
- The lowest pure premium program that maintains unexpected loss within the acceptable threshold.
- The most efficient program (best pure premium to quoted premium ratio).

Fig. 23 illustrates TCOR behavior using the above definition.

In scenarios where the retention level is low (scenario 1), the premium will be high and, conversely, in scenarios where the retention level is high, the premium will be low (scenario 6).

The lowest TCOR point will determine the optimal balance between premium and retained risk, and will largely depend on the TCOR definition used, as shown below.

Figure 23. Simulation of insurance scenarios

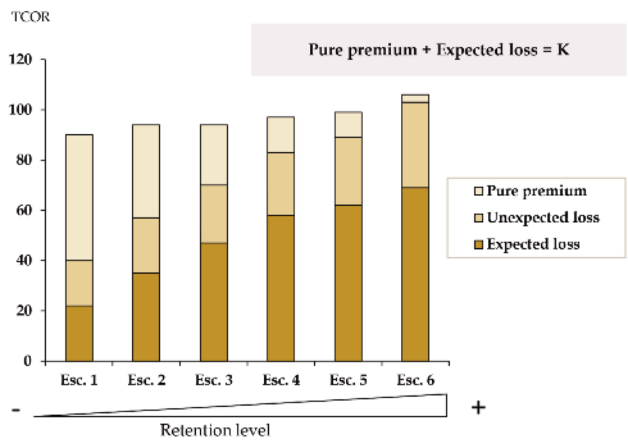
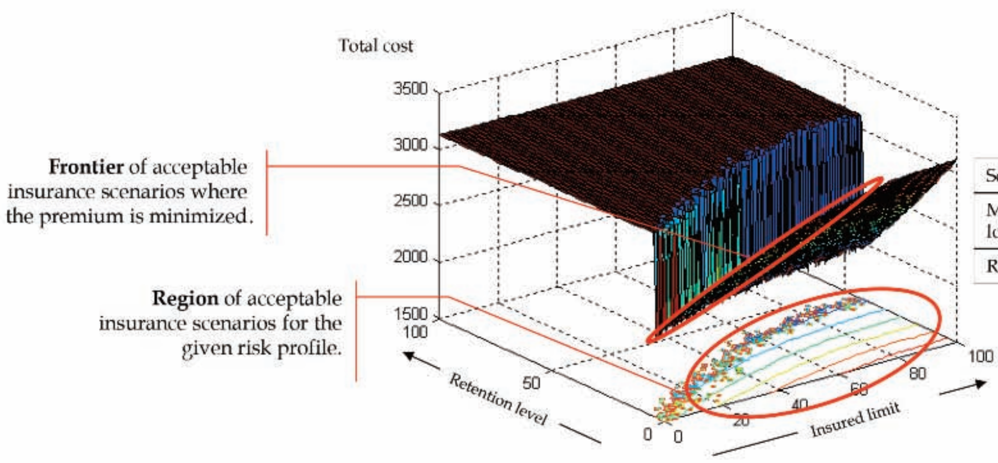


Figure 22. Acceptable region and efficient frontier



Scenarios	5,000
Max. acceptable loss (million €)	3.2
Risk aversion	∞

a) TCOR = pure premium + Expected loss + unexpected loss

As it happens, in this case the pure premium plus the expected loss is a constant that depends only on the gross loss (is equivalent to the expected gross loss).

Under these conditions, TCOR behaves qualitatively like the unexpected loss borne by the group. Therefore, the higher the level of retention, the greater the unexpected loss borne by the group, and the higher the TCOR value (Fig. 24).

If a cap on the loss to be borne by the group is introduced in the insurance program (through stop loss products, for instance), TCOR is no longer sensitive to changes in retention levels above the cap threshold (Fig. 25).

b) Incorporating cost of capital in the TCOR formula

Including cost of capital in the TCOR formula reduces the amount of the TCOR value (because it weighs the unexpected loss), whilst it does not alter its qualitative behavior (Fig. 26).

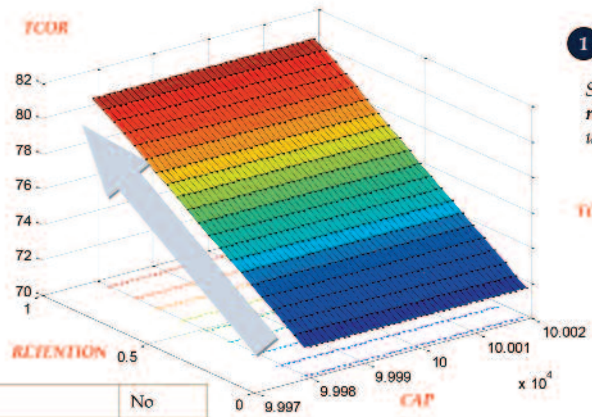
c) Incorporating the Premium Loading Factor in the TCOR formula

Introducing a loading factor causes the pure premium's behavior to be non-proportional to changes in the retention level and the limit. The effect observed is an increase in the TCOR value when retention levels are low, and a decrease in the TCOR value when retention levels are high (Fig. 27).

If the loading factor is made dependent on both the retention level and the cap, the following is observed (Fig. 28):

- In insurance scenarios where the retention level is low and the cap is high (region 1), the TCOR value is high due to the premium being high (since practically all risk is transferred under these scenarios).

