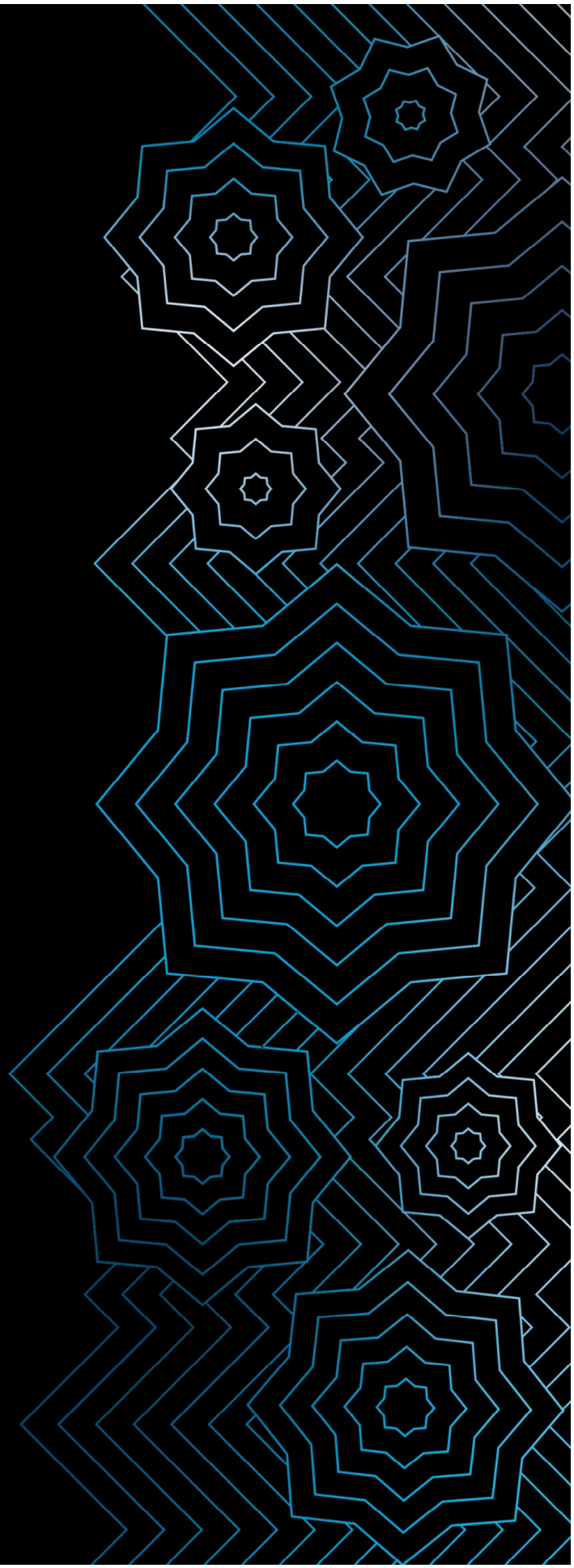
2024

FRM®

EXAM PART I

Foundations of Risk Management



GARP®

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PREFACE

I want to thank you on behalf of GARP's Board of Trustees and our professional certification program staff for your support of the Financial Risk Manager (FRM®) program.

It's gratifying to see that in the 26 years since the first FRM examination, the FRM program has become the global standard for educating and credentialing financial risk management professionals. Its worldwide effects in furthering the understanding and acceptance of financial risk management have been highly positive and, in many ways, transformative.

COVID is thankfully in the rearview mirror. We now can be much more flexible in expanding—and in certain instances re-focusing and updating—the FRM program to address the many new challenges encountered by financial institutions globally.

Our FRM program advisory committee, consisting of senior risk professionals from around the world, that meets regularly to debate and settle the FRM program's subject coverage, has found no shortage of subjects for inclusion in the FRM curriculum.

One of the advisory committee's more-material challenges is to understand and assess where the global financial services industry is headed, and then identify issues and subjects most important for risk management professionals.

The FRM advisory committee also recommends how the FRM program covers subject matter. Its objective is to ensure that candidates who complete the FRM program successfully can be confident that their skills have been assessed objectively, and that they possess the requisite knowledge to succeed as a risk management professional anywhere in the world.

The FRM program's coverage is dynamic. The advisory committee reacts to and tries to anticipate market changes, global economic trends, technological advances, and regulatory adjustments; and assesses how these will affect the necessary knowledge and skill sets of a risk management professional.

The biggest change to the program's coverage for 2024 revolves around credit risk measurement and management. About two-thirds of the subject readings in *Credit Risk Measurement and Management* were updated for 2024.

Notably in 2023, GARP expanded the FRM program's coverage of operational resilience, an issue of rapidly growing importance around the world. Materials deal with structural vulnerabilities and areas of the financial system that may be under stress. The transmission of shocks to the financial system, and the assessment, modeling, and measurement of potential points of failure are other important covered concepts.

Also notable in 2023, GARP added two chapters on machine learning (ML) in the FRM Part I *Quantitative Analysis* book. These chapters not only introduce the ML methods risk managers need to understand, but also address key issues associated with artificial intelligence (AI) and ML, including transparency, interpretability, and explainability; data considerations; and risks that arise from the use of AI/ML, including the potential for bias, discrimination, and unethical behavior.

Throughout the FRM curriculum, GARP aims, wherever possible, to present lessons learned from noteworthy current events to contextualize program content and give FRM candidates critical insight.

As you will see from reviewing the program's coverage and readings, it keeps up with a world that is becoming more interconnected and complex by the day.

GARP is committed to offering a program that is dynamic, sophisticated, and responsive to the needs of financial institutions and risk professionals around the world.

We wish you the very best as you study for the FRM exams. And much success in your career as a risk-management professional.

Yours truly,

Richard Apostolik

President & CEO

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1

The Building Blocks of Risk Management

Learning Objectives

After completing this reading, you should be able to:

- Explain the concept of risk and compare risk management with risk taking.
- Evaluate, compare, and apply tools and procedures used to measure and manage risk, including quantitative measures, qualitative risk assessment techniques, and enterprise risk management.
- Distinguish between expected loss and unexpected loss and provide examples of each.
- Interpret the relationship between risk and reward and explain how conflicts of interest can impact risk management.
- Describe and differentiate between the key classes of risks, explain how each type of risk can arise, and assess the potential impact of each type of risk on an organization.
- Explain how risk factors can interact with each other and describe challenges in aggregating risk exposures.

Risk, in the most basic sense, is the possibility that bad things might happen. Humans evolved to manage risks such as wild animals and starvation. However, our risk awareness is not always suited to the modern world (as anyone who has taught a child to cross the road knows). Behavioral science shows that we rely too much on instinct and personal experience, as biases skew our thought processes. Furthermore, even the way we frame risk decisions irrationally influences our willingness to take risk.

Even so, surprisingly sophisticated examples of risk management can be seen in early history. In ancient times, merchants and their lenders shared risk by tying loan repayments to the safe arrival of shipments using maritime loans (i.e., combining loans with a type of insurance). The insurance contract separated from the loan contract as early as the fourteenth century in northern Italy, creating the first standalone financial risk transfer instrument. From the seventeenth century onward, a more methodical approach to the mathematics of risk can be traced. This was followed by the development of exchange-based risk transfer in the form of agricultural futures contracts in the eighteenth and nineteenth centuries (Figure 1.2).

That methodical approach continued to evolve in the twentieth century and beyond, with major advances in financial theory in the 1950s; an explosion in risk management markets from the 1970s onwards; and the emergence of new instruments, such as cyber risk insurance, in the early twenty-first century. Risk management is an old craft but a young science—and an even younger profession.

How we think about risk is the biggest determinant of whether we recognize risks, assess them properly, measure them using appropriate risk metrics, and succeed in managing them.

This introductory chapter looks at the definitions of risk, the classic risk management process, the principal types of risk, and the tools used to track risk and make decisions. We isolate 10 risk management building blocks along the way (Figure 1.1).[1]

Most risk management disasters are caused by the failure to properly recognize and/or deal with one or more of these fundamental building blocks, rather than the failure of some sophisticated risk management technique. Centuries-old financial institutions have been bankrupted because their risk management procedures ignored a certain type of risk,

1. The risk management process
2. Identifying risk: knowns and unknowns
3. Expected loss, unexpected loss, and tail loss
4. Risk factor breakdown
5. Structural change: from tail risk to systemic crisis
6. Human agency and conflicts of interest
7. Typology of risks and risk interactions
8. Risk aggregation
9. Balancing risk and reward
10. Enterprise risk management (ERM)

Figure 1.1 **Ten risk management building blocks.**

misunderstood connections between risks, or did not follow the classic steps in the risk management process.

