Overview of Enterprise Risk Management

Casualty Actuarial Society

Enterprise Risk Management Committee

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Appendices

Overview of Enterprise Risk Management

I. Executive Summary

This document is intended primarily to further the risk management education of candidates for membership in the Casualty Actuarial Society (CAS). Current members of the CAS as well as other risk management professionals should also find this material of interest.

In Chapter II, the evolution to and rationale for enterprise risk management (ERM) is explained. The "ERM movement" is driven by both internal (e.g., competitive advantage) and external (e.g., corporate governance) pressures – pressures that are both fundamental and enduring.

Chapter III defines ERM for CAS purposes, and lays out its conceptual framework. The definition makes clear that ERM is a value-creating discipline. The framework describes both the categories of risk and the types of risk management processes covered by ERM. ERM is seen to extend well beyond the hazard risks with which casualty actuaries are particularly familiar, and well beyond the quantification of risks with which they are particularly skilled – but it is clear that the casualty actuarial skill set is extremely well-suited to the practice of ERM. ERM also extends well beyond the insurance industry, which presents a distinct opportunity for casualty actuaries to continue to expand their career horizons and take leadership roles in these varied industries.

The vocabulary of ERM is established in Chapter IV, which also describes the measures, models and tools supporting the discipline. The close linkage between ERM and corporate performance management is made clear in this discussion. Dynamic Financial Analysis (DFA) is introduced, along with alternative approaches to capture hazard and financial risks, and their roles within an ERM context is explained. Models that treat operational and strategic risks are also discussed. Applications of these measures, models and tools to support management decision-making are outlined at the conclusion of this chapter.

With the conceptual and technical foundations of ERM thus established, Chapters V and VI turn to the actual practice of ERM. Chapter V presents relevant case studies from various industries, and Chapter VI offers some practical considerations in implementing ERM.

For the reader interested in pursuing additional sources of learning on the subject, a bibliography of existing literature on ERM and its key components is included in Appendix C. (A continually updated, annotated and topically-organized road map through the literature can be found on the CAS Web site at http://www.casact.org/research/erm/.)

Enterprise risk management is a "big idea". Among other things, ERM can be viewed as the broad conceptual framework that unifies the many varied parts of the actuarial discipline. ERM provides a logical structure to link these subject areas together in a compelling way to form an integrated whole. In so doing, ERM addresses critical business issues such as growth, return, consistency and value creation. It expresses risk not just as threat, but as opportunity – the fundamental reason that business is conducted in a free enterprise system. Through ERM, the clear linkage between business fundamentals and actuarial theory and practice should engage students and professionals from various backgrounds in the study of actuarial science – a logical career strategy in a global business environment that has embraced ERM as a modern management discipline.

II. The ERM Evolution

Organizations have long practiced various parts of what has come to be called enterprise risk management. Identifying and prioritizing risks, either with foresight or following a disaster, has long been a standard management activity. Treating risks by transfer, through insurance or other financial products, has also been common practice, as has contingency planning and crisis management.

What has changed, beginning very near the close of the last century, is treating the vast variety of risks in a holistic manner, and elevating risk management to a senior management responsibility. Although practices have not progressed uniformly through different industries and different organizations, the general evolution toward ERM can be characterized by a number of driving forces. We discuss these characteristic forces below.

More – and More Complicated – Risks

First of all, there is a greater recognition of the variety, the increasing number, and the interaction of risks facing organizations. Hazard risks such as the threat of fire to a production facility or liability from goods and services sold have been actively managed for a long time. Financial risks have grown in importance over the past number of years. New risks emerge with the changing business environment (e.g., foreign exchange risk with growing globalization). More recently, the awareness of operational and strategic risks has increased due to a succession of high-profile cases of organizations crippled or destroyed by failure of control mechanisms (e.g., Barings Bank, Enron) or by insufficient understanding of the dynamics of their business (e.g., Long Term Capital Management, General American Insurance Company). The advance of technology, the accelerating pace of business, globalization, increasing financial sophistication and the uncertainty of irrational terrorist activity all contribute to the growing number and complexity of risks. It is reasonable to expect that this trend will continue.

Organizations have come to recognize the importance of managing *all* risks and their interactions, not just the familiar risks, or the ones that are easy to quantify. Even seemingly insignificant risks on their own have the potential, as they interact with other events and conditions, to cause great damage.

External Pressures

Motivated in part by the well-publicized catastrophic failures of corporate risk management cited above, regulators, rating agencies, stock exchanges, institutional investors and corporate governance oversight bodies have come to insist that company senior management take greater responsibility for managing risks on an enterprise-wide scale. These efforts span virtually every country in the civilized world. A sampling of these requirements and guidelines has been compiled in Appendix A.

In addition to these codified pressures, publicly traded companies are well aware of the increasingly vocal desire of their shareholders for stable and predictable earnings, which is one of the key objectives of ERM for many organizations.

Portfolio Point of View

Another characteristic force is the increasing tendency toward an integrated or holistic view of risks. Developments in finance (i.e., Modern Portfolio Theory) provide a framework for thinking about the collective risk of a group of financial instruments and an individual security's contribution to that collective risk. With ERM, these concepts have been generalized beyond financial risks to include risks of all kinds, i.e., beyond a portfolio of equity investments to the entire collection of risks an organization faces. A number of principles follow from this thinking, including:

- Portfolio risk is not the simple sum of the individual risk elements.
- To understand portfolio risk, one must understand the risks of the individual elements plus their interactions.
- The portfolio risk, or risk to the entire organization, is relevant to the key risk decisions facing that organization.

The implications of these principles are having a significant impact on the practice of ERM. There is growing recognition that risks must be managed with the total organization in mind. To do otherwise (sometimes referred to as managing risk within "silos") is inefficient at best, and can be counter-productive. For example, certain risks can represent "natural hedges" against each other (if they are sufficiently negatively correlated). A classic case is that of an insurer selling both life insurance and annuity business to similarly situated customers and thereby naturally hedging away its mortality risk. To separately hedge mortality risk on these products (e.g., through reinsurance) would be cost inefficient and entirely unnecessary. Another example is that of a global conglomerate with one of its divisions long in a certain foreign currency and another short in the same currency. Separate currency hedges, while seemingly advisable from the point of view of the individual division heads, are unreasonable for the enterprise as a whole.

A holistic approach helps give organizations a true perspective on the magnitude and importance of different risks.

Quantification

A fourth characteristic force, closely tied to the third, is the growing tendency to quantify risks. Advances in technology and expertise have made quantification easier, even for the infrequent, unpredictable risks that historically have been difficult to quantify. Following a series of natural disasters, most notably hurricane Andrew in 1992, the practice of catastrophe modeling arose and is now a standard practice in insurance companies. This combination of meteorological (in the case of hurricane modeling), structural engineering, insurance and technological expertise leading to probabilistic models is a huge advancement over previous quantification attempts. By the end of the twentieth century, insurance and reinsurance companies routinely measured their exposure to hurricanes, earthquakes and other natural disasters with a greater degree of precision leading to a greater confidence in the ability to manage the exposure. More recently, such exposure-based quantification of exposure to losses has been extended to even less predictable, man-made disasters such as terrorist attacks.

The emergence of Value-at-Risk as a regulatory and management standard in the financial services industry has been aided by the speed and ease in measuring certain financial risks. Data is collected constantly allowing risk profiles to be adjusted as portfolios and market conditions change. This gives financial institutions and the regulatory bodies that oversee them a level of confidence in their ability to take actions to operate within established parameters.

Despite these advances, there will always remain risks that are not easily quantifiable. These include risks that are not well defined, unpredictable as to frequency, amount or location, risks subject to manipulation and human intervention, and newer risks. Man-made risks, operational and strategic risks are examples of these. Operational risk is a general category for a wide variety of risks, many of which are influenced by people and many of which do not have a long historical record. The tendency to quantify exposure to all these risks will certainly continue.

In the same way there has been a continuing effort to better quantify individual risks, there is a growing effort to quantify portfolio risk. This effort is much more difficult because in addition to individual risks, one must quantify or explain interactions between individual risk elements. This can be extremely complex and challenging. However, there often is not the need for a great deal of precision; even a directionally correct answer may be valuable. The attempt at quantification allows the organization to analyze "what if" scenarios. They are able to estimate the magnitude of risk or degree of dependency with other risks sufficiently to make informed decisions. Further, simply going through the quantification process gives people a better qualitative perspective of the risk. They may gain insight as to the likelihood or severity of the risk or to ways to prevent or mitigate the exposure.

Boundaryless Benchmarking

A fifth characteristic force pertains to scope. Common ERM practices and tools are shared across a wide variety of organizations and across the globe. The process, tools, and procedures laid out in this overview are not limited to the insurance or even financial service industries but rather are common to many organizations. Information sharing has been aided by technology but perhaps more importantly, because these practices are transferable across organizations. Organizations have become quite willing to share practices and efficiency gains with others with whom they are not direct competitors.

An example of a phenomenon common to many organizations and having risk management implications is real options. Many organizations face operating and strategic situations where events are uncertain, players make initial investments to get in the game and then have the opportunity to make successive investments contingent on future events. The drug approval process in the pharmaceutical industry is an example where organizations face options-like decisions (see Chapter V). Option pricing techniques provide organizations with a means of better thinking about and managing these risks.

Different industries and organizations will continue to develop and employ variations of ERM. Different risks will be more or less important to organizations and risk management practices will differ in particular ways that best suit the organization, but there will be general concepts and broad general practices and techniques that are recognized and employed by organizations throughout the world.

Risk as Opportunity

A sixth characteristic force pertains to the outlook organizations have toward risk. In the past, organizations tended to take a defensive posture towards risks, viewing them as situations to be minimized or avoided. Increasingly, organizations have come to recognize the opportunistic side, the value-creating potential of risk. While avoidance or minimization remain legitimate strategies for dealing with certain risks, by certain organizations at certain times, there is also the opportunity to swap, keep, and actively pursue other risks because of confidence in the organization's special ability to exploit those risks.