Figure 24. TCOR sensitivity to the retention level

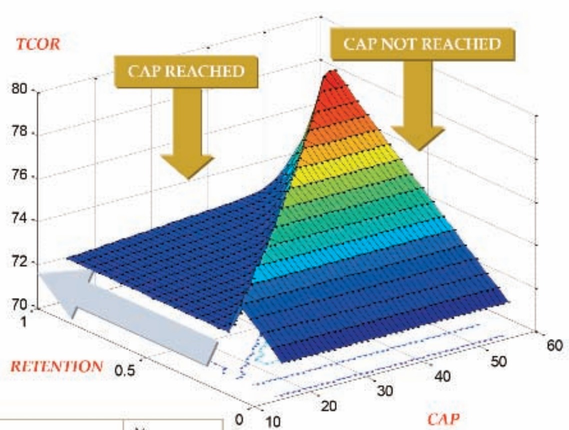


Cap	No
Wacc	No
Premium sensitivity	No

1

Since there is no cap, ***TCOR responds linearly to the retention level****, as changes in this level directly affect unexpected loss.*

Figure 25. TCOR sensitivity to retention level and cap



Cap	Yes
Wacc	No
Premium sensitivity	No

2 $TCOR = K + (P_\alpha - EL_{group})$

Including the cap as a variable in TCOR analysis eliminates premium sensitivity to the retention level *once this level has been reached, since* P_α *is no longer sensitive to retention-level increases once it is limited by the cap value.*

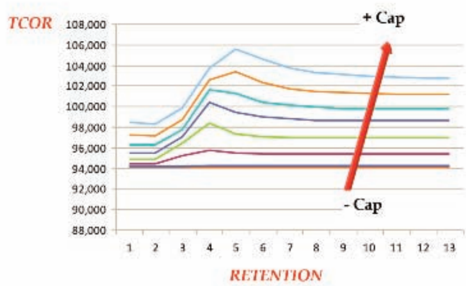
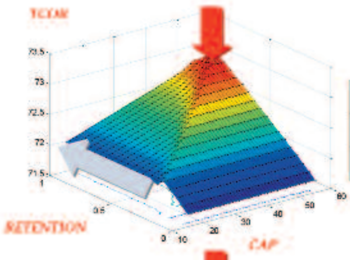


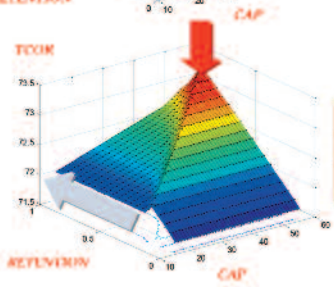
Figure 26. Impact of WACC on TCOR



Cap	Yes
Wacc	Yes (8%)
Premium sensitivity	No

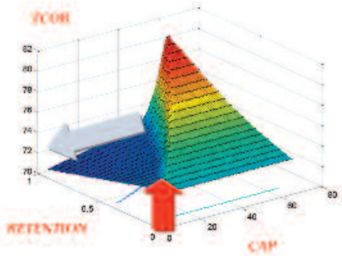
3

Weighing the unexpected loss by a factor such as ***WACC modifies TCOR****. Factoring in the cost of capital associated with the unexpected loss makes* ***TCOR less sensitive to lower insurance scenarios (those where unexpected losses are greater), but it does not change the qualitative behavior*** *of TCOR, as this is constant once the cap has been reached.*



Cap	Yes
Wacc	Yes (12%)
Premium sensitivity	No

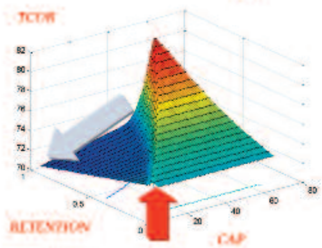
Figure 27. Impact of premium loading factor on TCOR



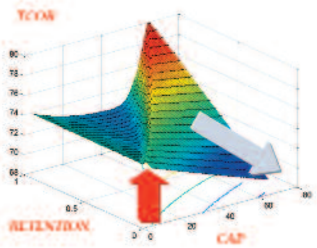
Cap	Yes
Wacc	No
Premium sensitivity (retention level)	Yes (5%)

4

By applying a loading factor to the pure premium, making it ***sensitive to either the retention level or the cap****, TCOR behavior is modified, as TCOR is sensitive to retention levels for a given cap even if the cap has been reached.*

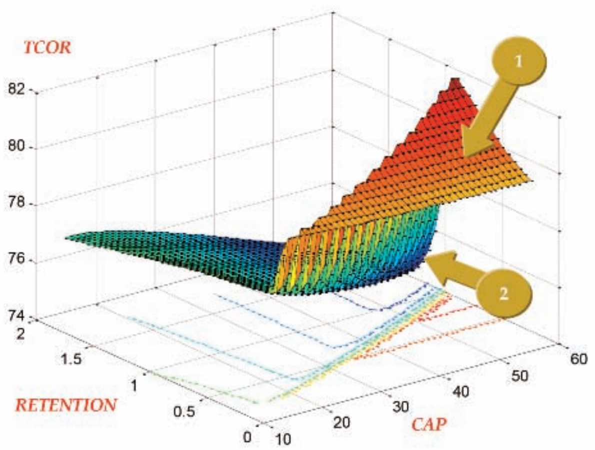


Cap	Yes
Wacc	No
Premium sensitivity (retention level)	Yes (10%)