1.1 TYPOLOGY OF RISKS AND RISK INTERACTIONS

Risk is a wild animal, circling the campfire in the dead of night. But what kind of animal is it?

Figure 1.3 sets out a typology of risks in the financial industry.[2] Given the variety of business models that firms pursue, corporate risks take many forms. However, most firms face risks that can be categorized within the risk typology discussed in this chapter.

This kind of typology has many uses. It can help organizations drill down into the risk-specific factors within each risk type, map risk management processes to avoid gaps, and hold staff accountable for specific risk domains.

Indeed, Figure 1.3 relates quite closely to how risk functions are organized at many banks and large corporations, where there are often particular functions for market risk, credit risk, etc. Many of these risk functions worked quite independently of one another until an effort to build a more unified risk management approach began in the mid-1990s.

Each key risk type demands a specific set of skills and its own philosophical approach. For example, most banks treat market and credit risks as a natural part of their business. They recognize that risk scales alongside reward and actively pursue risky assets

[1] Not every risk practitioner will agree with our choice. The building blocks are not discussed in order of importance, and not every firm needs to develop a sophisticated approach to each building block, but we would argue that an awareness of each of our 10 building blocks is a good place to start thinking about risk management.

[2] For a more detailed description of financial risks see M. Crouhy, D. Galai, and R. Mark, *The Essentials of Risk Management*, 2nd ed. (Ch. 1, App.), McGraw Hill, 2014.

c.1750 BC—Code of Hammurabi records Babylonian maritime loan insurance.

Roman era—Burial societies cover funerary expenses with regular premiums.

Early medieval period—Early guilds support members who suffer financial loss.

1300s—Shipping insurance matures in Genoa.

1583—First recorded life insurance policy in London

1650s—Blaise Pascal and Pierre de Fermat lay foundation of probability theory.

1666—Great Fire of London inspires early fire insurance companies.

1688—Lloyds (of London) coffee house first mentioned

1690s–early 1700s—Development of mortality tables in London

Late 1600s—early 1700s—Jakob Bernoulli describes law of large numbers/statistical inference.

1730—Japanese rice futures traded in Osaka (world's first futures).

1730—Normal distribution and standard deviation described by Abraham de Moivre.

1762—First life insurer to calculate premiums in scientific manner (forerunner of Equitable Life)

1764—Publication of Thomas Bayes' 1750s work (Bayesian statistics)

1846—Cologne Re: first dedicated reinsurance company

1864—Chicago Board of Trade lists first US standardized futures contracts (corn).

1875—Francis Galton, British statistician, describes regression to the mean.

1900—Louis Bachelier models Brownian motion to investigate financial assets.

Early 1900s—Lloyds underwriters collect catastrophe risk data for pricing, for example, hurricane records.

1921—Frank Knight explores 'Risk, Uncertainty and Profit'.

1950s–1960s—Large corporations self-insure; "risk manager" used for widened insurance purchaser role.

1952—Diversification and modern portfolio management: Harry Markowitz

1961–1966—Capital Asset Pricing Model: William Sharpe and John Lintner

1970s—Decade of market liberalization and price and interest rate volatility

1972 —CME currency futures contracts

1973—Chicago Board of Trade (CBOT) options on stocks; Chicago Board Options Exchange (CBOE) created

1973—Black-Scholes option pricing formula

Mid 1970s—Treasury bill and bond futures

1979–1980—OTC currency options and swaps

Early 1980s—Growth of early OTC markets; first interest rate swaps

1983—Interest rate caps and floors

1987—Commodity swaps; average options; and other path-dependent options

1988—Basel Accord (Basel I) banking reform, focused on credit risk

1990—Collateralized loan obligations

Early 1990s—Credit derivatives develop, for example, credit default swaps

1993—CBOE volatility index (VIX)

1994—J.P. Morgan publishes value-at-risk (VaR) methodology (RiskMetrics)

1994–1995—Classic cases of derivative misuse, for example, Orange County, Barings Bank

1996—Market Risk Amendment for Basel I

1998—Russia financial crisis, LTCM near collapse

1998–1999—Synthetic CDOs (collateralized debt obligations); CDOs of CDOs (CDO squared)

2001—Terrorist attacks on World Trade Center (9/11); Enron collapse, corporate scandals

2002—Sarbanes-Oxley Act (SOX) to prevent fraudulent accounting

2004—Basel II (including operational risk capital)

2004–2006—VIX futures, options

2007–2009—Global Financial Crisis

2009—Contingent convertible bonds (CoCos)

2010—Basel III ongoing (including liquidity risk)

2010—Dodd–Frank Act

2011 onwards—Fast development of cyber risk transfer market

2016—Solvency II reform in effect for insurance industry

2017—Finalized Basel III reforms released

Figure 1.2 Risk management timeline.

Note: The dates in this timeline are sometimes an approximation; in particular, the development date of various OTC risk transfer instruments can be open to debate.

(e.g., particular credit segments). An increase in operational risks, on the other hand, does not lead to greater reward, so banks avoid these risks when they can. Below we look at the key risk types in turn, but first a word of warning. Risk typologies must be flexible because new risks are always emerging. A banking industry risk typology made in the early 1990s may have not considered rogue trading risk or even the entire operational risk class. As of 2020, "new" forms of operational risk are again climbing

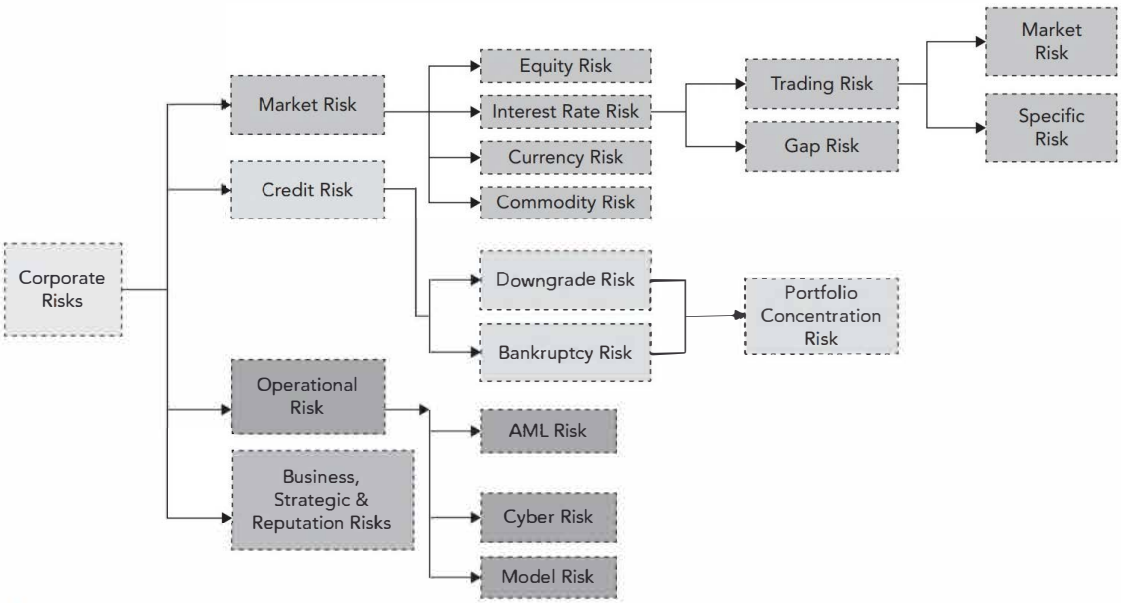

Figure 1.3 **A typology of risks for the banking industry.**

up the risk manager's watch list: cyber risk (particularly the risk of hackers stealing and destroying data and compromising systems) and data privacy risk.[3]

Furthermore, the risk types interact with one another so that risk flows. During a severe crisis, for example, risk can flow from credit risk to liquidity risk to market risk, (which was the case during the global financial crisis of 2007–2009). The same can occur within an individual firm: the "fat finger" of an unlucky trader (operational risk) creates a dangerous market position (market risk) and potentially ruins the standing of the firm (reputational risk). That is why a sophisticated understanding of risk types and their interactions is an essential building block of risk management.