There are a number of reasons for this shift in attitude. Over time and with practice, organizations have become more familiar with and more capable of managing the risks they face. They develop expertise in managing those risks both because of familiarity and confidence in the organization's abilities. As a result, they may keep their own exposure and seek out opportunities to assume other organization's risks. Over time, better information about risk has become available. This has led to new markets for trading risks and more information about the cost of risks. This has allowed organizations to better evaluate risk and return trade-offs and see that the costs of transfer sometime outweigh the benefits. In addition, the existence of risk-trading markets contributes to a greater degree of confidence. Organizations can adopt a more aggressive stance if they know they can switch to a defensive stance quickly, if needed.

In some cases organizations seek out risks to increase diversification, realizing that the addition of some risks may have a minimal impact on overall risk, or in the case of hedges, may decrease enterprise risks. In essence, there is a realization that risk is not completely avoidable and, in fact, informed risk-taking is a means to competitive advantage.

Summary

It is reasonable to expect that the forces cited above will continue. Accordingly, risk management practices will become more and more sophisticated. As capabilities continue to improve, organizations will increasingly adopt ERM because they can.

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Overview of Enterprise Risk Management

Note: For additional thoughts on the subject of this chapter, see Lisa K. Meulbroek, "Integrated Risk Management for the Firm: A Senior Manager's Guide", *Harvard Business School's Division of Research Working Papers 2001-2002*, http://www.hbs.edu/research/facpubs/workingpapers/papers2/0102/02-046.pdf.

III. ERM Definition and Conceptual Framework

Definition

Several texts and periodicals have introduced or discussed concepts such as "strategic risk management", "integrated risk management" and "holistic risk management". These concepts are similar to, even synonymous with, ERM in that they all emphasize a comprehensive view of risk and risk management, a movement away from the "silo" approach of managing different risks within an organization separately and distinctly, and the view that risk management can be a value-creating, in addition to a risk-mitigating, process.

The CAS Committee on Enterprise Risk Management has adopted the following definition of ERM:

> **"ERM is the discipline by which an organization in any industry assesses, controls, exploits, finances, and monitors risks from all sources for the purpose of increasing the organization's short- and long-term value to its stakeholders."**

Several parts of this definition merit individual attention. First, ERM is a discipline. This is meant to convey that ERM is an orderly or prescribed conduct or pattern of behavior for an enterprise, that it has the full support and commitment of the management of the enterprise, that it influences corporate decision-making, and that it ultimately becomes part of the culture of that enterprise. Second, ERM, even as it is defined for CAS purposes, applies to all industries, not just the property/casualty insurance industry with which casualty actuaries are intimately familiar. Third, the specific mention of exploiting risk as a part of the risk management process (along with the stated objective of increasing short- and long-term value) demonstrates that the intention of ERM is to be value creating as well as risk mitigating. Fourth, all sources of risk are considered, not only the hazard risk with which casualty actuaries are particularly familiar, or those traditionally managed within an enterprise (such as financial risk). Lastly, ERM considers all stakeholders of the enterprise, which include shareholders and debtholders, management and officers, employees, customers, and the community within which the enterprise resides.

Implicit in this definition is the recognition of ERM as a strategic decision support framework for management. It improves decision-making at all levels of the organization.

Conceptual Framework

A useful way to conceptualize ERM is along two dimensions: one spanning the *types* of risk included, and the other spanning the various risk management *process* steps, as below:

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ERM Framework				
	Types of Risk			
Process Steps	Hazard	Financial	Operational	Strategic
Establish Context				
Identify Risks				
Analyze/Quantify Risks				
Integrate Risks				
Assess/Prioritize Risks				
Treat/Exploit Risks				
Monitor & Review				

In discussing these risk types and process steps, we will consider an enterprise, the Coldhard Steel Company ("Coldhard Steel"), which manufactures steel products, such as roller and ball bearings, used in other industrial machinery. Coldhard Steel operates in the "rust belt" of the midwestern U.S., is family-owned, and has a unionized labor force.

<u>Types of Risk</u>

Coldhard Steel is exposed to a number of ***hazard risks***. First-party hazard risks include the possibility of fire or tornadoes damaging its plant and equipment, and the resulting loss of revenue (i.e., business interruption). Second-party hazard risks include injury or illness to its employees, including work-related injuries that would result in workers compensation claims. Given Coldhard Steel's use of heavy machinery, as well as the benefit provisions in its principal state of operation, Coldhard Steel's workers compensation exposure is substantial. Third-party hazard risk would include the possibility of slips and falls of visitors on its premises, products recall and/or products liability from defective products produced by Coldhard Steel.

Since Coldhard Steel has significant sales in Latin America and Europe, it is exposed to foreign exchange risk, one of many ***financial risks***. Coldhard Steel is tangentially exposed to additional foreign exchange risk in that even though it buys its steel from U.S. manufacturers, these prices are influenced by imported steel. Other financial risks for Coldhard Steel to consider are commodity risk (due to possible changes in prices in the raw materials it and its suppliers use in production) and credit risk (due to its significant accounts receivables asset).

Since many employees are in the local machinists union, labor relations represents a significant ***operational risk*** for Coldhard Steel. Also, since the company is privately held, succession planning is critical for the time when the current owner either sells the company or passes down control to heirs. Coldhard Steel spends considerable time assessing the efficiency and reliability of its machines and processes.

Strategic risks for Coldhard Steel include fluctuations in the demand and the market price for its finished products (and substitute products), competition from suppliers of other steel products, regulatory/political issues associated with the steel industry, and technological advances in its customers' machines that could potentially render Coldhard Steel's current products obsolete.

In general, enterprises (like and unlike Coldhard Steel) are exposed to risks that can be categorized into the following four types:

- *Hazard Risks* include risks from:
  - fire and other property damage,
  - windstorm and other natural perils,
  - theft and other crime, personal injury,
  - business interruption,
  - disease and disability (including work-related injuries and diseases), and
  - liability claims.

- *Financial Risks* include risks from:
  - price (e.g. asset value, interest rate, foreign exchange, commodity),
  - liquidity (e.g. cash flow, call risk, opportunity cost),
  - credit (e.g. default, downgrade),
  - inflation/purchasing power, and
  - hedging/basis risk.

- *Operational Risks* include risks from:
  - business operations (e.g., human resources, product development, capacity, efficiency, product/service failure, channel management, supply chain management, business cyclicality),
  - empowerment (e.g., leadership, change readiness),
  - information technology (e.g., relevance, availability), and
  - information/business reporting (e.g., budgeting and planning, accounting information, pension fund, investment evaluation, taxation).

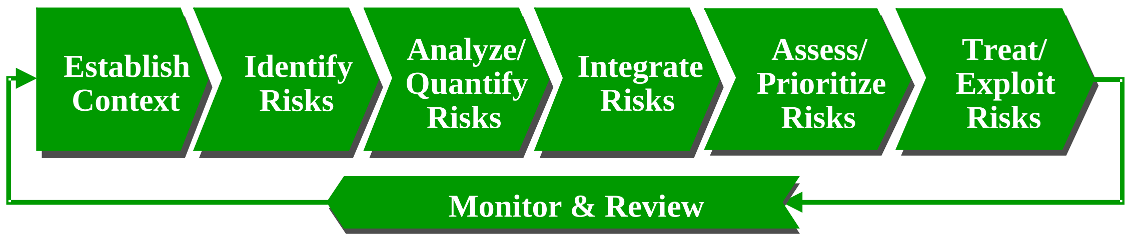
- *Strategic Risks* include risks from:
  - reputational damage (e.g., trademark/brand erosion, fraud, unfavorable publicity)
  - competition,
  - customer wants,
  - demographic and social/cultural trends,
  - technological innovation,
  - capital availability, and
  - regulatory and political trends.

The precise slotting of individual risk factors under each of these four categories is less important than the recognition that ERM covers all categories and all material risk factors that can influence the organization's value.

Overview of Enterprise Risk Management

Process Steps

The following steps of the risk management process, which are based on those originally detailed in the Australian/New Zealand Standard in Risk Management (AS/NZS 4360), describe seven iterative elements.



- *Establish Context* – This step includes External, Internal and Risk Management Contexts.

  - The External Context starts with a definition of the relationship of the enterprise with its environment, including identification of the enterprise's strengths, weaknesses, opportunities, and threats ("SWOT analysis"). This context-setting also identifies the various stakeholders (shareholders, employees, customers, community), as well as the communication policies with these stakeholders.

  - The Internal Context starts with an understanding of the overall objectives of the enterprise, its strategies to achieve those objectives and its key performance indicators. It also includes the organization's oversight and governance structure.

  - The Risk Management Context identifies the risk categories of relevance to the enterprise and the degree of coordination throughout the organization, including the adoption of common risk metrics.

  Returning to our example, Coldhard Steel has formed a Risk Management Committee that is headed by its chief financial officer, with representatives from loss control/safety, quality control, human resources, marketing, and finance. In consideration of the makeup of its labor force, a representative from the labor union is invited periodically to meetings. In terms of establishing common criteria for assessing all risks, Coldhard Steel adopted a Value at Risk approach, with an annual timeframe.

- *Identify Risks* – This step involves documenting the conditions and events (including "extreme events") that represent material threats to the enterprise's achievement of its objectives or represent areas to exploit for competitive advantage.

  In our example, Coldhard Steel has used a variety of methods (e.g., surveys, internal workshops, brainstorming sessions and internal auditing) to identify the significant hazard, financial, operational and strategic risks described in the previous section.

- *Analyze/Quantify Risks* – This step involves calibrating and, wherever possible, creating probability distributions of outcomes for each material risk. This step provides necessary input for subsequent steps, such as integrating and prioritizing risks. Analysis techniques range along a spectrum from qualitative to quantitative, with sensitivity analysis, scenario analysis, and/or simulation analysis applied where appropriate.

  As indicated previously, workers compensation represents a significant hazard risk for Coldhard Steel. However, it has a number of years of claims and exposure data, and, based on quantitatively extrapolating cost trends into the future, Coldhard Steel's consulting actuaries are able to determine reasonable expectations of costs and variability of these costs into the near future.

  Coldhard Steel regularly monitors its account sales and accounts receivables, including performing credit analysis on its largest customers before extending additional credit. Although all sales are transacted in U.S. dollars, orders from Mexico generate 10 percent of all sales, and Coldhard Steel's financial analysts have considered hedging against devaluations in the Mexican peso.