Cap	Yes
Wacc	No
Premium sensitivity (Cap)	Yes (10%)

Figure 28. Overall impact of the loading factor and WACC on TCOR



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Overall premium sensitivity to the retention level and the cap value *is used to identify optimal insurance strategies characterized by:*

1. *A region* ***where the cap threshold is not reached and the TCOR sensitivity to this threshold is low.***
2. *A region of retention levels where the* ***cap threshold is reached*** *and the premium sensitivity to the retention level determines the* ***optimal strategy.***

Cap	Yes
Wacc	No
Premium sensitivity	Franchise + Cap (stop-loss)

- The optimal TCOR value is found in insurance scenarios where the retention level is average and the cap is reached (region 2).

Applied example

An example of how this methodology is applied to a company in the electricity business is shown below. This example aims to illustrate the modeling of material damage (MD) and loss of profit (LP) for the whole of the power generation and distribution activities over a five-year period.

Risk analysis and data processing

The input data are[36]:

Historical loss: Figure 29 shows cumulative historical losses over the five-year period including a detail of the type and number of assets affected as well as the cumulative impact in terms of material damage and loss of profit.

The historical average loss amount was 74 million euros, with the gross loss and net loss breakdown being shown in Fig 30. At first sight, it can be seen that the net loss is not subject to the same fluctuations as the gross loss, which suggests that the insurance program is able to maintain the loss stable for the company at approximately 34 million euros.

Insurance program: the group has an insurance program (Fig. 31) for each of the three countries in which it operates and for each aspect under analysis in this example: MD and LP.

Expert and industry data have not been used in this example.

In accordance with the methodology, events have been filtered in order to identify those that should be excluded from the analysis (outliers, negative value data, data whose dates do not fall within the time window selected for the analysis, etc.).

Once the data input has been filtered and events included have the right characteristics for the analysis, event groupings are classified into ORCs.

[36] Actual data modified for confidentiality purposes.

Figure 29. Loss events and impact by asset type

Activity	Nº Claims	MD+PL Impact (thousands of €)
Combined cycles	46	176,001
Hydro	15	39,594
Conventional thermal	14	71,987
Renewable	371	27,293
Electric power networks	65	43,547
Substations	125	12,530
Total	**663**	**370,995**

Figure 30. Historical loss over a period of 5 consecutive years

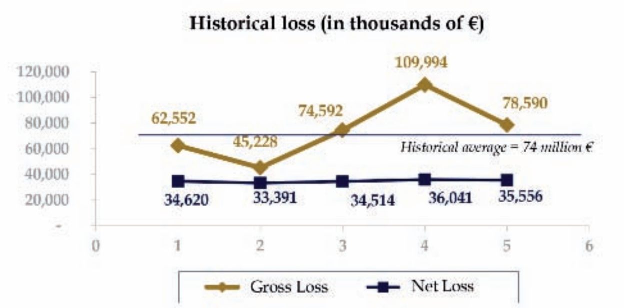


Figura 31. Insurance program structure by asset type and country

Activity	DEDUCTIBLE (thousands of €)						RETAINED BY CAPTIVE (thousands of €)			
	Country 1		Country 2		Country 3		CAP		STOP LOSS	
	MD	LP	MD	LP	MD	LP	MD	LP	MD	LP
Combined cycles	1,500	2,500	1,200	2,250	1,700	2,750	8,000	NA	10,000	
Hydro	750	1,325	800	1,425	1,100	1,600	3,500	NA		
Conventional thermal	800	1,000	550	1,000	1,100	1,000	2,600	NA		
Renewable	1,000	400	NA	NA	950	200	2,000	NA	2,000	
Electric power networks	125	75	140	60	450	130	NA	NA	1,000	
Substations	500	750	800	1,200	NA	NA	6,000	NA	3,000	

ORC Selection

ORCs are defined by grouping events with similar characteristics (according to their frequency and severity). Events are classified according to the type of activity and the type of risk.

The matrix in Table 4 shows the types of activities and risks identified as well as the number of events within their intersection.

The data set was tested for statistical uniformity and the following was decided:

- Joint treatment of damage to physical assets and loss of profit caused by accidents for each of the power generation activities (ORC 1, 2, 3 and 4).
- Joint treatment of damage to physical assets in distribution activities, whether they relate to electric power networks or substations (ORC 5), and likewise for all loss of profit (ORC 6).
- Separate treatment of purposeful damage to electric power networks (ORC 7).
- Joint treatment of all natural disasters, regardless of the business activity (ORC 8).

Thus, there are eight ORC defined (Table 5).

Model premises and data treatment

Once the ORCs have been defined, the data is analyzed to verify it complies with the model assumptions. The analysis must be conducted on each ORC, so that if any one of them should fail the test, it shall be modified, which may impact on the grouping of data for the others.