Market Risk

Market prices and rates continually change, driving the value of securities and other assets up and down. These movements create the potential for loss, as price volatility is the engine of market risk.

Market risk takes many forms depending on the underlying asset. From a financial institution's perspective, the key forms are equity risk, interest rate risk, currency risk, and commodity price risk.

[3] New risks tend to be born out of a fundamental change in market and industry practice. Bank rogue trading risk rose out of the growth of the derivatives industry and a rise in proprietary trading; bank liquidity risk during the global financial crisis arose out of insidious changes in bank funding strategies and leverage; legal risk in the period since the crisis has been exacerbated by a new wave of class action lawsuits and claims for compensation (not to forget some poor bank behavior); and cyber risk is a product of the digital revolution.

Each of these markets has its own risk management tools and methodologies, and we give examples of corporate applications and strategies in Chapter 2. However, across all these markets, market risk is driven by the following.

- *General market risk:* This is the risk that an asset class will fall in value, leading to a fall in the value of an individual asset or portfolio.
- *Specific market risk:* This is the risk that an individual asset will fall in value more than the general asset class.

Market risk can be managed through the relationships between positions. The diversification benefits of a large equity portfolio, for example, form the bedrock of investment risk management.

However, market risk also arises from these relationships. For example, an equity portfolio designed to track the performance of an equity market benchmark might fail to track it perfectly-—a special form of market risk. Likewise, a position intended to balance out, or hedge, another position or market price behavior might do so imperfectly—a form of market risk known as basis risk.

For risk managers, this mismatching of price movements is often a bigger problem than any single market risk exposure. For example, a commodity risk manager might decide to use crude oil futures to hedge the price of jet fuel based on the historical relationship between crude oil price movements and jet fuel price movements. However, the hedge may fail due to an adverse change in the historical relationship between the price movement of these two commodities that renders the hedge ineffective, or worse, results in a greater loss than if no hedge was placed.

Credit Risk

Credit risk arises from the failure of one party to fulfill its financial obligations to another party. Some examples of credit risk include

- A debtor fails to pay interest or principal on a loan (bankruptcy risk or default risk);
- An obligor or counterparty is downgraded (downgrade risk), indicating an increase in risk that may lead to an immediate loss in value of a credit-linked security; and
- A counterparty to a market trade fails to perform (counterparty risk), including settlement or Herstatt risk.[4]

Credit risk is driven by the probability of default of the obligor or counterparty, the exposure amount at the time of default, and the amount that can be recovered in the event of a default. These levers can all be altered by a firm's approach to risk management through factors such as the quality of its borrowers, the structure of the credit instrument, and controls on exposure. The structure of the credit instrument involves whether the credit instrument is collateralized or not, the type of collateral if it is collateralized, the priority of the creditor in the case of bankruptcy, and inclusion of protective covenants in the loan agreement that impose restrictions on the borrower so as to protect the lender.

The exposure amount is clear with most loans but can be volatile with other kinds of transactions. For example, a derivative transaction may have zero credit risk at the outset because it has no immediate value in the market. However, it can quickly become a major counterparty credit exposure as markets change and the position of one counterparty gains at the expense of the other counterparty.

Traditionally, the probability of default of an obligor is assessed through identifying and evaluating a selection of key risk factors. For example, corporate credit risk analysis looks at key financial ratios, industry sectors, etc. Meanwhile, the risk in whole portfolios of credit risk exposures is driven by obligor concentration (i.e., the exposure to each obligor relative to the portfolio's value) as well as the relationship between risk factors. The portfolio will be a lot riskier if:

- It has a small number of large loans rather than many smaller loans;
- The returns or default probabilities of the loans are positively correlated (e.g., borrowers are in the same industry or region);
- The exposure amount, probability of default, and loss given default amounts are positively correlated (e.g., when defaults rise, recovery amounts fall).[5]

Risk managers use sophisticated credit portfolio models to uncover risk arising from these combinations of risk factors.

Liquidity Risk

Liquidity risk is used to describe two quite separate kinds of risk: funding liquidity risk and market liquidity risk.

Funding liquidity risk is the risk that covers the risk that a firm cannot access enough liquid cash and assets to meet its obligations. Funding liquidity risk threatens all kinds of firms. For example, many small and fast-growing firms find it difficult to pay their bills quickly enough while still having sufficient funds to invest for the future.

Banks have a special form of funding liquidity risk because their business involves creating maturity and funding mismatches. One example of a mismatch is that banks aim to take in short-term deposits and lend the money out for the longer term at a higher rate of interest. Sound asset/liability management (ALM), therefore, lies at the heartening of the banking business to help reduce the risk. There are various techniques involved in ALM, including gap and duration analyses.[6]

Of course, banks sometimes get it wrong, with disastrous consequences. Many of the banks that failed during the 2007–2009 global financial crisis had built up large maturity mismatches and were vulnerable to the wholesale funding market's perception of their creditworthiness.

Market liquidity risk, sometimes known as trading liquidity risk, is the risk of a loss in asset value when markets temporarily seize up. If market participants cannot, or will not, take part in the market, this may force a seller to accept an abnormally low price, or take away the seller's ability to turn an asset into cash and funding at any price. Market liquidity risk can translate into funding liquidity risk overnight in the case of banking institutions too dependent on raising funds in fragile wholesale markets.

It can be very difficult to measure market liquidity risk. Measures of market liquidity in a normal market, for example, might look at the number or volume of transactions and at the spread between the bid-ask price. However, these are not necessarily good indicators that a market will remain liquid during a time of crisis.

[4] Named after the failure of Herstatt bank in Germany. The bank, a participant in the foreign exchange markets, was closed by regulators in 1974. The timing of the closure caused a settlement failure because Herstatt's counterparties had already paid their leg of foreign currency transactions (in Deutsche Marks) only to find the defunct Herstatt unable to pay its leg (in US dollars).

[5] These concepts will be explored later in this book.

[6] See M. Crouhy, D. Galai, and R. Mark, *The Essentials of Risk Management*, 2nd ed. (Ch. 8), McGraw Hill, 2014.

BOX 1.1 BANK OPERATIONAL RISK: MEASURE OR MANAGE?

No one doubts the importance of operational risk, but its measurement remains challenging. The banking industry embarked on the project in the late 1990s, mainly because it seemed logical to set capital aside for operational risk alongside that set aside for credit and market risks. The industry built extensive loss databases along with a set of risk measurement tools including statistical analysis, scorecard systems, sets of key risk indicators, and scenario analysis approaches.

However, many banking regulators remained skeptical about whether these tools could support accurate risk capital allocation. The Basel Committee signaled a change of direction in 2016.[7] It would continue to encourage banks to understand their operational risk using a variety of tools, but capital allocation would be based on a simpler standardized approach using weighted bank size with a multiplier based on a bank's record of larger operational risk losses.

However, this will not dampen bank efforts to manage operational risk. Operational risk includes the massive legal threats and claims for compensation that have plagued banks since the 2007–2009 global financial crisis. It includes the growing threat of cyber risk and the threat of penalties and lawsuits over data privacy infringements. In all its guises, operational risk remains one of the biggest threats to banks and other large corporations, even if it is impossible to properly measure its true cost.

Operational Risk

Operational risk can be defined as the "risk of loss resulting from inadequate or failed internal processes, people, and systems or from external events."[8] It includes legal risk, but excludes business, strategic, and reputational risk.

That is a deliberately broad definition, and it includes everything from anti-money laundering risk and cyber risk to risks of terrorist attacks and rogue trading. The outbreaks of rogue trading in the 1990s helped persuade regulators to include operational risk in bank capital calculations.

Looking beyond the banking industry, we might include many corporate disasters under the operational risk umbrella. These include physical operational mishaps and corporate governance scandals, such as the crisis at energy giant Enron in 2001. The management of operational risk is the primary day-to-day concern for many risk managers outside the financial industry, often through insurance strategies.

The definition and measurement of operational risk continues to be problematic, however, especially in the financial industry (Box 1.1).

Business and Strategic Risk

Business risks lie at the heart of any business and includes all the usual worries of firms, such as customer demand, pricing decisions, supplier negotiations, competition, and managing product innovation.

Strategic risk is distinct from business risk. Strategic risk involves making large, long-term decisions about the firm's direction, often accompanied by major investments of capital, human resources, and management reputation.