  Coldhard Steel's labor contract expires in three years, and although relations with the employees and union are considered good, senior management has asked its human resources to construct "best case", "expected" and "worst case" estimates of salary and benefit increases anticipated to be requested by labor. As part of the worst case scenario, management has asked its finance department to estimate the impacts of a prolonged labor dispute and its effects on revenue, expenses and inventories.

  Coldhard Steel buys its steel from U.S. manufacturers, even though some of its competitors are taking advantage of cheaper foreign steel. Coldhard Steel is actively monitoring political discussions to gauge the likelihood that additional tariffs will be imposed on foreign steel in the near future. Coldhard Steel also monitors price levels for its finished products in relationship to the cost of its raw materials, products of its competitors, and substitute products.

- *Integrate Risks* – This step involves aggregating all risk distributions, reflecting correlations and portfolio effects, and expressing the results in terms of the impact on the enterprise's key performance indicators (i.e., the "aggregate risk profile").

  Coldhard Steel's Risk Management Committee and external consultants have begun to develop a structural simulation model to integrate all risks. The various components of the model are supported by a common stochastic economic scenario generator.

- *Assess/Prioritize Risks* – This step involves determining the contribution of each risk to the aggregate risk profile, and prioritizing accordingly, so that decisions can be made as to the appropriate treatment.

Coldhard Steel has not yet quantified all risks into probability distributions, let alone integrated these risks into a complete aggregate risk profile. However, Coldhard Steel has developed judgmental assessments as to frequency and severity, and it has developed a “Risk Map”, which plots all risks by these two components. Coldhard Steel has prioritized a number of risks including its workers compensation exposure (hazard), account bad debt/credit risk (financial), labor relation risk (operational), and product obsolescence risk (strategic).

- *Treat/Exploit Risks* – This step encompasses a number of different strategies, including decision as to avoid, retain (and finance), reduce, transfer, or exploit risk. For hazard risks, the prevalent transfer mechanism has been the insurance markets. Alternative risk transfer (ART) markets have developed from these with a goal of striking a balance between risk retention and risk transfer. With respect to financial risks, the capital markets have exploded over the last several decades to assist companies in dealing with commodity, interest rate, and foreign exchange risk. Until recently, companies had no mechanisms to transfer operational or strategic risks, and simply had to avoid or retain these risks.

  Coldhard Steel has historically insured its workers compensation exposure. However, given its comfort in assessing its loss experience, as well as increases in insurance rates, it is considering securing coverage with a large per occurrence deductible. With respect to financial risk, Coldhard Steel is instituting new standards regarding the extension of credit to its customers. In order to avoid potential labor disputes down the road, Coldhard Steel has decided to hold early discussions with union personnel regarding wages and benefits.

  Coldhard Steel believes that it is likely that additional tariffs will be imposed on foreign steel in the near future, so it is attempting to exploit this strategic risk by locking into fixed price agreements with its domestic suppliers.

- *Monitor & Review* – This step involves continual gauging of the risk environment and the performance of the risk management strategies. It also provides a context for considering risk that is scalable over a period of time (one quarter, one year, five years). The results of the ongoing reviews are fed back into the context-setting step and the cycle repeats.

  Coldhard Steel’s newly formed Risk Management Committee met extensively toward the end of the previous year for planning purposes, and intends to meet monthly to monitor progress on goals established.

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Note: The ERM Framework in this chapter was originally developed in the *Final Report of the Advisory Committee on Enterprise Risk Management* (the predecessor committee to the Enterprise Risk Management Committee). This November 2001 report is available on the CAS Web site at http://www.casact.org/research/erm/report.htm.

IV. ERM Language, Measures, Models and Tools

As outlined in the preceding chapter, the first process step in the ERM framework is to establish the context (internal, external and risk management) within which the organization operates. Critical to establishing this context – and one of the worthy goals of ERM in its own right – is the creation of a common risk vernacular across all functional areas and relevant disciplines throughout the organization. This chapter summarizes the terminology in common usage among companies that practice ERM, forming a large part the emerging global "language of risk". In so doing, this chapter introduces and discusses the measures, models and tools that help organizations perform the balance of the ERM process steps.

Where appropriate, certain items are compared and contrasted; and where some items represent alternative approaches to a similar issue, relative strengths and weaknesses are discussed.

<u>Overall Corporate Performance Measures</u>

ERM clearly links risk management with the creation of organizational value and expresses risk in terms of impact on organizational objectives. An important aspect of ERM is therefore the strong linkage between measures of risk and measures of overall organizational performance. Thus, our discussion of ERM terminology begins with a description of key corporate performance measures. Our focus is on publicly traded corporations, and where industry-specific details are introduced, we use the financial services industry (and, more specifically, the insurance industry) for illustration.

In addition to establishing context, these performance measures have specific application in the identification of risks. Risk identification is the qualitative determination of risks that are material, i.e., that potentially can impact, for better or worse, the organization's achievement of its financial and/or strategic objectives. These objectives are usually expressed, of course, in terms of the overall corporate performance measures.

The measures defined below are fundamental to the evaluation of corporate performance. It is assumed that the reader is already familiar with the more basic accounting terms and concepts such as net income, net worth, etc.

- General Industry
  - Return on equity (ROE) — net income divided by net worth.
  - Operating earnings — net income from continuing operations, excluding realized investment gains
  - Earnings before interest, dividends, taxes, depreciation and amortization (EBITDA) — a form of cash flow measure, useful for evaluating the operating performance of companies with high levels of debt (when the debt service costs may overwhelm other measures such as net income).
  - Cash flow return on investments (CFROI) — EBITDA divided by tangible assets.

- Weighted average cost of capital (WACC) — the sum of the required market returns of each component of corporate capitalization, weighted by that component's share of the total capitalization.
- Economic value added (EVA) — a corporate performance measure that stresses the ability to achieve returns above the firm's cost of capital. It is often stated as net operating profits after tax less the product of required capital times the firm's weighted average cost of capital.

- Financial Services Industry
  - Return on risk-adjusted capital (RORAC) — a target ROE measure in which the denominator is adjusted depending on the risk associated with the instrument or project.
  - Risk-adjusted return on capital (RAROC) — a target ROE measure in which the numerator is reduced depending on the risk associated with the instrument or project.
  - Risk-adjusted return on risk-adjusted capital (RARORAC) — a combination of RAROC and RORAC in which both the numerator and denominator are adjusted (for different risks).

- Insurance Industry
  - Economic capital — market value of assets minus fair value of liabilities. Used in practice as a risk-adjusted capital measure; specifically, the amount of capital required to meet an explicit solvency constraint (e.g., a certain probability of ruin).
  - RAROC — expected net income divided by economic capital (thus, the more technically correct label is RORAC – see above – but in the insurance industry, RAROC is the term commonly used). RAROC is typically employed to evaluate the relative performance of business segments that have different levels of solvency risk; the different levels of solvency risk are reflected in the denominator. Evaluating financial performance under RAROC calls for comparison to a benchmark return; when the benchmark return is risk-adjusted (e.g., for volatility in net income), the result is similar to RARORAC (see above), though the term RAROC is still applied.
  - Embedded value — a measure of the value of business currently on the books of an insurance company; it comprises adjusted net worth (the market value of assets supporting the surplus) plus the present value of expected future profits on in-force business. (Embedded value differs from appraisal value in that the latter also includes the value of future new business.) The performance measure is often expressed in terms of growth (i.e., year-on-year increase) in embedded value.
  - Risk Based Capital (RBC) — a specific regulatory capital requirement promulgated by the National Association of Insurance Commissioners. It is a formula-derived minimum capital standard that sets the points at which a state insurance commissioner is authorized and expected to take regulatory action.

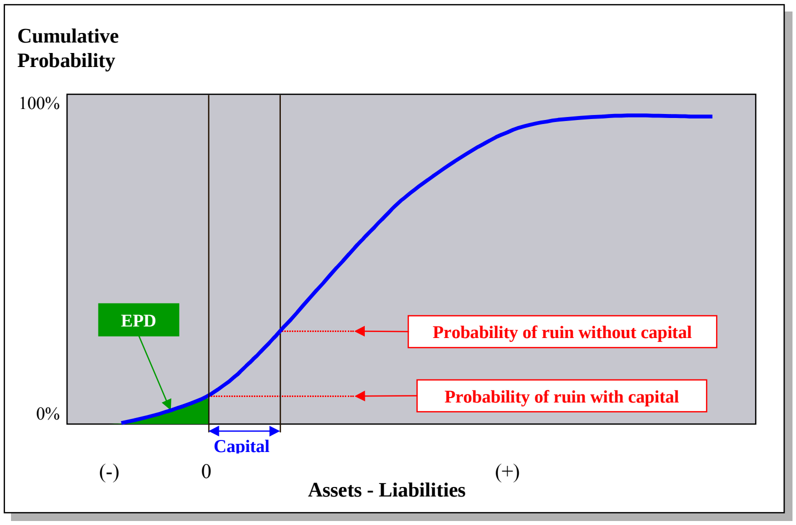
Risk Measures

In this section, reference is made to the term *"risk profile"* to represent the entire portfolio of risks that constitute the enterprise. Some companies represent this portfolio in terms of a cumulative probability distribution (e.g., of cumulative earnings) and use it as a base from which to determine the incremental impact (e.g., on required capital) of alternative strategies or decisions. It is in this sense that the term is used below.