Table 5. ORC defined

	Risk category	Asset class
ORC 1 (40)	Accident - MD & LP	Combined cycles
ORC 2 (12)	Accident - MD & LP	Hidro
ORC 3 (13)	Accident - MD & LP	Conventional thermal
ORC 4 (371)	Accident - MD & LP	Renewable
ORC 5 (77)	Accident - MD	Distribution
ORC 6 (65)	Accident - LP	Distribution
ORC 7 (7)	Aggression- MD	Electric power networks
ORC 8 (51)	Natural disaster - MD & LP	Generation and distribution

By performing and exploratory data analysis we are able to verify effective compliance with model assumptions (Fig. 32).

Definition of operational risk-related costs

In this exercise, total cost of risk is defined as:

$$TCOR = EL_{Reinsurance} + EL_{Group} + UL_{Group}\ (\alpha)$$

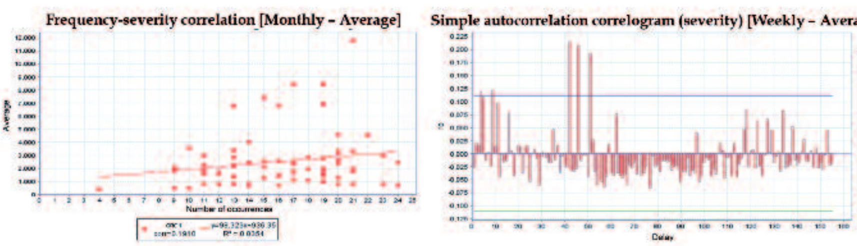
This expression includes:

- $EL_{Reinsurance}$: expected underwriting loss, which is an approximation to the risk premium under the insurance program.
- EL_{Group}: expected loss for the group.
- $UL_{Group}\ (\alpha)$: unexpected loss for the group.

Table 4. ORC groupings (with number of events)

		Accident MD	Accident LP	Aggression MD	Natural Disaster MD	Natural Disaster LP
GEN	Combined Cycles	ORC 1 (40)			ORC 8 (51)	
GEN	Hydro	ORC 2 (12)				
GEN	Conventional thermal	ORC 3 (13)				
GEN	Renewable	ORC 4 (371)				
DIS	Electric power networks	ORC 5 (77)	ORC 6 (65)	ORC 7 (7)		
DIS	Substations					

Figure 32. Model assumption analysis outcome



	Durbin-Watson		Ljung-Box		Rachas	
Level of significance		0,050000		0,050000		0,050000
Number of delays		1		1		1
Value of statistic		2,023029		2,651750		0,593450
Critical values	dL	1.58000	X	0.10343	Z	1.959964
	dU	1.64000				
Conclusion from test	There is no negative correlation		There is no correlation		There is no correlation	

Frequency and severity modeling

Frequency distribution calculation

To fit the frequency distribution of the empirical data, two aspects need to be considered: the chosen frequency distribution itself and the time series data for each ORC.

The chi-squared test is used to select a frequency distribution and time series combination, yielding a p-value for each combination. This indicator shows the distribution that best fits the sample data; in principle, the combination with the highest p-value is the best choice (Fig. 33).

In addition, a graphical fitting of the empirical data to the theoretical data can be used to supplement the p-value analysis on the different distributions (Fig. 34). This analysis is useful when more than one distribution and time series combination shows a high p-value.

A similar process is followed for all ORCs defined, and the distribution that best models the frequency of events in each ORC is selected.

Distributions typically used for modeling frequency discriminate whether the variability in the number of claims has above average volatility (negative binomial), below average volatility (binomial) or near-average volatility (Poisson). It should be noted that the binomial and negative binomial distributions are complementary, and cannot be fitted simultaneously.

The choice of a frequency distribution, therefore, does not determine the mean values of the claims model, but it does determine the outliers or unexpected losses.

Severity distribution calculation

The next step is to fit the severity distributions. In this example, a statistical analysis covering ten different theoretical distribution types was carried out based on the loss amounts attributable to the events in each ORC.

Once the parameters for each of these distributions have been obtained, it is possible to compare their suitability using goodness of fit tests. Two tests were conducted in this case: Kolmogorov-Smirnov (KS) and Kuiper (K). For the particular case of ORC 1, a lognormal distribution was selected (Figs. 35 and 36).

Table 6 shows the chosen distributions for each ORC.

Gross loss distribution calculation

After selecting the frequency and severity distributions for each ORC, both functions are convoluted. This convolution provides the simple loss distribution for each ORC, which may be used to estimate expected and unexpected losses individually. The simple loss distributions are then added together to obtain the aggregate loss distribution (Fig. 37).

This outcome represents the gross loss which, according to the model, the company will incur from their power generation and distribution activities for the risks considered.

It can be seen that the expected loss is approximately 74.3 million euros and the unexpected loss, at a 95% confidence level, would reach 107.2 million euros in the absence of diversification; i.e. the loss to be expected over a 20 year period would exceed this amount. However, taking into account existing diversification across ORCs, the unexpected loss would amount to 85.3 million euros; i.e. a gain of 22 million euros is obtained from diversification. This effect, known as the "portfolio effect" is due to the independence of loss events between business lines.