Business and strategic risks consume much of the attention of management in non-financial firms, and they are clearly also a key concern in financial firms. However, it is not obvious how they relate to the other risks that we discuss or fit within each firm's risk management framework. For example, today banks and other financial institutions are facing competition from so-called financial technology [FinTech] companies. Bank management must decide whether to develop those same services internally, acquire those companies, or partner with FinTech companies.

A sudden fall in customer demand, the failure to launch the right kind of new product, or a misplaced major capital investment can threaten a firm's survival. Responsibility for these risks lies with the firm's general management. So what is the role of the risk manager?

The answer lies in three observations.

1. First, the firm's management needs to define its appetite for risk in a holistic manner that embraces the risk of significant business and strategic decisions. Firms can be very conservative with respect to credit risk, yet very entrepreneurial with respect to business risk. However, the logic for that divergence needs to be articulated by management.
2. Second, the chief risk officer and supporting team may have specific skills they can bring to bear in terms of quantifying aspects of business and strategic risk. Credit experts, for example, often become involved in managing supply chain risk. As we discuss in a later chapter, new techniques such as macroeconomic scenario analysis can be adopted to improve business and strategic decisions.
3. Third, business decisions generate large exposures in other risk management areas, such as credit risk and commodity price risk. As a result, financial risk managers must be involved at the start of business planning. For example, it may be impossible to fund

[7] Basel Committee, Standardised Measurement Approach for Operational Risk, March 2016: https://www.bis.org/bcbs/publ/d355.pdf. The move built on earlier proposals in 2014.

[8] Basel Committee on Banking Supervision, Principles for the Sound Management of Operational Risk, June 2011, https://www.bis.org/publ/bcbs195.pdf, page 3, footnote 5.

the construction of a power station without having some form of energy price risk management strategy in place. Meanwhile in the financial industry, expanding a credit business will increase credit exposures and may necessitate the deliberate lowering of credit standards. Banks that fail to coordinate business, strategic, and risk management goals do not survive for long.

Reputation Risk

Reputation risk is the danger that a firm will suffer a sudden fall in its market standing or brand with economic consequences (e.g., through losing customers or counterparties).

Reputation risk usually comes about through a failure in another area of risk management that damages confidence in the firm's financial soundness or its reputation for fair dealing. For example, a large failure in credit risk management can lead to rumors about a bank's financial soundness. Rumors can be fatal in themselves. Investors and depositors may begin to withdraw support in the expectation that others will also withdraw support. Banks need to have plans in place for how they can reassure markets and shore up their reputations.

A reputation for fair dealing is also critical. Large firms are expected to behave in certain ways. If a firm misrepresents a product's risks, it can lose important customers.

Reputation with regulators is particularly important to financial institutions. Regulators wield considerable informal as well as formal power. A bank that loses the trust of a regulator may become the subject of extensive examinations and/or its activities may be criticized or curtailed.

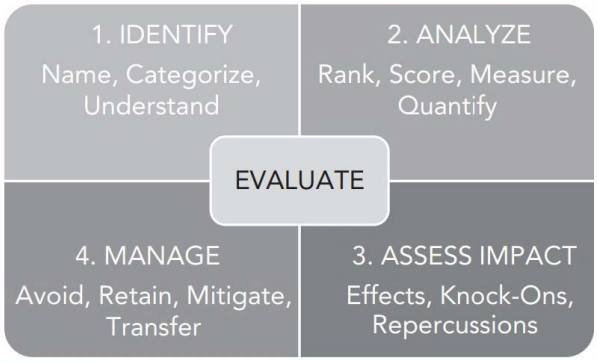

Figure 1.4 The risk management process.

1.2 THE RISK MANAGEMENT PROCESS

We take risks in pursuit of reward, whether that reward is food, shelter, or digital currencies. But the key questions are twofold: (1) is the risk commensurate with the reward, and (2) could we lower the risk and still get the reward? Our attempt to address these questions gives rise to our first building block: the classic risk management process (Figure 1.4).

During this process, the risk manager attempts to: identify the risk (e.g., Box 1.2), analyze and measure the risk, assess the effects of any risk event, and finally manage the risk.

BOX 1.2 BRAINSTORMING AND TRIAGING RISKS

The first steps toward risk identification and triage take some classic forms.

- *Brainstorming:* This could include discussions with representatives from different business divisions to discuss the risk exposures they face and scenarios that could negatively impact their divisions. The most obvious approach is to put the key professionals (e.g., business leaders, audit professionals, etc.) in a room and talk to them. What is your personal professional nightmare? What else could go wrong, why would it go wrong, and how badly could it go wrong? What are the root causes and what are the consequences (e.g., in terms of triggering further risks)? Who is accountable?
- *Structured interviews, questionnaires, and surveys:* These are an attempt to push that initial inquiry out to a wider group of professionals within the company or throughout the industry. They should include open-ended questions.
- *Industry resources:* Unless the activity is unique, there will be industry resources available in the form of checklists, professional and regulatory standards, industry surveys, and expert opinions. These resources should be used to enrich the brainstorming process.
- *Loss data analysis:* Brainstorming often identifies many potential risks. The analyst will next want to look at how the wider industry categorizes each risk and at any internal and external loss records available, to gauge the frequency and severity of loss events and how they relate to specific risk factors.
- *Basic risk triage:* Not every risk is quantifiable in an exact way, but risk managers should be able to determine a given risk's frequency and severity.
- *Hypothetical what-if analysis:* Initial research may suggest worst-case scenarios that the brainstorming team can be asked to consider.
- *Front line observation:* There is no substitute for going to the business line or function and looking at how things are done. Have front-line staff been included in the risk information gathering process?
- *Following the trail:* How are key processes conducted and what are the risks associated with them? Can we see weaknesses or gaps in the process? Can we track our worst nightmares backwards through the process?

Identifying the risk can be just as important as its size in determining the appropriate risk management strategy. Across the corporate world, some risks are regarded as natural to a business and others as quite foreign. Manufacturers, for example, often accept and manage the operational risks of complex factory processes but try to avoid or transfer large market or credit risks. Investors often react badly to mishaps concerning risk types they believe are unnatural to a firm (e.g., a loss from a speculative derivatives position held by a non-financial corporation).

The risk management process culminates in a series of choices that both manage risk and help to define the identity and purpose of the firm.

- *Avoid* Risk: There are risks that can be sidestepped by discontinuing the business or pursuing it using a different strategy. For example, selling into certain markets, or off-shoring production, might be avoided to minimize political or foreign exchange risks.
- *Retain* Risk: There are risks that can be retained within the firm's risk appetite. Large risks can be retained through mechanisms such as risk capital allocation, self-insurance, and captive insurance.
- *Mitigate* Risk: There are risks that can be mitigated by reducing exposure, frequency, and severity (e.g., improved operational infrastructure can mitigate the frequency of some kinds of operational risk, hedging unwanted foreign currency exposure can mitigate market risk, and receiving collateral against a credit exposure can mitigate the severity of a potential default).
- *Transfer* Risk: There are risks that can be transferred to a third party using derivative products, structured products, or by paying a premium (e.g., to an insurer or derivatives provider).

As the risk taker improves its risk management strategy, it will begin to avoid or mitigate non-essential or value-destroying risk exposures, which in turn will allow it to assume more risk in areas where it can pursue more value-creating opportunities for its stakeholders. Investment in risk management thus allows farmers to grow more food, metals producers to produce more metal, and banks to lend more money. Risk management allows firms to excel.

In modern economies, risk management is therefore not only about corporate survival. It is critically important to the broader processes of specialization, scaling, efficiency, and wealth creation.

This explains why risk never really goes away. Risk management success is a platform for greater endeavors. The risk manager is constantly identifying, evaluating, and managing risks to achieve the right balance between creating value and exposing the firm to undue risk. However, identifying and analyzing risk in a fast-changing world remains a major challenge.

Figure 1.5 **Risk managers face the unknown and unexpected.**

1.3 IDENTIFYING RISK: KNOWNS AND UNKNOWNS

One of the easiest mistakes to make is to focus on risks that are known and measurable while ignoring those that are unknown or sets out.

Figure 1.5, our *second building block*, sets out a fundamental classification of known versus unknown risk that considers a classic paper on risk by economist Frank Knight,[9] and the much-quoted words of Donald Rumsfeld, former United States Secretary of Defense:

"There are things we know that we know. There are known unknowns . . . But there are also unknown unknowns."[10]

Rumsfeld said this when trying to encapsulate the danger of terrorists using weapons of mass destruction. His point was that humans tend to focus on the risks for which they have data and ignore potentially larger risks that are unknown or poorly understood. Yet those risks exist and must be managed.