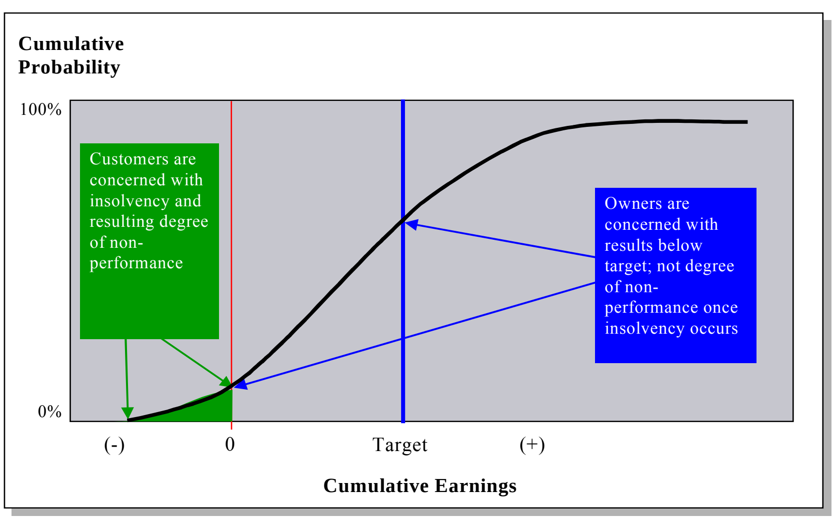
Most of the measures common in the practice of ERM can be placed in one of two categories: those measures related to the degree of the organization's *solvency*, and those related to the volatility of the organization's *performance* on a "going concern" basis. The measures in these two categories are used for distinctly different purposes and focus on distinctly different areas of the organization's risk profile. Following and complementing the narrative descriptions of these measures are illustrations and formulas where appropriate.

- *Solvency-related* measures (these measures concentrate on the adverse "tail" of the probability distribution – see "risk profile" above – and are relevant for determining economic capital requirements, i.e., they relate to the risks captured in the denominator of RARORAC; they are of particular concern to customers and their proxies, e.g., regulators and rating agencies):
  - Probability of ruin — the percentile of the probability distribution corresponding to the point at which capital is exhausted. Typically, a minimum acceptable probability of ruin is specified, and economic capital is derived therefrom.
  - Shortfall risk — the probability that a random variable falls below some specified threshold level. (Probability of ruin is a special case of shortfall risk in which the threshold level is the point at which capital is exhausted.)
  - Value at risk (VaR) — the maximum loss an organization can suffer, under normal market conditions, over a given period of time at a given probability level (technically, the inverse of the shortfall risk concept, in which the shortfall risk is specified, and the threshold level is derived therefrom). VaR is a common measure of risk in the banking sector, where it is typically calculated daily and used to monitor trading activity.
  - Expected policyholder deficit (EPD) or economic cost of ruin (ECOR) — an enhancement to the probability of ruin concept (and thus shortfall risk and VaR) in which the *severity* of ruin is also reflected. Technically, it is the expected value of the shortfall. (In an analogy to bond rating, it is comparable to considering the salvage value of a bond in addition to the probability of default.) For insurance companies, the more common term is EPD, and represents the expected shortage in the funds due to policyholders in the event of liquidation.
  - Tail Value at Risk (Tail VaR) or Tail Conditional Expectation (TCE) — an ECOR-like measure in the sense that both the probability and the cost of "tail events" are considered. It differs from ECOR in that it is the expected value, from first dollar, of all events beyond the tail threshold event, not just the shortfall amount.

- Tail events – unlikely but extreme events, usually from a skewed distribution. Rare outcomes, usually representing large monetary losses.



- *Performance-related* measures (these measures concentrate on the mid-region of the probability distribution –see "risk profile" above – i.e., the region near the mean, and are relevant for determination of the volatility around expected results, i.e., the numerator of RARORAC; they are of particular concern to owners and their proxies, e.g., stock analysts):
  - Variance — the average squared difference between a random variable and its mean.
  - Standard deviation — the square root of the variance.
  - Semi-variance and downside standard deviation — modifications of variance and standard deviation, respectively, in which only *unfavorable* deviations from a specified target level are considered in the calculation.
  - Below-target-risk (BTR) — the expected value of unfavorable deviations of a random variable from a specified target level (such as not meeting an earnings target).



Risk Measure	**Formula**
Standard Deviation	$\sqrt{\dfrac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n}}$ where n is the number of simulation iterations and *xbar* is the average value over all iterations. This is a commonly used measure of risk by academics and capital markets. It is interpreted as the extent to which the financial variable could deviate either above or below the expected value. Note that equal weight is given to deviations of the same magnitude regardless of whether the deviation is favorable or unfavorable. (There are different schools of thought on whether standard deviation in this context should measure total volatility or only the non-diversifiable volatility.)
Shortfall Risk *Value at Risk (VaR)*	$\dfrac{\sum_{i=1}^{n}[if\ \left(x_i \le T\right)\ \ then\ 1,\ else\ 0]}{n} * 100\%$ where T is the target value for the financial variable and n is the number of simulation iterations. This is an improvement over standard deviation because it reflects the fact that most people are risk averse, i.e., they are more concerned with unfavorable deviations rather than favorable deviations. It is interpreted as the probability that the financial variable falls below a specified target level. In VaR-type measures, the equation is reversed: the shortfall risk is specified first, and the corresponding value at risk (T) is solved for.
Downside Standard Deviation *Below Target Risk (BTR)*	$\sqrt{\dfrac{\sum_{i=1}^{n}(\min[0\,,\left(x_i - T\right)])^2}{n}}$ where T is the target value for the financial variable and n is the number of simulation iterations. This is a further improvement over the other metrics because it focuses not only on the probability of an unfavorable deviation in a financial variable (as with shortfall risk) but also the extent to which it is unfavorable. It is interpreted as the extent to which the financial variable could deviate below a specified target level. BTR is similar, but the argument is not squared, and there is no square root taken of the sum.

Risk Modeling

Risk modeling refers to the methods by which the risk and performance measures described above are determined. This chapter discusses the major classes of models used in the ERM process. It should be noted that these are general classes of models. The models used within any organization will typically be customized to accommodate the unique needs of, and the specific risks faced by, that organization. No two such models are exactly alike.

Most organizations will have at least a simple financial model of their operations that describes how various inputs (i.e., risk factors, conditions, strategies and tactics) will affect the key performance indicators (KPIs) used to manage the organization. For any given organization, these KPIs may be one or more of the overall corporate performance measures described earlier in this chapter (e.g., revenue growth, earnings growth, earnings per share, growth in surplus, growth in embedded value, customer satisfaction and/or brand image). For publicly traded companies, the KPIs are often explicitly or implicitly defined by the market (i.e., they are the measures focused upon by the organization's stock analysts). These models are often used in developing strategic and operational plans. For example, insurance companies typically make assumptions regarding future trends in claim costs by business segment (e.g., by line of business, by region), which are used to determine needed rate levels by segment. These rate level projections are then combined with assumptions on volume growth and other relevant inputs to derive a pro forma estimate of overall corporate earnings (or some other KPI). Often, business decisions (e.g., rate level, volume growth) are fine-tuned in order to produce the desired expected KPI result. Because these models explicitly capture the structure of the cause/effect relationships linking inputs to outcomes, they are termed *structural (or causal) financial models*.

These structural financial models are generally *deterministic* models because they describe *expected* outcomes from a given set of inputs without regard to the probabilities of outcomes above or below the expected values. These models can be transformed into *stochastic* (or *probabilistic*) models by treating certain inputs as variable. For example, expected future claim cost trend might be an input to a deterministic model of corporate earnings; recognizing that there is uncertainty in this trend, a probability distribution around the expected trend would be an input to a stochastic model. The model output, corporate earnings in this case, would then also be a probability distribution.

As outlined below, the two general classes of stochastic risk models are *statistical analytic models* and *structural simulation models*. "Statistical" vs. "structural" refers to the manner in which the relationships among random variables are represented in the model; "analytic" vs. "simulation" refers to the way in which the calculations are actually carried out. These four terms are defined separately below; the way they are combined is illustrated and contrasted in the table that follows the definitions.

- Analytic methods — models whose solutions can be determined "in closed form" by solving a set of equations. These methods usually require a restrictive set of assumptions and mathematically tractable assumed probability distributions. The principal advantage over simulation methods is ease and speed of calculation.

- Simulation methods (often called Monte Carlo methods) — models that require a large number of computer-generated "trials" to approximate an answer. These methods are relatively robust and flexible, can accommodate complex relationships (e.g., so-called "path dependent" relationships commonly found in options pricing), and depend less on simplifying assumptions and standardized probability distributions. The principal advantage over analytic methods is the ability to model virtually any real-world situation to a desired degree of precision.

- Statistical methods — models that are based on observed statistical qualities of (and among) random variables without regard to cause/effect relationships. The principal advantage over structural models is ease of model parameterization from available (often public) data.

- Mean/variance/covariance (MVC) methods — a special class of statistical methods that rely on only three parameters: mean, variance, and covariance matrix.

- Structural methods — models that are based on explicit cause/effect relationships, not simply statistical relationships such as correlations. The cause/effect linkages are typically derived from both data and expert opinion. The principal advantages over statistical methods is the ability to examine the causes driving certain outcomes (e.g., ruin scenarios), and the ability to directly model the effect of different decisions on the outcome.

- Dynamic Financial Analysis (DFA) — the name for a class of structural simulation models of insurance company operations, focusing on certain hazard and financial risks and designed to generate financial pro forma projections.

Note: As a practical matter and as noted above, the choice of modeling approach is typically between ***statistical analytic models*** *and* ***structural simulation models****. The contrast between these modeling approaches is summarized in the table below:*

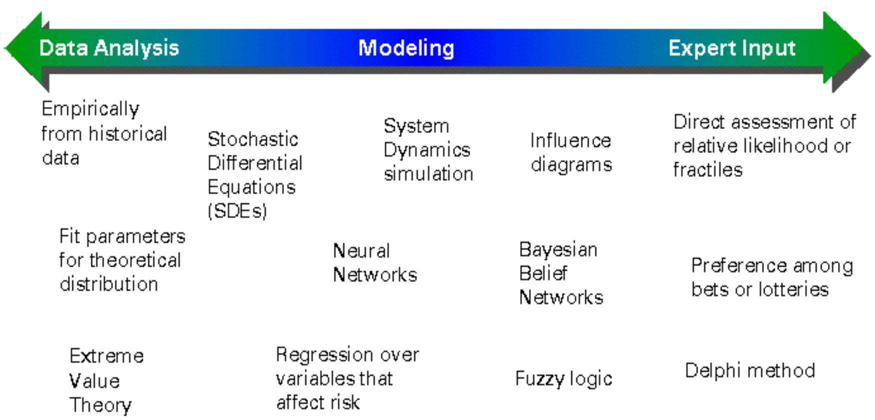
Representation of Relationships	Calculation Technique	Examples	Relative Advantages
Statistical (based on observed statistical qualities without regard to cause/effect)	Analytic (closed-form formula solutions)	▪ RBC ▪ Rating agency models	Speed; ease of replication; use of publicly available data (well suited for industry oversight bodies)
Structural (based on specified cause/effect linkages; statistical qualities are outputs, not inputs)	Simulation (solutions derived from repeated "draws" from the distribution)	▪ DFA ▪ Many options pricing models	Flexibility; treatment of complex relationships; incorporation of decision processes; ability to examine scenario drivers (well suited for individual companies)

The models described above generally presuppose the existence of sufficient data with which to fully parameterize the models. This is often not the case in practice, particularly as respects operational and strategic risks.