Figure 33. Fitting of ORC 4 frequency distributions

			Poisson		Binomial			Negative Binomial		
	μ	σ	λ	p-Value	N	p	p-Value	N	p	p-Value
Daily	0.236846	0.117437	0.236846	0.000000				-	-	-
Weekly	1.659433	3.181793	1.659433	0.000000	-	-	-	2.000000	0.521540	0.000000
Fortnightly	3.557551	7.749485	3.557551	0.000000	-	-	-	3.000000	0.459069	0.000000
Monthly	7.213924	7.656642	7.213924	0.344657	-	-	-	118.000000	0.942178	0.057135
Bimonthly	14.427847	12.094377	14.427847	0.824004	90.000000	0.161734	0.939026	-	-	-
Quarterly	21.515883	20.187273	21.515883	0.000000	323.000000	0.067208	0.600899	-	-	-
Every 4 months	28.855694	30.821258	28.855694	0.000000	-	-	-	424.000000	0.936227	0.000000
Half-yearly	43.283542	51.612462	43.283542	0.000000	-	-	-	225.000000	0.838626	0.000000
Yearly	74.200357	1,857.606607	74.200357	0.000000	-	-	-	4.000000	0.039944	0.000000

Figure 34. Graphical fitting of empirical distribution to theoretical distribution

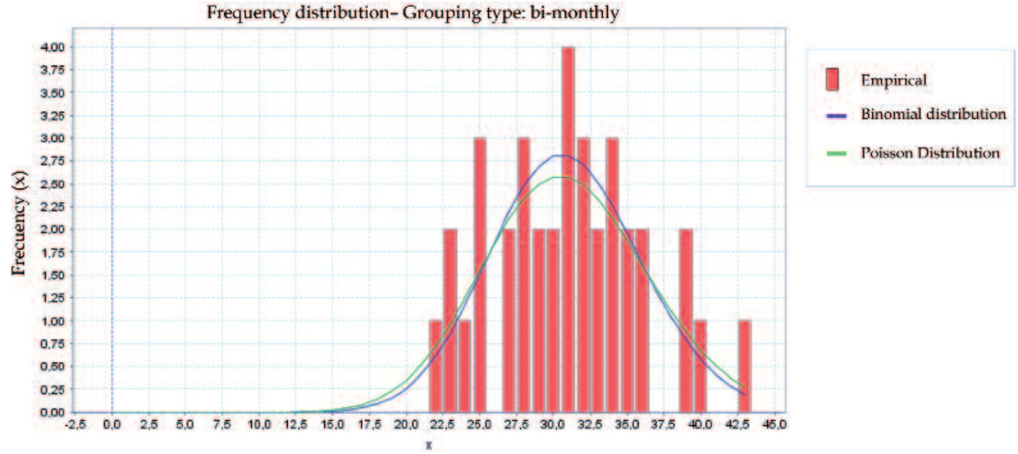


Figure 35. Severity distribution fitting for ORC 1

Distributions	Parameters			KS	Kuiper
Exponential	λ	0.000434		0.000000	0.000000
GH	a	437.87358		0.777082	0.852642
	b	827.693048			
	g	1.842524			
	h	b1	0.000000		
		b2	0.002903		
		b3	0.000000		
Gamma	a	0.391986		0.000000	0.000000
	b	5,873.040785			
Generalized Extreme Value	ξ	1.475074		0.031380	N/A
	σ	352.385050			
	μ	217.213979			
Inverse Burr	τ	3.223515		0.078648	0.004608
	γ	0.66456			
	θ	47.978590			
Epanechnikov Kernel	h	299.662924		N/A	N/A
Gaussian Kernel	h	299.662924		N/A	N/A
Lognormal	μ	6.085496		0.926887	0.905265
	σ	1.908726			
Pareto	η	0.211633		0.000000	0.000000
	β	3.897471			
Weibull	η	1,139.501404		0.001041	0.000000
	β	0.542065			

Figure 36. Cumulative probability function for ORC 1 –lognormal distribution

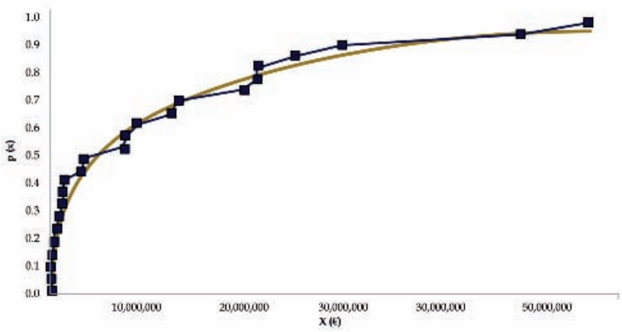
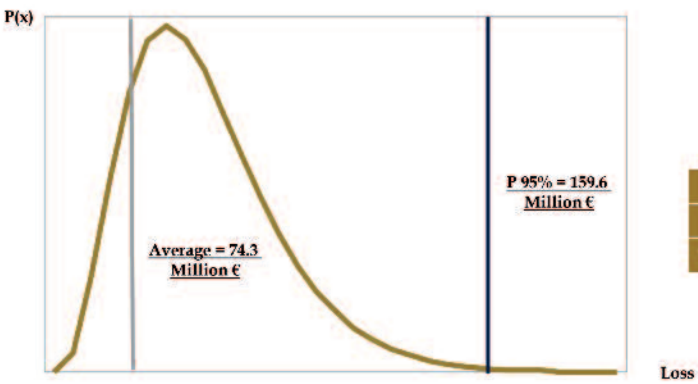