Some of the distinctions in Figure 1.5 are much older than Rumsfeld's quote. In his famous 1921 paper, Knight distinguished between variability that cannot be quantified at all, which he called uncertainty, and "true" risk that can be quantified in terms of statistical science. (Box 1.3)

[9] F. Knight, *Risk, Uncertainty, and Profit* (New York: Houghton Mifflin, 1921).

[10] Donald Rumsfeld, US Secretary of Defence, press conference, NATO HQ, Brussels, 6 June 2002, responding to a question regarding terrorism and weapons of mass destruction and the possible inadequacy of intelligence information: https://www.nato.int/docu/speech/2002/s020606g.htm

BOX 1.3 RISK VERSUS UNCERTAINTY

Economists have argued about the distinction between risk and uncertainty since the early 1920s. The distinction was first made in 1921 by two economists, Frank Knight[a] and John Maynard Keynes.[b] Knight explained the distinction between risk and uncertainty as follows which he referred to as "measurable risk" or "risk proper." Risk, according to Knight, applies to decision making when the outcome of the decision is unknown, but the decision maker can fairly accurately quantify the probability associated with each outcome that may arise from that decision. Knight viewed uncertainty, which he referred to as "unmeasurable uncertainty" or "true uncertainty," as applicable to decisions when the decision maker cannot know all the information needed in order to obtain all the probabilities associated with the outcomes. Today we refer to this as Knightian uncertainty. As similar distinction between risk and uncertainty was made by Keynes in 1921. He argued that there is risk that can be calculated and another sort of risk he labeled "irreducible uncertainty." He understood that for some decisions, the risks cannot be calculated because attempting to do so would necessitate the reliance on assumptions about the future that have no basis in probability theory.

[a] Frank Knight, *Risk, Uncertainty, and Profit* (New York: Houghton Mifflin, 1921).

[b] John Maynard Keynes, Treatise on Probability (New York: Macmillan, 1921)

BOX 1.4 METEORS AND MOONWALKING, ICEBERGS AND ELEPHANTS

When is a risk truly unknown? Perhaps when it arrives out of the blue like a meteor. But many risks are more unseen than unknown. In a 2018 speech, the Bank of England's Alex Brazier separated these risks into "moonwalking bears" and "underwater icebergs."

Moonwalking bears are named after a viral video that shows how people avidly watching a basketball game failed to see a bear impersonator on the screen. This kind of risk can be seen during periods of compressed yields in the debt market: the evidence that risk is being bought too cheaply is plain to see on every financial screen, but investors keep on buying.

The underwater icebergs are more difficult to spot and include the growth in leverage in some financial firms in the run up to the 2007–2009 global financial crisis. After the risk event, these risks also seem obvious because they are usually concerned with some fundamental weakness.

To this ensemble, we might add the age-old elephant in the room. This is the risk that is easy to see, that everyone has indeed spotted, but that it would be impolite to publicly acknowledge.

Source: Alex Brazier, Executive Director for Financial Stability Strategy and Risk, Bank of England, "Moonwalking Bears and Underwater Icebergs," 26 April 2018.

Incalculable Knightian uncertainties can be very large and important. Nuclear war is a major threat to the world, but its chances of happening are impossible to estimate.

Even so, Knightian uncertainties can be managed through avoidance and other forms of risk management. Multilateral nuclear disarmament, whether wise or not, would remove the risk of nuclear war. For difficult actions to be taken, however, there has to be agreement that the Knightian uncertainty is plausible and extremely threatening in terms of its severity (if unquantifiable in terms of frequency).

The boundary between Knightian uncertainty and measurable, statistical risk can be fluid Before 1950, the size of the health threat from smoking was uncertain and cigarette producers regularly advertised their brand as the one that doctors chose to smoke. By the mid-1970s, dedicated researchers had turned this uncertainty into a quantified statistical health risk or "known known": one in two long-term smokers die from the habit.[11]

Do the distinctions between the risk classes in Figure 1.5 matter to financial risk managers? Yes. Risk managers take responsibility for all sorts of risk, not just those that can be measured. They must continuously search for Rumsfeld's "unknown unknowns," including risks that are hiding in plain sight (Box 1.4). They cannot simply ignore Knightian uncertainties. In fact, they sometimes need to make sure their firms avoid or transfer them.

[11] This may be a conservative estimate, with the most recent research suggesting that smoking eventually kills around two in three smokers. See M. Roberts, "Tobacco Kills Two in Three Smokers,'" BBC News online, 24 February 2015: http://www.bbc.co.uk/news/health-31600118

Where they can, risk managers move poorly understood risks from the periphery of Figure 1.5 to a position nearer to the center. As cigarettes have demonstrated, Knightian uncertainties can be more severe and prevalent than we initially suspect.

However, risk managers must never treat risks that cannot be measured as if they are a known quantity. Uncertainty and ambiguity must be acknowledged because they exist in much greater amounts for some risky activities than for others. Our confidence in a risk measure shapes how the result should be applied in decision-making.[12]

1.4 QUANTITATIVE RISK METRICS

Figure 1.5 makes an important distinction between expected and unexpected loss. This distinction is our third building block.

Expected loss (EL) is the average loss a position taker might expect to incur from a position or portfolio. In theory, some portfolios realize losses that rarely depart far from this average. The losses from this kind of portfolio may be amenable to statistical measurement over a relatively short period of time with a fair degree of confidence. They might vary, for example, from year to year, but not by too much.

The EL of a portfolio can be calculated by identifying and estimating values for the key underlying risk factors. In general, EL is a function of (1) the probability of the risk event occurring; (2) the firm's exposure to the risk event; and (3) the severity of the loss if the risk event occurs. In the case of the credit risk of a loan, these become the borrower's probability of default (PD); the bank's exposure at default (EAD); and the severity of loss given default (LGD). Thus, EL is simply:

$$EL = EAD \times LGD \times PD$$

Where EL can be calculated with confidence, it can be treated like a variable cost or predictable expense rather than a risk or uncertainty. The bank can make a profit simply by adding a price margin that covers the cost of the EL.[13] Here, the risk manager's role is primarily to measure the amount of EL and to make sure the portfolio does not lose its predictable quality.

Expect the Unexpected

That said, well-behaved portfolios inevitably offer surprises. EL is created from good and bad days. On a bad day, losses can range above the expected level (e.g., the result of an announcement of fraud in a credit card business or simply an unlucky sequence of losses). The extent to which losses depart from the average is called the unexpected loss level.

In a credit portfolio, the potential for unexpected loss might be driven by something quite simple, such as the number and size of the loans. When a portfolio is composed of a large proportion of small loans, there is little chance of one very important loan defaulting. In addition, if the portfolio is well diversified, there is little chance of multiple losses occurring together to generate unexpected loss levels.

Also, consider that the amount of EL (and unexpected loss) in a credit portfolio is changing continuously. These fluctuations are driven by factors such as changes in the macroeconomic environment and size and constitution of the portfolio (e.g., its credit quality or correlations). Estimating expected losses for even a well-behaved portfolio involves a fair amount of art as well as science—and some big assumptions.

From Unexpected to Extreme

Some credit portfolios, however, exhibit a much more extreme variance in their losses over intervals of time (e.g., a decade). Here, the expected losses over time are constructed from both long runs of good years (when losses are much lower than average) and short runs of bad years (when losses are much higher than average). In the bad years, losses reach unexpected and even extreme levels.

These portfolios can be very deceptive from a risk management point of view. It is easy to be lulled into a complacent view of risk exposure and then experience a sudden shock. For this kind of risky position or portfolio, banks need to allocate large amounts of risk capital to protect against large unexpected losses that can trigger insolvency and default. This allocation of risk capital is done in addition to pricing EL into the product directly.