There is a wide variety of risk modeling methods that can be applied to a specific risk. They can be thought of as lying on a continuum that is based on the extent to which they rely on historical data vs. expert input (see Figure A below). Along the continuum of sources of information, the methods listed on the left are ones that rely primarily on the availability of historical data. They include, for example, empirical distributions, parametric methods to fit theoretical probability density functions, regression, stochastic differential equations and extreme value theory. These methods have been used extensively by financial institutions to model financial risks.

The methods listed on the right in Figure A rely primarily on expert input, including for example, Delphi method, preference among bets or lotteries, and influence diagrams. These have been used successfully for several decades by decision and risk analysts to model operational risks in support of management decision-making in manufacturing, particularly in the oil and gas industry, and in the medical sector. The methods listed in the middle of the continuum rely on data, to the extent that it is available, and expert judgment to supplement the missing data. In these methods, expert judgment is used to develop the model logic indicating the interactions among key variables and to quantify cause/effect relationships based on experience and ancillary or sparse data. Methods such as system dynamics simulation, Bayesian belief networks and fuzzy logic in particular are ideally suited for quantifying operational and strategic risks.

Figure A – There is a continuum of methods for modeling risks. Each method has advantages/disadvantages over others, so it's important to select the best methods based on facts and circumstances



Definitions and descriptions of the risk modeling methods that lie along this continuum are in Appendix B.

<u>Risk Integration</u>

Several of the risks of interest to the organization may be correlated with one another. For example, economic inflation (a driver of cost trends across multiple business segments) is highly correlated with interest rates (a driver of asset values and investment returns). It is important to capture these correlations – indeed, this is the essence of ERM. There are several ways to do this.

A direct way to express dependencies among risks is to estimate the statistical correlations between each of the individual risks. These estimates are often arrayed in a "covariance matrix".

- Covariance — a statistical measure of the degree to which two random variables are correlated. Related to correlation coefficient (correlation coefficient = covariance divided by the product of the standard deviations of the two random variables). A correlation coefficient of +1.0 indicates perfect positive correlation; -1.0 indicates perfect negative correlation (i.e., a "natural hedge"); zero indicates no correlation.

- Covariance matrix — a two-dimensional display of the covariances (or correlation coefficients) among several random variables; the covariance between any two variables is shown at their cross-section in the matrix.

The estimation of these covariances can be a practical difficulty, as the number of estimates required rises as the square of the number of risks.

An alternative way to capture risk interrelationships is through a *structural simulation model* of the enterprise, described above. In essence, a structural simulation model allows one to capture the dependencies among variable inputs in a simple, accurate and logically consistent way by virtue of the model's cause/effect linkages of these inputs to common higher-level inputs.

For example, interest rates and inflation rates are often generated stochastically by means of an economic scenario generation model, wherein these two random variables are linked to higher-level economic forces. In turn, other lower-level random variables, such as product costs, prices, asset values and investment income, are linked causally to interest rates and inflation rates within the model. Without such structural linkages, other models (such as MVC models, described above) can generate sets of random variables that are unrealistic relative to each other, regardless of how accurate the correlation estimates among them may be.

The statistical correlations among risks that are related through a structural simulation model are an emergent property (i.e., an output) of the model, not values to be separately estimated. To the extent that certain inputs are not related to a common higher-level input, yet one believes that a relationship exists between them, these correlations can be stated explicitly in terms of a covariance matrix, whose values can be determined through data analysis, expert opinion or both.

Risk Prioritization

Risk prioritization is ranking material risks on an appropriate scale, such as frequency, severity or both.

- Risk mapping — the visual representation of identified risks in a way that easily allows ranking them. This representation often takes the form of a two-dimensional grid with frequency (or likelihood of occurrence) on one axis, and severity (or degree of financial impact) on the other axis; the risks that fall in the high-frequency/high-severity quadrant are typically given highest priority risk management attention.

A more useful ranking of risks is in terms of each risk's impact on the organization's overall key performance indicators (KPIs). The marginal contribution of each individual risk factor to the overall risk profile of the organization can be determined by "turning off" that risk factor (changing that particular input from stochastic to deterministic) and examining the impact on the KPI probability distribution. This technique provides a straightforward way of isolating the impact of a particular risk factor (such as natural catastrophes) on overall capital adequacy, for example. In this way, the prioritization of risk factors, which is often done qualitatively, can be more rigorously validated.

<u>Tool Applications for Treating/Exploiting Risks</u>

The techniques, models and measures above are used in various combinations to assist management decision-making in a number of areas. Several of these specific applications are discussed below, following the definitions of two generic applications ("optimization" and "candidate analysis") that are employed within some of these specific applications. Note that the following list of specific applications is not exhaustive, and is expected to grow as ERM matures as a discipline. Virtually any decision that requires evaluating risk/return trade-offs is a candidate for ERM treatment.

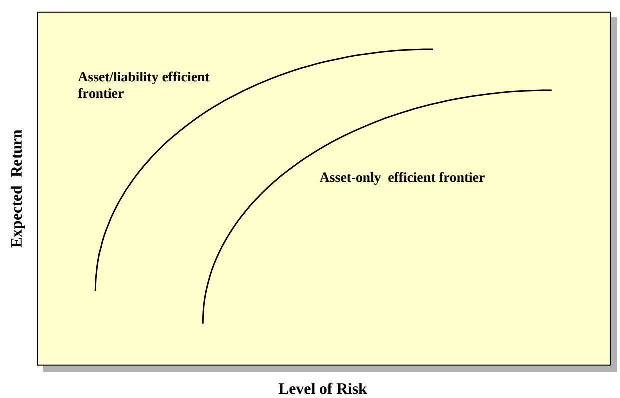
- Generic applications:
  - Optimization — the formal process by which decisions are made under conditions of uncertainty. Components of an optimization exercise include a statement of the range of decision options, a representation of the uncertain conditions (usually in the form of probability distributions), a statement of constraints (usually in the form of limitations on the range of decision options), and a statement of the objective to be maximized (or minimized). An example of an optimization exercise is an asset allocation study (see below under risk management applications). [See also "candidate analysis, below.]
  - Candidate analysis — a restricted form of optimization analysis in which only a finite number of prespecified decision options are considered, and the best set among those options is determined through the analysis. Optimization and candidate analyses can be contrasted as follows. An optimization analysis would typically result in the derivation of an "efficient frontier" curve in risk/return space, which contains the decision options that result in maximum return for each level of risk (i.e., the optimal decision option for each level of risk). A candidate analysis would not derive the efficient frontier curve, but would simply show the finite number of decision options in comparison with each other in risk/return space (i.e., a "scatter plot"). It would not be known how close each option is to the efficient frontier of options. Conceptually, if a candidate analysis were performed on an infinite number of candidate decision options, then the "envelope" or boundary of those options would form the efficient frontier.

- Capital management:
  - Capital adequacy — the determination of the minimum amount of capital needed to satisfy a specified economic capital constraint (e.g., a certain probability of ruin), usually calculated at the enterprise level.

- Capital structure — the determination of the optimal mix of capital by type (debt, common equity, preferred equity), given the risk profile and performance objectives of the enterprise.
- Capital attribution — the determination of the assignment of enterprise level capital to the various business segments (e.g., lines of business, regions, projects) that make up the enterprise, in recognition of the relative risk of each segment, for purposes of measuring segment performance on a risk-adjusted basis (e.g., to provide the denominator for a RORAC or RARORAC analysis by segment).
  - Diversification credit — the recognition of the "portfolio effect", which is the fact that the economic capital required at the enterprise level will be less than the sum of the capital requirements of the business segments calculated on a stand-alone basis. The diversification credit is typically apportioned to the business segments in a manner that attempts to preserve the relative equity of the capital attribution process.
- Capital allocation — the actual deployment of capital to different business segments.

- Performance measurement — the development and implementation of appropriate risk-based metrics for evaluation of business segment performance, reflecting capital consumption, return and volatility.

- Investment strategy/asset allocation — the determination of the optimal mix of assets by asset class (usually to maximize expected return at each level of risk, i.e., according to Modern Portfolio Theory). In advanced applications, the analysis reflects the nature and structure of both assets and liabilities and is called asset/liability management (ALM).



- Insurance/reinsurance/hedging strategy optimization — the determination of the optimal insurance/reinsurance/hedging program, reflecting program costs and risk reduction capability; usually conducted through candidate analysis. The risk reduction capability manifests itself in terms of both reduction in required economic capital and reduction in the cost of capital or required risk-adjusted rate of return.

- Crisis management — the proactive response of an organization to a severe event that could potentially impair its ability to meet its performance objectives.

- Contingency planning — the process of developing, and embedding in the organization, crisis management protocols in advance of crisis conditions.

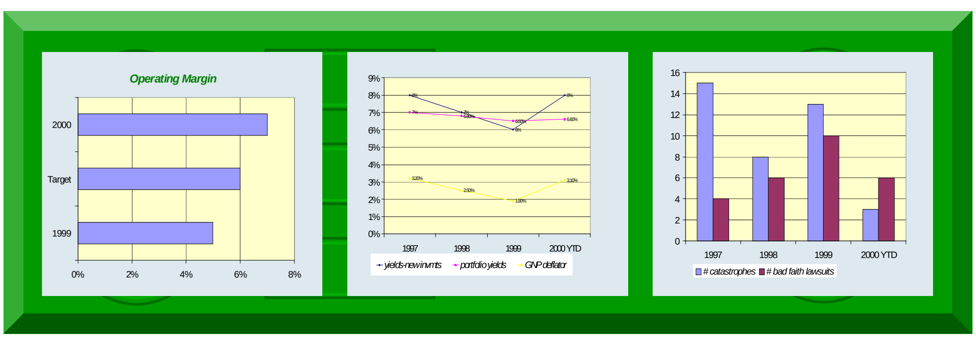
- Business expansion/contraction strategy — the evaluation of merger, acquisition and divestiture options in terms of their incremental impact on the risk profile of the enterprise.