Table 6. Distribution fitting for each ORC

	Risk category	Asset class	Frequency distribution	Severity distribution
ORC 1 (40)	Accident - MD& LP	Combined cycles	Negative binomial	Lognormal
ORC 2 (12)	Accident - MD& LP	Hydro	Binomial	Gamma
ORC 3 (13)	Accident - MD& LP	Conventional thermal	Binomial	Lognormal
ORC 4 (371)	Accident - MD& LP	Renewable	Binomial	Lognormal
ORC 5 (77)	Accident - MD	Distribution	Poisson	GH
ORC 6 (65)	Accident - LP	Distribution	Negative Binomial	Weibull
ORC 7 (7)	Aggression - MD	Electric power networks	Binomial	Weibull
ORC 8 (51)	Natural disaster - MD & LP	Generation and distribution	Binomial	Lognormal

Figure 37. Aggregate loss distribution



	Not diversified	Diversified
	Baseline scenario	Baseline scenario
EL	74,324,578	74,361,004
UL	107,217,589	85,282,891
VaR	181,542,167	159,643,895

Figure 38. Simulation of company losses

Without Stop Loss	Measures (million euros)									
	TOTAL		Retained by Group		Retained by Business		Retained by Captive		Transferred	
	Expected Loss	VaR 95%	Expected Loss	VaR 95%	Expected Loss	VaR 95%	Expected Loss	VaR 95%	Expected Loss	VaR 95%
TOTAL GROUP	76.2	161.4	53.4	111.5	21.0	43.5	32.4	70.1	22.7	58.0
GENERATION	65.1	151.1	42.7	94.6	16.5	36.9	26.2	59.0	22.4	66.7
Combined cycles	37.3	91.5	25.4	58.0	8.9	20.9	16.5	38.1	11.8	36.6
Hidro	8.3	38.3	6.1	26.9	3.1	12.0	3.0	17.2	2.2	9.8
Conventional thermal	14.6	27.0	6.3	26.7	2.2	8.6	4.0	19.5	8.3	21.2
Renewable	5.0	10.2	5.0	10.2	2.3	4.2	2.7	7.1	0.0	0.1
DISTRIBUTION	11.1	30.2	10.8	30.2	4.5	11.5	6.2	20.6	0.4	1.0
Electric power networks	8.6	24.4	8.3	24.4	3.1	9.6	5.2	16.5	0.3	0.8
Substations	2.5	9.6	2.4	9.5	1.4	3.9	1.0	6.6	0.1	0.2

With Stop Loss	Measures (million euros)									
	TOTAL		Retained by Group		Retained by Business		Retained by Captive		Transferred	
	Expected Loss	VaR 95%	Expected Loss	VaR 95%	Expected Loss	VaR 95%	Expected Loss	VaR 95%	Expected Loss	VaR 95%
TOTAL GROUP	76.2	161.4	46.2	76.7	21.0	43.5	25.2	26.3	30.0	85.3
GENERATION	65.1	151.1	35.5	75.2	16.5	36.9	19.0	23.0	29.6	91.0
Combined cycles	37.3	91.5	18.7	34.5	8.9	20.9	9.8	13.6	18.5	59.8
Hydro	8.3	38.3	5.7	25.5	3.1	12.0	2.6	16.8	2.5	10.3
Conventional thermal	14.6	27.0	6.2	26.7	2.2	8.6	3.9	19.9	8.4	23.9
Renewable	5.0	10.2	4.9	10.2	2.3	4.2	2.7	7.1	0.1	0.2
DISTRIBUTION	11.1	30.2	10.7	30.2	4.5	11.5	6.2	20.6	0.4	1.2
Electric power networks	8.6	24.4	8.3	24.4	3.1	9.6	5.1	16.6	0.3	1.0
Substations	2.5	9.6	2.4	11.4	1.4	3.9	1.0	6.6	0.1	0.2

Modeling of insured losses

Based on the calibration results, it is possible to analyze the effect that the current insurance program would have on the retained loss and the transferred loss. To do this, we followed a process for the simulation of 100,000 scenarios such as that described in the methodology. As a result, we obtained the distribution for the losses borne by the company and by the insurance. Company losses are also broken down into those borne by the captive and those borne by each business (Fig. 38, in million euros).

It can be seen that, under the current insurance program (with a stop loss) the expected gross loss amounts to 76.2 million euros, of which 41.4 would be transferred to reinsurance and 34.8 would be retained by the group. Of these 34.8 million euros, 15.9 would be borne by the business and 18.9 by the captive.

Pure premium calculation

The pure premium, as it has been defined here, would be the expected loss transferred to reinsurance. Therefore, the premium for the insurance program analyzed (with stop loss) would amount to 41.1 million euros.

Since we are able to break down the effect that the insurance program has on each business activity, we can estimate the pure premium attributable to each of them. In the example, the power generation business appears to have contributed 39.3 million euros to the total pure premium amount for this program. This breakdown allows us to identify the weight or contribution of each business to the group's loss and establish a system to define the cost of risk based on market mechanisms (i.e. transferring the cost of the premiums quoted according to their contribution to loss).