Risky Relationships

A classic example of this loss level variability can be seen in the regular cycles of boom and bust in commercial real estate (CRE) markets around the world.[14]

[12] For further discussion of the role of uncertainty in economics, see A. Lo and M. Mueller, "Warning: Physics Envy May Be Hazardous to Your Wealth!" March 19, 2010: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1563882

[13] Theoretically, therefore, banks should not need to set aside provisions for expected losses where these are accurately priced into a product, though they will need to allocate risk capital for unexpected loss levels. For a discussion about why banks should, in the real world, provision for expected losses as well see B. Cohen and G. Edwards, "The New Era of Expected Credit Loss Provisioning," *BIS Quarterly Review*, March 2017: https://www.bis.org/publ/qtrpdf/r_qt1703f.htm

[14] This classic cycle is well documented in the literature, for example, European Systemic Risk Board, *Report on Commercial Real Estate and Financial Stability in the EU*, December 2015, available at: https://www.esrb.europa.eu/pub/pdf/other/2015-12-28_ESRB_report_on_commercial_real_estate_and_financial_stability.pdf

First, demand for commercial property strengthens, often in line with general economic upswings. But CRE supply is inelastic[15]: it takes time to construct a property. Prices rise, attracting investors, banks, and other lenders, who may begin to relax loan-to-value ratios and other safeguards to gain market share.

Eventually, prices begin to weaken through a combination of cyclical oversupply of property and deteriorating economic conditions. Banks begin to withdraw credit from investors and developers in the market, exacerbating the fall. Overextended property developers experience cash flow problems. Property loses value as collateral. The financial condition of CRE lenders deteriorates and lending dries up. One fire sale later—and the market has entered a devastating cycle of feedback.

The result for lenders is that the probability of default by property developers rises at the same time collateral values fall—a bad combination referred to as *wrong way risk*. The global CRE markets are one of the clearest examples of how risk factors act together to produce waves of extreme loss.

There are many other examples in the financial markets of risk factors that can act together to generate risk. For example, in derivative markets, the value of a contract with a counterparty may tend to rise simultaneously with the default risk of the counterparty (another example of wrong way risk).

Value-at-Risk

In January 1990, Dennis Weatherstone, newly appointed CEO of J.P. Morgan, called for a report on the total risk of his bank to be delivered to his desk every day at 4:15 p.m. The request helped to drive the development of a new global risk metric: Value-at-Risk (VaR).[16]

Jorion defines the VaR measure as the "worst expected loss over a given horizon under normal market conditions at a given level of confidence."[17] For example, suppose that a bank's trading portfolio has a weekly VaR at the 95% confidence level of $10 million. This means that under normal market conditions, there is a 5% probability that the bank's trading portfolio will lose more than $10 million over the next week. As another example, suppose that a fund's monthly VaR at the 99% confidence level is a loss of 3%. This means that under normal market conditions, there is a 1% probability that the fund will have a loss that is greater than 3%.

VaR uses the loss distribution associated with a position or portfolio to estimate losses at a given level of likelihood (or confidence). However, an important point is that for any given loss distribution, the VaR number would tend to fall if we eased the confidence level to 95%. The number would also rise or fall if the shape of the loss distribution changed. For example, a loss distribution with a much fatter tail incurs more unexpected loss and a larger VaR number.

Expected Shortfall

While VaR is a useful measure, it fails to quantify how much risk there is in the tails. A measure that overcomes that drawback is expected shortfall (ES), also referred to as conditional value-at-risk (CVaR). For a given tail probability, ES is defined as the average of the VaR numbers that exceed the VaR at that tail probability. That is, ES focuses on the losses in the tail that are larger than the corresponding VaR level.

1.5 RISK FACTOR BREAKDOWN AND INTERACTIONS BETWEEN FACTORS

The example of the CRE cycle demonstrates how important it is for risk analysts to break risk down into discrete risk factors—in this case, PD, LGD, and EAD—and understand how these risk factors might interact over time and under stress to generate losses.[18]

In turn, each primary risk factor is driven by a more fundamental set of risk factors. For example, the probability of default by a firm may be driven by its strength or weakness in terms of key financial indicators, industry sector, management quality, etc.

Breaking risk down into its key risk factors and understanding their importance as loss drivers—and their relationships with each other and the wider business environment—is a key activity for risk managers and is our fourth building block.

A key question concerns how granular each risk factor analysis should be. Ideally, risk managers would like to understand every significant risk factor and analyze each factor's importance and dynamics through the data available.

To score the risk factor, the risk manager may want to look at its sub-factors. For example, what is it that drives the credit risk variable of management quality: management's years of

[15] An inelastic supply refers to a market situation wherein a change in the price of a product (in this case CRE) does not result in a corresponding change in supply of that product.

[16] Other firms such as Bankers Trust, a US merchant bank, had been working to build global risk reports in the period, and many of the concepts underlying VaR appeared prior to the 1990s. J.P. Morgan published the methodology behind its VaR model in 1993/4.

[17] P. Jorion, *Value at Risk: The New Benchmark for Managing Financial Risk*. New York, NY: McGraw-Hill, 2001

[18] Understanding the dynamics of a loss record greatly increases its predictive power. To prepare for a key banking reform, Basel II, some years ago, banks had to spend millions of dollars re-engineering their credit rating systems when the regulators asked them to improve their risk modeling by recording probability of default, loss given default, and credit exposure as separate risk factors.

BOX 1.5 WILL DATA SCIENCE REVOLUTIONIZE RISK ANALYSIS?

Data science includes big data, artificial intelligence, and machine learning. Data science is helping risk managers approach the identification of risk variables in a new way. This should allow risk managers to isolate innumerable risk factors and understand their relationships at a greater level of complexity.

In the insurance world, for example, analysts are bringing together public databases, social data, crediting rating data, and unstructured data to understand risk at the individual level—the "segment of one," as the industry calls it.

Across the risk industries, massive computing power can now help risk managers spot patterns and relationships in data more quickly. Unsupervised machine learning can help the risk manager identify the "unknown unknowns" through identifying clusters and correlations without specifying the area of interest in advance. Risk managers are about to enter an age of plenty in terms of data volume and risk factor analysis.

experience? Or what drives a firm's vulnerability to cyber risk: systems, processes, or people?

Finding the answers to such questions is important, but practicalities often impose their own limits. Analytical resources may not be available. The loss data that can be used to isolate and statistically examine the power of each risk variable may be limited in quantity, quality, or descriptive detail.

That being said, new streams of data offering an undreamt level of granularity, analyzed by means of machine learning and massive cloud-based computational power, may prove revolutionary in the identification of discrete risk factors (Box 1.5).

1.6 STRUCTURAL CHANGE: FROM TAIL RISK TO SYSTEMIC CRISIS

Some risk events have a diabolical side that seems designed to outwit the human mind. This may be because such events are very rare and extreme or they arise from unobserved structural changes in a market.

In complex systems, such as the global climate or financial markets, extremely rare events can happen over long time periods, even if the system remains structurally stable. These risks, really an extreme version of unexpected loss, are difficult to identify in the data because (by definition) there are not a lot of them.

Tail risk events (or outliers) might be rare, but a long enough time series of data should reveal evidence of their existence. Where data are scarce, modern risk management can sometimes apply statistical tail risk techniques, utilizing a branch of statistics called Extreme Value Theory (EVT) to help make tails more visible and to extract the most useful information.[19]

[19] For accessible reviews of the literature, see A. Pazarbasi, "Tail Risk Literature Review," *Alternative Investment Analyst Review*; D. Levine, "Modelling Tail Behavior with Extreme Value Theory," *Risk Management*, September 2009, Issue 17.

When the structure underlying a system changes, risk increases. Large loss events may suddenly increase in frequency or size. Risk factors might suddenly move in lockstep. Entirely new sources of loss, in terms of risk type, may appear. In this case, more historical data will not help and "once-in-100-year" events might pop up once a decade until the structural problem is fixed, or proper risk management processes are adopted.

A change in events does not only affect tail risk—the amounts of EL and unexpected loss might change as well. Risk managers are continuously trying to assess the risk in systems that are changing in ways that might, or might not, matter.

While this is a problem for all risk managers, there is a special twist for those working in the financial markets. Unlike most mechanical and natural systems, human systems (such as financial markets) are subject to constant structural change from levers such as social behavior, industry trends, regulatory reforms, and product innovations.

An important recent example was the growth in subprime mortgage lending by US banks and other financial institutions starting in the early 2000s and its role in the creation of the 2007–2009 global financial crisis. Unusual types of mortgages, such as interest-only mortgages and below market initial loan rates, rose quickly from comprising a small fraction of total loans originated to a substantial share of all new mortgages. At the same time, the proportion of loans that were subprime (i.e., mortgages to borrowers with blemished credit histories) also increased. Structural change—looking out for it and modeling its future effects—is our fifth building block of risk management.

1.7 HUMAN AGENCY AND CONFLICTS OF INTEREST

Structural change is not the only wild card in financial systems. Unlike natural systems, human systems are run by intelligent participants that can react to change in a self-reflective or even a calculating manner.