- Distribution channel strategy — the systematic evaluation of alternative channels (e.g., direct, agency, Internet), by means of simulation analysis to test impacts on growth, market share, profitability, etc. on a risk/return basis.

- Strategic planning — the use of structural simulation modeling, such as "real options" modeling, as a decision tool to assist management in selecting among alternative strategies, such as long-term research projects (see "Scientific Management at Merck", *Harvard Business Review*, 1994).

<u>Risk Monitoring</u>

Continual monitoring of the risk environment, and of the performance of the risk management processes, is often done by means of a senior management *risk dashboard* — the graphical presentation of the organization's key risk measures (often against their respective tolerance levels), as in the chart below.



Typical measures included in the dashboard are shown in the following tables.

Marketing

- New business sold
- Retention of old business
- Mix of business: new and renewal
- Market share by customer type
- Average premium or assets by per customer
- % high-yield customers
- Customer satisfaction
- Average # of products per customer

Financial

- Revenue
- Underwriting profit
- Investment profit
- Pre-tax operating income
- Net income
- Return on equity and total capital
- Economic value added

Human Resources

- Agency composition (number, age, service)
- Total employment by department
  - Number and percentage leaving the company
  - Vacancy rates
  - Average salary increase vs. plan
- Employee commitment and engagement

Sales/Distribution

- Acquisition costs per sale
- Sales by distribution channel
- Growth/retention of agents

Claims

- Frequency and severity of claims
- Claims department productivity

Underwriting

- Price achieved vs. target price
- Exposure data (number of cars, payroll, etc.)
- Exposure mix
- Quotes accepted/declined
- Variance analysis
- Premium persistency
- Loss ratio
- Loss adjustment expense

Investments

- Cash flow
- Yield on new investments
- Yield on portfolio by class and duration
- Convexity of assets
- Duration of assets
- Investment mix: new and portfolio
- Credit default
- Total return

External Data

- Audit compliance
- Inflation rates
- Interest rates
- GNP
- Competitor pricing

* * * * *

Note: Certain material in this chapter was drawn from the article "The Language of Enterprise Risk Management: A Practical Glossary and Discussion of Relevant Terms, Concepts, Models and Measures", by Jerry Miccolis, in the Enterprise Risk Management Expert Commentary section of the Web site of the International Risk Management Institute, http://www.irmi.com/expert/risk.asp. As noted therein, certain of these definitions were adapted from *The Dictionary of Financial Risk Management*, by Gastineau and Kritzman, 1996, Frank J. Fabozzi Associates. Certain other material was drawn from the Tillinghast – Towers Perrin monograph *RiskValueInsights™: Creating Value Through Enterprise Risk Management*, (http://www.tillinghast.com).

V. ERM Case Studies

This chapter recounts a number of success stories in which organizations made the commitment to and then benefited from ERM. Some of these benefits are explicit and measurable (e.g., increased investment returns, decreased capital requirements), others are more intangible but no less real (e.g., more enlightened strategic planning, more rigorous performance measurement/management). There should be elements from this collection of cases that will resonate with any given organization.

It also should be clear from these cases that, in terms of objectives, scope (of risks and of processes), organization, tools and techniques, there are a number of legitimate approaches to ERM and no single "correct way" that is appropriate for all entities. The proper approach to ERM for any enterprise is one that fits within the culture of that enterprise.

Risk Assessment

A large, market-leading manufacturer and distributor of consumer products with an uninterrupted 40-year history of earnings growth, embarked on ERM well before its competitors. This step followed their philosophy of "identifying and fixing things before they become problems". They were spurred by their rapid growth, increasing complexity, expansion into new areas, and the heightened scrutiny that accompanied their recent initial public offering. They conducted a comprehensive assessment of all risks that could potentially prevent the company from achieving its promised results. Views of company executives on key performance measures and risk thresholds were validated against financial models of stock analyst expectations. Multiple methodologies were used to rank order risks from all sources (hazard, financial, operational and strategic) on the basis of expected impact, and the results cross-validated. High-priority risk factors were interpreted and classified (as "strategic", "adaptation", "manageable", "business as usual") for appropriate response, and strategies for mitigation and exploitation were developed. In addition, a "Business Risk Self-assessment Toolkit" was created for ongoing use. Senior management attributes the ERM effort, and their communication of that effort to the investment community, as one of the drivers of the company's superior market valuation.

A large health plan had traditionally conducted separate and uncoordinated risk assessments through its risk management, legal and internal audit functions. It undertook an enterprise-wide risk assessment covering all functional and operational divisions. The objective was to prioritize all sources of risk against a common set of financial and customer metrics to enable senior management to focus the organization's limited resources on the proper short list of critical concerns. In addition to providing a meaningful and useful calibration of risks of varied types, this exercise surfaced critical business risks that had not been identified through any previous audit or strategic planning exercise. Senior management uses the results of this assessment to set its strategic agenda.

Distribution Strategy

A medium-sized life insurance company wanted to reconsider their distribution strategy in light of plans to demutualize the following year. The bulk of their production came from a network of career agencies, and the company wanted to investigate not only other distribution channels but also the possibility of becoming a wholesaler to other financial institutions. They decided to analyze the risk/value economics of alternative operational strategies by developing a financial model of the underlying business dynamics. The process of model development and assumption setting forced the management team to articulate the alternative strategies more clearly and with greater specificity than they had thus far. The model was used iteratively to evaluate further variations in strategy suggested by a review of the projected financials at each prior iteration. Modeling the economics provided the management team with valuable information on the risks and opportunities underlying alternative strategies. As a result, the team was able to reach consensus on a distribution strategy that was better understood and provided the best prospects of success.

Performance Measurement

A large multinational financial services group undertook an assessment of the relative levels of economic capital required by each of its life and nonlife insurance subsidiaries. This involved identifying the major sources of risk in each line of business and modeling the impact of these risk areas on the projected cash flows. The results were used to determine an appropriate level of capital at individual product level, subsidiary level, product group level (across subsidiaries) and finally at group level. An economic scenario generation model was used to allow cross-currency aggregation. The resulting attribution of capital is used as the foundation for a performance measurement system relating shareholder risk to return on capital and total shareholder return. Actual return on capital is compared to the hurdle rate implied by the shareholder risk and differences are analyzed into above- and below-the-line effects.

Asset Allocation

A property/casualty insurance company's conservative asset mix resulted in performance returns that were not competitive. They evaluated alternative asset allocation strategies, along with an integrated reinsurance program, to enhance the returns from investments and manage the risk of their business. However, the company did not want its rating from A.M. Best to be affected as a result of implementing a more aggressive investment strategy. They developed a comprehensive model of the company and evaluated multiple scenarios of economic value in relation to risk. The model allowed them to develop a strategy to alter their asset allocation. A financial integrated stop-loss reinsurance program was designed with an investment hedge to mitigate the possibility that the investment portfolio may underperform a target return. The result: enhanced expected returns of the investment portfolio and lowered downside risk on operating income. The executive team's understanding of their return opportunities in relation to the risks of the business was deepened. This insight was used to focus the work of line managers, and also used in discussions with outside parties regarding overall risk management.

Strategic Planning

A leading global manufacturer and distributor of patented pharmaceuticals has developed its ERM approach around a "real options" model. In an industry noted for very expensive, very long-term research projects, success is dependent on making the right "bets" on those research projects, both at their outset and at critical decision junctures throughout the projects' life span. The company credits its pioneering work on its Research Planning Model as a key contributor to its competitive advantage. This model captures the important medical, operational and financial risks of each project, and applies sophisticated options pricing theory to discern among alternative projects and to manage the continuing investments in projects that pass the initial screening process. This approach, by recognizing the dynamics of the *staged* research decision process, has allowed the company to pursue ultimately successful projects that would have failed a more traditional net present value screening process. (*Note*: This case study is documented in "Scientific Management at Merck: An Interview with CFO Judy Lewent", *Harvard Business Review*, January-February 1994.) Certain tools developed for this approach – most notably "decision trees" – have become routinely used in management discussions of unrelated issues throughout various organizational levels, thus contributing to the company's "common language of risk".

The board of directors at a large electric utility, motivated both by local corporate governance guidelines and the opening of their industry to competition, mandated an integrated approach to risk management throughout the organization. They piloted the process in a business unit that was manageable in size, represented a microcosm of the risks faced by the parent, and did not have entrenched risk management systems. This same unit was the focus of the parent's strategy for seeking international growth – a strategy that would take the organization into unfamiliar territory – and had no established process for managing the attendant risks in a comprehensive way. The pilot project was deemed a success and, among other things, the ERM unit is now a key participant in the organization's strategic planning process. This participation takes the form of building stochastic models around the key drivers of the strategic plan (weather conditions, customer demands, economic conditions, etc.) to assess the robustness of the plan. The board will not approve the strategic plan without such an ERM evaluation.

Product Design

A life insurer was looking to improve the product design features of its flagship universal life product; specifically, incorporating a market value adjustment to protect against having to credit high interest in times of falling asset market values. The market value adjustment could have been a serious detriment to potential policyholders and might not have received regulatory approval. Working together, senior management, an actuarial team and the investment fund manager determined that an ALM model be developed using a set of stochastically generated interest rate scenarios. Various investment strategies were considered, covering a varying mix of mortgages, high-quality corporate bonds and CMO's. The ALM model then made projections based on the modeled relationship between the yield on these asset classes and the yield curve for treasuries as produced by the stochastic interest rate generator. Appropriate assumptions were made for defaults and prepayment risk. The yield relationships and other asset assumptions were reviewed by the fund management team, which also appraised the actuaries' assumptions underlying the model that was used to create the stochastically generated interest rate scenarios. Duration and convexity of both assets and liabilities were then analyzed, and the product design and the planned investment strategy fine-tuned to bring the assets and liabilities into balance. At this point, senior management analyzed various profit metrics for different investment strategies, looking at extreme scenarios for special review. Based on this analysis, the product appeared to hold up well even under the most extreme interest rate scenarios without any market value adjustment. The ALM analysis was effectively used to establish the product design and set the investment policy, and the product was filed without any market value adjustment.