Acceptable region and efficient frontier definition

As previously mentioned, acceptable risk is determined by a company's risk appetite. In order to simplify the example, risk appetite was defined as a EUR 100 million cap on operational risk losses at a 95% confidence level.

Under the current insurance program, the loss borne by the company, both from the business deductible and from the amount retained by the captive, amounts to 57.7 million euros (87.7 million euros without stop loss). At a 95% confidence level, as seen above (Fig. 38), this would be a possible acceptable insurance scenario for the company.

Insurance scenarios involving losses above 100 million euros for the company would not be acceptable, such as a non-risk transfer or non-insurance scenario setting the loss at 161.4 million euros, as seen in the VaR total in Fig 38.

This means that the definition of acceptable region establishes insurance scenarios which: (1) are consistent with the company's risk appetite and policies and (2) correspond to insurance programs that can be accessed on the market. Within the feasible region, the most efficient insurance scenario will be that in which the difference between the theoretical and the quoted premium is the lowest (which minimizes the premium cost inefficiency arising from the insurer's risk aversion, trade costs, etc.).

Optimal scenario definition

Changes can be made to the franchise and excess conditions in an insurance program with a view to analyzing the effect these changes would have on the total cost of risk and therefore be able to determine the optimal insurance scenario. Figure 39 shows the results of applying 20% per cent increases and reductions to the franchise and stop loss levels.

In this case, the minimum total cost of risk (TCOR) would be achieved under a scenario with a 60 % increase in the franchise and a 60% reduction in the stop loss. This is to say, that in TCOR terms it would be beneficial to increase the retention level while at the same time decreasing the stop loss. The loss for the group under this scenario would be 52 million euros at a 95% confidence level, which is within the acceptable region and hence within the company's risk appetite policy.

In this example, the optimal insurance scenario corresponds to the lowest stop loss level because the cost of risk definition is proportional to the percentile or unexpected loss that the company is able to withstand, i.e. the sum of the expected loss retained and the expected loss transferred to the reinsurance market (the latter is an approximation to the theoretical premium) is a constant independent from the insurance program and corresponds to the expected loss for the asset portfolio. Therefore, the TCOR value is proportional to the unexpected loss or percentile and is directly affected by the arranged stop loss level if the latter is activated (when the annual loss percentile exceeds the stop loss level).

Figure 39. TCOR optimization

Million euros		Δ Retention						
		-60%	-40%	-20%	-	20%	40%	60%
Δ Stop Loss	-60%	100.89	99.43	99.02	98.96	98.83	98.77	98.35
	-40%	101.15	100.58	99.83	99.56	99.40	99.33	98.84
	-20%	101.86	102.38	101.16	100.67	100.44	100.30	99.83
	-	102.51	104.21	103.02	102.26	101.89	101.69	101.13
	20%	104.58	107.56	106.19	105.15	104.58	104.29	103.70
	40%	106.09	110.41	109.37	108,25	107.49	107.03	106.34
	60%	107.90	112,70	112.69	111.41	110.45	109.84	109.20
Without Stop Loss		120.12	124.46	129.96	133.27	136.94	140.10	146.14

Case study conclusions

This case study, necessarily simplified, illustrates how the methodologies discussed throughout the document help to objectivize and quantify the level of insurable operational risk as well as to assess the most suitable insurance program for a company. These methodologies also provide useful information for insurance negotiation purposes, such as the estimated cost of the premium or a measurement of possible "inefficiencies" in the premium quote. The process that has been followed in the practical example can therefore provide answers to some key questions related to operational risk management, such as:

- The loss that the company is exposed to, i.e. the level of risk inherent in the business assets and activity. This loss is quantified by modeling the gross loss distribution (loss prior to implementing an insurance program) under specific scenarios (different distribution percentiles for measuring loss exposure every year or every x years). In the example, the potential loss would amount to about 161 million euros every 20 years (95th percentile in the distribution) versus an expected annual gross loss of 76 million euros.

- How much each business contributes to the Group's total risk amount. The amount that each business activity or group of assets contributes to the company's risk profile, so that the company may objectively allocate costs and prioritize actions to renovate, improve, operate or maintain assets. In the example (Figure 38), power generation assets contribute about 85% of the Group's expected loss or claims, compared with 15% contributed by distribution assets. Within power generation assets, combined cycles are the cause of approximately 50% of Group claims. In terms of potential losses (every 20 years) the contribution of power generation and distribution activities is 93% and 18% respectively (112% altogether) and reveals that power generation and distribution assets have a 12% diversification effect between them (the Group's potential loss is 12% lower than the sum of the potential loss for each asset group).

- The reasonable cost of the premium for a particular insurance program, particularly regarding the theoretical or pure premium, which is the first of the three premium cost components (complemented by the commercial or management cost and a margin related to the insurer's risk aversion). This pure premium is estimated from the resulting loss function as the difference between the gross and net loss. In the example, it represents about 41 million euros.

- The total cost of risk for the company, i.e. the sum of the cost from expected losses, the premiums paid and the potential losses. In the example: 35, 41 and 58 million euros, respectively.

- The ways for improving and optimizing the current insurance program, i.e. management levers to optimize not only the premiums paid, but the total cost of risk. In the example (which uses fictitious data), an increase in the franchise and a reduction in the stop loss of around 60% reduces the total cost of risk by 4%, changing from 102 to 98 million euros.