For example, consider a trader who carefully attempts to predict the effects of a market reform. The trader's peers can try to second guess his or her predictions. Perhaps a regulator that helped draft the reform joins a financial consulting firm and advises the industry on how to circumvent the safeguard.

This type of behavior is true inside the firm as well. Those who understand how risk is generated and managed are in the best position to game it. They also often have the least incentive to make the risk transparent: Why would they broadcast the potential for unexpected loss levels or tail risks? This is one reason many financial firms employ three lines of defense:

1. First line: Business line that generates, owns, and manages risk;
2. Second line: Risk managers that specialize in risk management and day-to-day oversight; and
3. Third line: Periodic independent oversight and assurance, such as an internal audit.

The safeguards do not always work. Risk management systems always have loopholes and become obsolete quickly in the face of industry innovations. For example, in a worrying number of rogue trading cases in the banking industry, the trader had first worked in the middle or back office and thus understood the loopholes in the risk management infrastructure. Sometimes traders and business leaders deliberately undermine the credibility of risk management systems. Understanding the role of human agency, self-interest, and conflict of interest, is the sixth building block of risk management.

1.8 RISK AGGREGATION

Given the many different types of risk and risk metrics, a key problem in risk management is the challenge of seeing the bigger picture. How can senior managers identify the riskiest businesses on their watch and tell when the firm's aggregate risk is approaching intolerable levels?

Market risk tends to be the most amenable risk type to quantification and aggregation but controlling this risk factor is challenging. Until recent decades, market risk exposures were largely compared in terms of the notional amount held in each asset (e.g., USD 10 million of a large capitalization stock) rather than both the notional amount held in each asset and their volatilities.

This was never satisfactory. Some stocks and industry sectors were historically more volatile in price than others. Making matters worse, it made no sense to use notional amounts to compare the risks taken by, for example, the US Treasury trading desk and a desk dealing in a volatile commodity.

The advent of the derivatives markets in the 1970s made it imperative to improve market risk measures. Derivatives can be highly volatile and are an easy way to build up large risk exposures. Their value and their risk are driven by factors only tangentially related to the notional value of the instrument.

Portfolios of derivatives are often designed so that the individual instruments offset each other's market risk. It therefore makes no sense to treat the aggregate notional amounts in the portfolio as an indicator of portfolio risk.

Options trading specialists developed their own measures of risk, including delta (i.e., sensitivity of option value to a change in the value of the underlying) and theta (i.e., the change in option value as the option expiration date approaches). These measures, commonly referred to as the "Greeks," were—and still are—invaluable risk measures on the options trading desk.

The Greeks are of limited help at an enterprise level, however, because they cannot be added together; nor do they imply the same level of risk across markets (e.g., delta in foreign exchange versus commodity markets). Large financial institutions needed a risk measure that was much more comprehensive.

VaR was a popular risk aggregation measure in the years leading up to the crisis. However, it was not calculated using a set methodology, and there were at least three principal methodologies (and many ways to implement them). In fact, the concept of VaR also involves many simplifying assumptions.

The concept proved almost too useful. It was quickly applied to manage risk across much longer time horizons, across many institutions and whole industries, and across many different risk types.

The shortcomings of VaR as a risk measure were understood well before the global financial crisis of 2007–2009, but the crisis brought these weaknesses to the forefront and led to a reaction against over-dependence on this risk metric. VaR does, however, remain an important tool for risk managers.

Bank regulators have tried to improve the way VaR is calculated, make its calculation across the industry more consistent and reliable, and strengthen the role of supplementary risk measures such as ES and worst-case scenario analysis (Box 1.6).

The inherent drawbacks of VaR have encouraged risk managers to adopt a broader approach to risk metrics. Aggregate risk measures are useful in their place, but they inevitably fail to capture key dimensions of risk and must be supplemented with other approaches. Understanding risk aggregation and its strengths and weaknesses is our eighth risk management building block.

BOX 1.6 TAKING ACCOUNT OF TAIL RISK

VaR only looks at the largest loss at a given likelihood threshold; it does not examine the size of losses beyond this threshold. For that reason, it is often said to ignore tail risk (i.e., the effect of very severe but rare events). After the global financial crisis of 2007–2009, various remedies for this were put forward. One of these was expected shortfall (ES), which is a statistical measure designed to quantify the mean risk in the tail of the distribution beyond the cut-off of the VaR measure.

Banks and their regulators also turned to scenario stress testing and reverse stress testing. Scenario analysis and stress testing ignore the problem of measuring the frequency or probability of a rare event. Instead, they focus analytical resources on imagining a reasonably plausible worst-case scenario that may develop in stages over an extended period. The risk manager develops the scenario—or is handed it by a regulator—and then analyzes the impact of the event on the institution given its risk exposures and reactive capabilities. Scenario analysis and stress testing can be highly quantitative and involve complex modeling, but the numbers are all focused on assessing severity rather than frequency.

Reverse stress testing starts at the other end. The institution applies its modeling capabilities to work out how bad losses could get, then works backwards to try to understand how those losses were linked to its exposures and activities. How could the institution manage its activities to avoid the worst that might happen?

1.9 BALANCING RISK AND REWARD

A major advantage of a VaR approach is that it helps the firm to compare the risk exposures of different business lines. Firms come to understand the expected and unexpected loss levels associated with different activities. Furthermore, the firm can protect itself against these risks by making sure that its risk capital—also known as economic capital—is large enough to absorb the unexpected risk.

In the banking industry, economic or risk capital is the amount of capital the firm requires based on its understanding of its economic risks. It is distinct from regulatory capital, which is calculated based on regulatory rules and methodologies. Economic capital and regulatory capital are sometimes in alignment, but often generate quite different numbers.

Economic capital provides the firm with a conceptually satisfying way to balance risk and reward. For each activity, firms can compare the revenue and profit they are making from an activity to the amount of economic capital required to support that activity.

A firm can then take these risk capital costs into account when it prices a product and when it compares the performance of different business lines. There are clear reasons to do this. For example, Business A might attract significant costs every year in terms of EL but incur little in the way of unexpected losses. Business B, on the other hand, might attract very little in the way of EL but suffer from very large losses at the end of every business cycle.

Without a sophisticated risk-adjusted analysis of profitability, it will be difficult to compare Business Division A and Business Division B. Most likely, Business Division B will look very attractive during the benign part of the cycle. The firm might decide to cut product prices to build up business volume. This frequently results in unexpected losses when the cycle turns. (Banking industries globally have tended to behave in exactly this manner, exacerbating the tendency for whole economies to go from boom to bust.)

To factor in the cost of risk of both expected and unexpected losses, the bank can apply a classic formula for risk-adjusted return on capital (or RAROC):[20]

$$\text{RAROC} = \text{Reward}/\text{Risk}$$

where reward can be described in terms of After-Tax Risk-Adjusted Expected Return, and risk can be described in terms of economic capital.

After-Tax Net Risk-Adjusted Expected Return also needs to be adjusted for Expected Losses:

$$\text{RAROC} = \text{After-Tax Net Risk-Adjusted Expected Return}/\text{Economic Capital}$$

For an activity/portfolio to add value to shareholders (and the stock price), RAROC should be higher than the cost of equity capital (i.e., the hurdle rate or minimum return on equity capital required by the shareholders to be fairly compensated for risk).

There are many variants on the RAROC formula, applied across many different industries and institutions. Their level of sophistication varies but all have the same purpose: to adjust performance for risk. Four day-to-day applications stand out.

- *Business comparison:* RAROC allows firms to compare the performance of business lines that require different amounts of economic capital.

[20] See M. Crouhy, D. Galai, and R. Mark, *The Essentials of Risk Management*, 2nd ed. (Ch. 17), McGraw Hill, 2014.

BOX 1.7 HARD NUMBERS?

Risk reports are full of numbers that look objective and empirical. Risk analyses perform a confusing array of tasks (Figure 1.6). Some are intended to quantify risk in some absolute sense—for example, Risk Probability xExposure x Severity—though the data and the modeling that underpin these numbers vary in quality.

Other risk reports track some component of this equation, such as risk exposure. However, a drop in one risk component may not mean risk is declining, unless everything else remains the same. For example, a bank losing market share might remedy this by loosening credit quality: The drop in loan volume may not mean less credit risk.