<u>Dividend Strategy</u>

A medium-sized foreign life insurance company wanted to analyze the viability of their current dividend strategy for traditional business. Its market provided stable long-term dividend rates at a high level, even while market interest rates have declined, by smoothing book yields via accrual and realization of "hidden" reserves (unrealized capital gains on assets) and unallocated bonus reserves. In the prevailing low interest rate environment, the key competitive issue had become how long companies could finance their current dividend rates from existing buffers as compared to the market. In order to analyze the company's competitive position, ALM models were built for the company and a representative market company, reflecting the company's specific portfolio structure and strategies. On the basis of stochastic scenarios generation, the estimated time until ruin (until buffers had been exhausted) was determined for a range of potential ALM strategies for the company and compared to the results for the market. By varying the investment strategy, the company improved its risk/return positioning. As a result of the benchmark study, the life insurer received an indication of its current competitive position and a quantification of alternative ALM strategies, which led the company to reassess its dividend setting strategy for the entire traditional life portfolio.

<u>Risk Financing</u>

A very large retail company's CFO wanted to "assess the feasibility of taking a broader approach to risk management in developing the organization's future strategy". As part of this effort, they hoped to "evaluate our hazard risk and financial risk programs and strategies, to identify alternative methods of organizing and managing these exposures on a collective basis". As a first step, the company designed and built a model to provide an improved capability to evaluate its hazard and financial risks, both individually and on an aggregate portfolio basis. Criteria were developed to evaluate alternative risk financing programs based on appropriate measures of performance for risk and return. These evaluation criteria allowed the company to develop risk/return "efficient frontiers", representing a range of possible changes from their current program, on which to make informed management decisions. These decisions included:

- Choosing among competing insurance program submissions
- Determining retention levels
- Developing negotiating strategies
- Designing an overall risk financing strategy
- Prioritizing risk management activities (e.g., risk control).

The process for developing this capability included the determination of both appropriate return measures (e.g., net income, net cash flow) and appropriate risk measures (e.g., magnitude of potential loss, variance in financial measures, liquidity, compliance with bond covenants). These measures recognized and were developed from the variety of needs of key decision-makers, identified via structured interviews. Additionally, the process provided an understanding of those factors that have the greatest impact (in risk and return terms) on the performance of individual risks as well as the portfolio of all risks. To codify this process, the company developed a computer-based decision-support tool (with "senior management-friendly" graphics) that facilitated the evaluation of hazard and financial risks and allowed the decisions to be fact-based and consistent.

* * * * *

In addition to these examples, there are numerous others that demonstrate additional collateral benefits to undertaking an ERM process. These include:

- Improved communication and collaboration within the organization;

- Better-informed decisions at all levels in the organization by having gone through a rigorous and systematic risk identification/prioritization process; and

- Valuable change in mindset wherein risk can be a source of opportunity and not merely a threat to be avoided.

VI. Practical Considerations in Implementing ERM

Once an enterprise decides to adopt ERM, it has to deal with a number of practical considerations in its successful implementation. These include, but are not limited to, the following:

Designating an ERM "Champion"

Given the implementation challenges, a unique individual is needed to spearhead the effort, becoming, in effect, the "champion" of the initiative. This role is often fulfilled by naming a Chief Risk Officer (CRO), who typically reports to the Chief Executive Officer or Chief Financial Officer. It is important that the organizational structure created for ERM (e.g., the CRO, the CRO's staff, the Risk Management Committee) is accountable and has the authority to be a change agent. Senior sponsorship needs to be high enough in the organization to have a top-level view of all the risks facing the enterprise, see across all organizational "silos", and have sufficient authority to effect changes in business practice.

Making ERM part of the enterprise culture ("tearing down the silos")

Under the historical, fragmented approach to risk management, numerous personnel are involved in various aspects of risk management. Typical of such approaches, the risk management department is responsible for hazard risks; the treasury department is responsible for financial risks; the human resources department is responsible for workers compensation, health, and employee risks; information technology is responsible for many operational risks; and the marketing department is responsible for many strategic risks. More than likely, these departments report to different managers within the organization, use different risk assessment procedures and terminology, calibrate risk on different scales, and have different timeframes in mind. Instituting such a sweeping change as implementing ERM may invoke defensive postures as these departments try to protect "their turf". The successful ERM approach would be one that coordinates all these different departments, recognizes the need for education, but allows for individual department initiative, flexibility, and autonomy.

Determining all possible risks of the organization

As the list of risks included in the ERM Framework demonstrates, there is a multitude of risks facing every enterprise. Often the greatest risks are those not contemplated. Who in the property and casualty insurance industry could have conceived the magnitude of environmental risks assumed in insurance policies prior to the mid-1980's, or the terrorism exposure in the early 2000's? Who in the pharmaceutical industry could have conceived of effect of criminal tampering with products on store shelves? How can these risks be quantified, integrated or treated, if they cannot be identified? Some organizations have used their risk management committees to conduct and participate in periodic, structured "disaster scenario" brainstorming exercises specifically to contemplate and, as appropriate, plan for such "unthinkable" events.

Quantifying operational and strategic risks

Although a great body of literature exists in the quantification of hazard and financial risks, not all enterprises are able to quantify intangible risks such as operational and strategic risk. It is difficult to determine point estimates of likelihoods (i.e., frequency) and consequences (i.e., severity) of these risks, let alone determine probability distributions around these estimates. Not only do models generally not exist, but historical data that are the input to these models often do not exist either. Even if attempted, the cost of quantifying these risks needs to be considered in relationship to its benefit.

Enterprises can overcome these difficulties by starting with qualitative analysis of operational and strategic risk to determine those that are material and to prioritize them. In addition, some have advocated the use of causal models, as opposed to parametric models, to quantify these risks. These causal models often already exist (e.g., in strategic planning, in logistics) in some form within the organization and may simply need to be "stochasticized".

Integrating risks (determining dependencies, etc.)

Actuaries and financial analysts know of the difficulty in determining appropriate relationships or correlations for risks just within their respective areas of expertise, hazard and financial risks. These difficulties include:

- Past causal relationships are often not indicative of future relationships.
- There are differences in time frames (short-term, medium-term, long-term) to consider.
- Selecting correlation factors becomes cumbersome as the number of risks to review increases.

These difficulties are compounded when considering operational and strategic risks, both within these risk categories and among other risk categories.

Building structural models in modular form, which allows enhancement in manageable successive stages over time, is one practical approach some companies have employed.

Lack of appropriate risk transfer mechanisms

Although risk transfer mechanisms for hazard and financial risks exist via the insurance, reinsurance and capital markets, these markets are not complete in the sense of being able to provide all products and services that enterprises may need. These markets need to continue to evolve over time (such as the development of the alternative risk market for hazard risks) in order to provide products that will meet the risk transfer needs of enterprises. Risk transfer mechanisms for operational and strategic risks are even less mature.

Monitoring the Process

Ideally, ERM is not a one-time "project", but a discipline that evolves over time as risks and opportunities within an enterprise change. The successful ERM process will include regular progress reports and comparisons to previous risk assessments so changes and refinements can be made as appropriate. Changes in the risk environment, based on new information, may result in changing strategies employed to treat and exploit risk. Regularly monitoring results can, and should, be tied to the time scales identified for the risks actively managed.

Start Slowly – Build Upon Successes

Because of the traditional, fragmented approach to risk management described earlier and the complexity of many businesses, enterprises often find it useful to start their ERM initiative slowly, tackling smaller projects first, so tangible results can be achieved early. The CRO or Risk Management Committee or both also may have limited resources initially, so they have to think on a smaller scale until successful projects are completed. However, the early successes can help to generate momentum and enthusiasm (and perhaps funding) for future ERM initiatives.

The case studies in the preceding chapter include examples of how different companies in various industries started small in terms of any or all of the following:

- Risk type (e.g., combining hazard and financial risks first, then planning to layer in strategic and operational risks);
- Process step (e.g., starting with a qualitative enterprise-wide risk assessment, then proceeding to risk quantification);
- Organizational component (e.g., piloting ERM within a single corporate division).

Just as there is no one correct approach to overall ERM design, there is no one correct path to incrementally building toward ERM. Both are dependent on the unique business imperatives and culture of each organization.

Appendix A — Risk-Related Regulatory, Rating Agency and Corporate Governance Guidelines and Requirements

Those developing ERM programs and policies need to consider a number of corporate governance guidelines and regulatory and rating agency requirements. The more prominent of these are described below.

- General Industry
  - Cadbury Report, et al (U.K.) — the London Stock Exchange has adopted a set of principles, the Combined Code, that consolidates previous reports on corporate governance by the Cadbury, Greenbury and Hampel Committees. This code, effective for all accounting periods ending on or after December 23, 2000 (and with a lesser requirement for accounting periods ending on or after December 23, 1999), makes directors responsible for establishing a sound system of internal control and reviewing its effectiveness, and reporting their findings to shareholders. This review should cover all controls, including operational and compliance controls and risk management. The Turnbull Committee issued guidelines in September 1999 regarding the reporting requirement for non-financial controls.
  - Dey Report (Canada) — commissioned by the Toronto Stock Exchange and released in December 1994, it requires companies to report on the adequacy of internal control. Following that, the clarifying report produced by the Canadian Institute of Chartered Accountants, "Guidance on Control" (CoCo report, November 1995), specifies that internal control should include the process of risk assessment and risk management. While these reports have not forced Canadian listed companies to initiate an ERM process, they do create public pressure and a strong imperative to do so. In actuality, many companies have responded by initiating ERM processes.
  - Australia/New Zealand Risk Management Standard — a common set of risk management standards issued in 1995 that call for a formalized system of risk management and for reporting to the organization's management on the performance of the risk management system. While not binding, these standards create a benchmark for sound management practices that includes an ERM system.
  - KonTraG (Germany) — a "mandatory bill" that became law in 1998. Aimed at giving shareholders more information and control and increasing the duty of care of the directors, it includes a requirement that the management board establish supervisory systems for risk management and internal revision. In addition, it calls for reporting on these systems to the supervisory board. Further, auditors appointed by the supervisory board must examine implementation of risk management and internal revision.