- The value of products such as stop loss insurance. This is the quantification of the reasonable cost associated with each of the components in the insurance program based on their economic impact on the Company's loss profile. It is calculated as the variation in the Group's total cost of risk resulting from inclusion in the program. In this example, figures 25 to 28 show those franchise and stop loss combinations in which the latter is not effective in terms of reducing the cost of risk for the company, while it does not substantially alter the potential loss. This analysis makes it

possible to determine whether it makes economic sense to modify the conditions of the insurance program, allowing the company to determine, for instance, the franchise or stop loss levels whose effectiveness in reducing risk justifies their price or a premium increase.

- The market response to changes in the insurance program design. This is a measure of the impact that a change in the franchise, insured value, etc. has on the premium. The existence of premium components other than the loss transferred to the insurer, such as the insurer's risk aversion or commercial costs, introduces uncertainty or inefficiency in the insurance cost faced by the insurance company, and this can be measured as the difference between the quoted premium and the theoretical premium, which varies as the insurance program conditions change (deductible - franchise- and stop loss).

Also, it is reasonable to assume that the insurance market will be very sensitive to significant changes in the insurance conditions (e.g. a nonlinear increase in the premium in response to significant reductions in retention levels). Therefore, in formulating total cost, cost reduction factors are taken into account. These can be estimated from market prices for equivalent programs, different only in retention and limit levels. This tighter market conditions, or exponential premium growth in response to changes in risk transfer levels, can result from recent accident rates, whether suffered by the company or by third parties, as well as from immaturity and from ignorance of the risk profile of new technologies, among other factors.

In this exercise, the TCOR behavior is determined by the limit or stop loss activation. This behavior makes it possible to identify those stop loss levels that do not affect the company's cost of risk, and hence those where a premium increase associated with a better stop loss does not justify the investment in terms of risk reduction.

Regarding the availability of information sources, using this type of methodology does not require significant amounts of historical event data, as results can be obtained with few occurrences. In such cases, events do not need to be grouped into ORCs at a high level of detail; coarse granularity is sufficient (for instance, events can be grouped by business activity and type of risk) to achieve reasonable results. If industry events are not available, as it is the case in the example, the model results shall only be tied to the company's recent history of events, which on the other hand tends to be the major input used by insurance companies to determine the premium for a given program. In any case, the analysis can be enriched by stress testing or sensitivity exercises, which can be used to estimate risk in response to changes in modeling parameters by incorporating hypothetical events that are representative of similar events in the industry as well as changes in the scope insured (e.g. those resulting from disinvestments in productive assets[37]).

[37]In this regard, the fitting of frequencies and severities should take account of scaling factors when incorporating changes arising from investments, disinvestments, new technology or corrective measures into the asset portfolio. For instance, the acquisition of a distribution network will increase the frequency of accidents but perhaps not their severity, and a power increase in an electricity generation turbine may result in increased profit loss if an accident occurs, while frequency will not be affected.

Glossary

Captive insurer: insurance and reinsurance company belonging to a business group whose mission is to cover the risks of the group.

Coverage: basic insurance component that defines the insured object, the entity that acquires the risk (insurer), the entity that transfers the risk (insured), the sum insured (limit), the deductible (franchise or excess) and the level of coverage (percentage covered).

Event: an event that results in operational loss. It is characterized by its cause (reason why the event occurs) and its impact (the loss that would not have been incurred had the event not happened). All impacts stemming from the same root cause are considered to be part of the same event.

Franchise or deductible: amount of the loss insured which is borne by the insured.

Limit: maximum amount of the insured loss covered by the insurance company. As a general rule, this limit may be of different types:

- Limit by occurrence: applies to each claim within the policy coverage.

- Aggregate limit: applies to the cumulative sum of claims covered so that, if at the nth event the aggregate loss from events of the same type exceeds the limit, the insurer is freed from the obligation to cover the excess.

Operational risk: risk of loss resulting from inadequate or failed internal processes, people or systems or from external events. Usually includes legal and compliance risk, and excludes strategic and reputational risk. The industry differentiates between:

- Insurable risk: operational risk that may be insured and may therefore be partially or fully transferred to another party, usually in return for payment of a premium. Includes damage to company assets and damage to third parties caused in the course of the business activity.

- Uninsurable risk: operational risk associated with process or system failure.

Policy: contract between the insurer and the insured whereby the insurance terms are fixed.

- Direct policy: document by which the insured transfers the risk to the insurer and the insurance conditions are established. The insurer, in turn, transfers the risk to the captive through what is called a "fronting agreement".

Premium: amount the insured pays the insurer to underwrite the policy. It consists of:

- Pure premium: real cost of risk borne by the insurer based on the expected loss.

- Surcharge or add-on: amounts that are added to the pure premium for administrative expenses, mark-up, administration expenses, etc.

Recovery: gross loss amount that is not ultimately lost by the company. Recovery is independent from the original loss. Two types of recoveries are usually considered in the industry: guarantees (amount of the loss covered by the asset producer) and insurance (amount of loss covered by the insurance, subject to the conditions of the previously subscribed policy).

Stop loss: a product that limits the captive's total loss to a specific amount.

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