Other numbers track key risk indicators (KRIs), which are quantitative measurements that are used to assess potential risk exposures. For example, a staff turnover metric might act as a KRI for a type of operational risk. In this case, the relationship of the risk indicator to the risk under examination is often based on judgment. Decision-makers looking at risk metrics going up and down sometimes fool themselves that they are watching risk itself, when they are really watching a risk proxy of uncertain utility.

Through either judgment or calculation, businesses must balance risk and reward. That makes RAROC and similar measures the ninth building block of risk management.

Figure 1.6 **Risk metrics capture many different dimensions of risk.**

- *Investment analysis:* A firm typically uses the RAROC formula that uses projected numbers to assess likely returns from future investments (e.g., the decision to offer a new type of credit product). RAROC results based on past returns can also be used to determine if a business line is providing a return above a hurdle rate demanded by the equity investors who are the providers of the firm's risk capital.
- *Pricing strategies:* The firm can re-examine its pricing strategy for different customer segments and products. For example, it may have set prices too low to make a risk-adjusted profit in one business segment, while in another it may have the ability to reduce prices and increase market share (and overall profitability).
- *Risk management cost/benefit analysis:* RAROC analyses can help a firm compare the cost of risk management (e.g., risk transfer via insurance, to the benefit of the firm).

There are many practical difficulties in applying RAROC, including its dependence on the underlying risk calculations. Managers of business divisions often dispute the validity of RAROC numbers, sometimes for self-interested reasons. As with other types of risk metrics (Box 1.7), decision-makers should always understand what the number means and what is driving it.

1.10 ENTERPRISE RISK MANAGEMENT (ERM): MORE THAN ADDING UP RISK?

One challenge to an effective firm-wide risk management process is that at many firms, business divisions manage their risk in a *siloed* approach (i.e., where each division manages its own exposures independently without considering the risk exposures of other divisions). Financial risk managers have long recognized that they must overcome this silo-based risk management process to build a broad picture of risk across risk types and business lines: enterprise risk management (ERM).

We devote Chapter 8 to ERM, the tenth building block of risk management. ERM projects encourage firms to think about enterprise risk using tools, such as a clear statement of corporate risk appetite, a cohesive approach to risk management rough global risk committees, and so on.

Oftentimes, historic ERM efforts have overemphasized the need to express risk as a single number such as economic capital or VaR. Expressing risk as a single number was too simplistic an approach.

BOX 1.8 DIGITAL RISK MANAGEMENT?

The digital era is changing the face of business in many ways, including the new ways that corporations interact with customers (mobiles, sensors) and new risks (cyber risk, privacy regulations). How will the digital era change the working day of the risk manager over the next few years?

According to a survey by McKinsey in 2017, the digital transformation of risk functions in financial institutions is occurring more slowly than the transformation of customer-facing operations. However, big changes are underway, including:

- Drawing information from a wider set of sources to apply advanced analytics to measure risk, for example, applying big data analytics to credit and operational risks;
- Faster and real-time decision-making based on more automated risk processes, for example, automated corporate credit scoring; and
- Greater productivity, as risk processes are engineered away from paper documents towards automated work flows, for example, for reviews of documentation.

The survey found that there are big challenges involved with digitizing risk management in the form of legacy infrastructure, limited data, and the need for new digital skills. Data scientists have the critical skill set for digitized risk functions and may soon be in as much demand as "rocket scientist" risk modelers.

Source: McKinsey & Co and Institute of International Finance: The Future of Risk Management in the Digital Era, October 2017; see Exhibit 23 regarding the need for data scientists in digital risk management functions.

Perhaps the biggest lesson of the 2007–2009 global financial crisis was that risk cannot be reduced to any single number.

- It is multi-dimensional, so it needs to be approached from many angles, using multiple methodologies.
- It develops and crosses risk types, so even a wide view of risk types—but at only one point in time—may miss the point.
- It demands expert judgment that is combined with application of statistical science.

Measuring risk in economic capital terms is important for balancing risk and reward. However, the key factor that saves an institution may come from another risk analysis tool—perhaps from worst-case scenario analysis or some new digital approach (Box 1.8). Firms need a comprehensive view of risk and this can only be built using a range of tools and a healthy amount of curiosity.

For example, insights might come from a risk manager digging deep and realizing the implications of a structural change in a market. It might come from looking at the competition and realizing that behavior across the industry might precipitate a market crisis. Or it might come from a new risk indicator such as a market-derived credit risk indicator that signals a change in credit condition at a major counterparty early enough for action to be taken.

That moment of realization, however, must be followed up with actions. The modern approach to ERM must also look at the processes that link information to action and also look at the firm's corporate governance and risk culture, as we discuss in Chapters 3 and 4. If the firm embarks on an aggressive push for growth only to realize that risks have not been fully understood, what is its process for changing course? Has that fire drill been tested?

ERM is no longer simply about aggregating risk across risk types and businesses. It is about taking a more holistic approach to the entire risk management process and its relationship to strategic decisions. It is about the way the firm thinks about risk, and in doing so establishes its corporate identity (Figure 1.7).

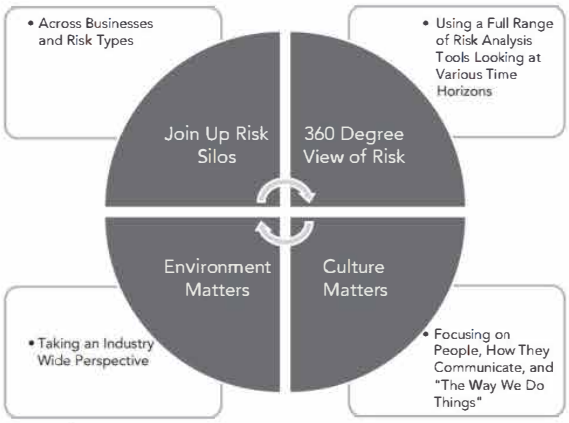

Figure 1.7 ERM needs to think a bit bigger.

The following questions are intended to help candidates understand the material. They are *not* actual FRM exam questions.

QUESTIONS

1.1 Describe and provide examples of fundamental risk factors and their sub-risk factors that drive the probability of a firm's default

1.2 What are the four components of a risk management process?

1.3 Provide an example of what is meant by basis risk.

1.4 What are two types of liquidity risk?

1.5 What drives market risk across all markets?

1.6 What is meant by strategic risk?

1.7 Describe how risk managers become involved in business risk.

1.8 What Is reputation risk? Provide examples in your answer.

1.9 What is meant by economic capital? Contrast it with regulatory capital.

1.10 What is the basic idea of RAROC? Provide the RAROC equation in your answer.

1.11 What are a few applications of RAROC? Provide examples in your answer

1.12 What is counterparty risk and give an example?

1.13 If a bank's management is told that under normal market conditions, the daily VaR at the 97.5% confidence level for its trading portfolio is USD 14 million. What does that mean?

1.14 Provide a list of examples of risk management that can be seen in early history.

1.15 Provide a list of the key risk management building blocks.

1.16 Provide a list of the four choices involved in the classic risk management process.

1.17 Unsupervised machine learning can help the risk manager identify the "unknown unknowns" through identifying clusters and correlations without specifying the area of interest in advance.

A. True
B. False

1.18 Banking regulators are encouraging tools that support using advanced analytical formulas to calculate regulatory operational risk capital.

A. True
B. False

1.19 The three lines of defense consists of:

- First line: Risk managers that specialize in risk management and day-to-day oversight;
- Second line: Business line that generates, owns and manages risk; and
- Third line: Periodic independent management oversight and assurance such as internal audit.

A. True
B. False

1.20 Reverse stress testing applies its modeling capabilities to estimate the size of potential losses.

A. True
B. False

1.21 Frank Knight referred to uncertainty as measurable risk.

A. True
B. False

1.22 The *expected shortfall* is the expected loss in the tail of the distribution.

A. True
B. False

1.23 Business risk involves making large, long-term decisions about the firm's direction, often accompanied by major investments of capital, human resources, and management reputation.

A. True
B. False

1.24 Enterprise Risk Management is the management of risk at the business unit level.

A. True
B. False

1.25 Track key risk indicators are quantitative measurements that are used to assess potential risk exposures.

A. True
B. False

1.26 Business risk applies only to large non-financial corporates.

A. True
B. False

1.27 Expected shortfall (ES) is

A. a statistical measure designed to quantify the mean risk in the tail of the distribution beyond the cut-off of the VaR measure.
B. the case where RAROC fails to be greater than a hurdle rate.