- Financial Services Industry
  - Basel Committee:
    - The Basel Committee on Banking Regulation and Supervisory Practices was established in 1974 (originally called the Cooke Committee) in response to the

erosion of capital in leading global banks. The committee meets under the auspices of the Bank for International Settlements (BIS) but is not part of the BIS. The committee consists of representatives from the central banks/supervisory authorities of the G10 countries and Luxembourg. The committee has no legal authority, but the governments of the representatives on the committee have always legislated to make the recommendations part of their own national law. The standards set by the committee are widely regarded to be best practice and a large number of other countries that are not formally represented on the committee have implemented the proposals. In the U.S., the Federal Reserve has adopted the Basel Capital Accord ("Basel I" – see below).

— "Basel I" — the 1988 Basel Capital Accord established a framework to calculate a minimum capital requirement for banks. The Accord focused on credit risk and was crude in its recognition of the relative risk of different loans. A number of amendments were made to the Accord (prior to "Basel II" – see below), the most significant of which is the market risk amendment in 1996; this extended the 1988 Accord to cover market risk and allowed for the use of internal models to quantify regulatory capital.

— "Basel II" — in 1999 the Basel Committee issued a draft proposal for a new accord and accepted comment. Based on feedback, the Committee issued a revised proposal in 2001 for review and comment. In this New Basel Capital Accord, proposed for implementation in 2004, among other changes a capital charge for operational risk is included as part of the capital framework. The charge reflects the Committee's "realization that risks other than market and credit" can be substantial. Operational risk is defined as "the risk of direct or indirect loss resulting from inadequate or failed internal processes, people and systems or from external events". The new capital adequacy framework is proposed to apply to insurance subsidiaries of banks and may apply to insurance companies as insurance and banking activities converge.

- OSFI (Canada) — the Office of the Supervisor of Financial Institutions supervisory framework defines "inherent risk" to include credit risk, market risk, insurance risk, operational risk, liquidity risk, legal and regulatory risk and strategic risk. It states that: "Where independent reviews of operational management and controls have not been carried out or where independent risk management control functions are lacking, OSFI will, under normal circumstances, make appropriate recommendations or direct that appropriate work be done."
- FSA (U.K.) — the Financial Services Authority (FSA – the recently created regulator of all U.K. financial services businesses) is introducing a system of risk-based supervision that will create a single set of prudential requirements organized by risk rather than by type of business. Regulated businesses will have to demonstrate that they have identified all material risks and have adequate systems and financial resources to manage and finance such risks, including market risk, credit risk, operational risk and insurance risk. There is also likely to be a requirement for formal documentation of the whole process in a format that is readily accessible to the FSA.

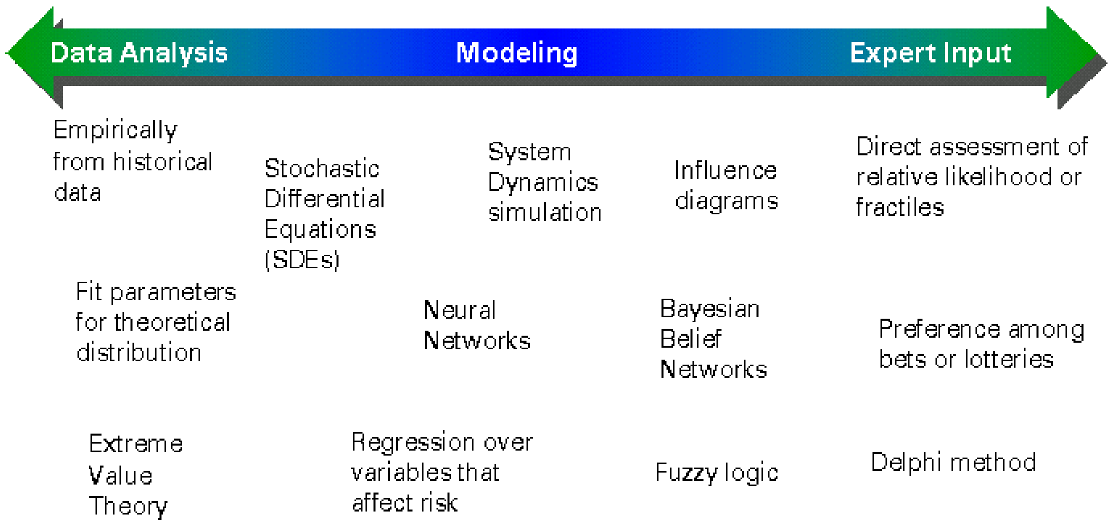
- Insurance Industry
  - A.M. Best — in its publication *Enterprise Risk Model: A Holistic Approach to Measuring Capital Adequacy*, A.M. Best describes its VaR-based method for determining the adequacy of capital for rating purposes. The report states: "The Enterprise Risk Model is a modular system designed to capture all risks, including noninsurance and non-U.S. related risks. VaR methodologies are somewhat controversial in insurance circles, but they are the standard for other financial-services organizations. More importantly, A.M. Best believes that VaR-based methodologies provide a more accurate assessment of risk and required capital, since they use observable market metrics. Beyond its application in the rating process, the model can also be a useful tool for financial managers, since the VaR framework provides a natural springboard to other applications, including risk-adjusted return on capital (RAROC) and dynamic financial analysis (DFA). The Enterprise Risk Model quantifies the risk to the future surplus – net worth – of an organization arising from a change in underlying risk variables, such as credit risk, insurance risk, interest rate risk, market risk and foreign exchange risk. The model also quantifies the benefits of diversification as it takes a macro view of the correlations among risks within an organization...Like other VaR-based models, it is calibrated to measure the risks over a defined holding period – one year – for a given level of statistical confidence – 99%."
  - Moody's — in its publication *One Step in the Right Direction: The New C-3a Risk-Based Capital Component* (June 2000), Moody's Investors Service states that it will use the new method devised by the NAIC and the American Academy of Actuaries for measuring a life insurance company's C-3a (interest rate) risk, as it incorporates a cash-flow testing requirement for annuity and single premium life products and is more consistent with industry advances in dynamic cash-flow testing. *One Step* states: "…the revised calculation is a more accurate barometer of the amount of capital required to support an insurer's interest-sensitive business, as it explicitly incorporates asset-liability mismatches in determining the appropriate amount of required regulatory capital for a company. Consequently, the new calculation should help discourage companies from taking unwarranted asset-liability risk."
  - Standard &Poor's — in its *Revised Risk-Based Capital Adequacy Model for Financial Products Companies* Standard & Poor's states: "Standard & Poor's Insurance Capital Markets Group has developed a new, risk-based capital adequacy model to analyze the credit, financial market, and operational risks of companies that are offering products or are using sophisticated risk management techniques that are not considered under the existing Rating Group's capital models. The model will also determine these companies' capital adequacy. The primary application of the model will be to analyze specialized financial product companies (FPCs) that are subsidiaries of insurance companies or that are credit enhanced by insurance companies…The model may also be applied to portions of insurance companies that control or mitigate their risks to a greater extent than is implied by the capital charges applied in the standard life/health capital adequacy

model, which bases charges for interest-rate risk and credit risk on industry averages and liability types rather than company-specific exposure."

- NAIC — The National Association of Insurance Commissioners:
  - Risk-Based Capital (RBC) — Following a detailed examination of the growing diversity of business practices of insurance companies conducted in 1990, the NAIC concluded that minimum capital requirements placed on companies needed to be increased to protect consumers. The NAIC adopted life/health risk-based capital requirements in December 1992 and adopted property/casualty risk-based capital requirements in December 1993. Although risks involved in these two segments of the industry are very different, the NAIC was able to develop a consistent two-step approach to setting risk-based capital requirements for individual companies:
    - Step 1 involves the calculation of a company's capital requirement and total adjusted capital, based on formulas developed by NAIC for each industry.
    - Step 2 calls for comparison of a company's total adjusted capital against the risk-based capital requirement to determine if regulatory action is called for, under provisions of the Risk-Based Capital for Insurers Model Act. The model law sets the points at which a commissioner is authorized and expected to take regulatory action.
  - Interest rate risk — the NAIC's Life Risk-Based Capital Working Group, in conjunction with the American Academy of Actuaries Life Risk-Based Capital Task Force, has finalized the development of an improved method for measuring a company's interest-rate risk. The method, which is effective for the year-end 2000 statements, "incorporates a cash-flow testing requirement for annuity and single premium life products and makes the RBC C-3a calculation more consistent with recent industry advances in dynamic cash-flow testing…The task force has recognized the need to accurately incorporate these additional risks into the RBC formula. They have stated that equity indexed annuities (EIAs) and variable products with secondary guarantees will be incorporated in a future C-3a update. This would be consistent with the task force's goal of upgrading C-3a from a measure of interest-rate risk to a more complete measure of asset/liability risk."
- Australian Prudential Regulation Authority (APRA) — a feature of ongoing reforms to the regulation of general insurers is a layer of four standards covering the subjects of capital adequacy, liability valuation, reinsurance arrangements and operational risk. APRA is implementing an approach based on development of, and compliance with, a range of risk management strategies. These strategies will need to deal with the myriad interlocking risks involved in managing a general insurance company. Each company will need to have its strategy agreed upon by APRA and will then be responsible for managing compliance. APRA has made it clear that an internal enterprise risk model with appropriate specifications will go a long way toward meeting compliance objectives.

Appendix B — A Continuum of Risk Modeling Methods

Figure A – There is a continuum of methods for modeling risks. Each method has advantages/disadvantages over others, so it's important to select the best methods based on facts and circumstances



There is a continuum of methods for developing probability distributions. The choice of method depends significantly on the amount and type of historical data that is available. The methods also require varying analytical skills and experience. Each method has advantages and disadvantages over the other methods, so it is important to match the method to the facts and circumstances of the particular risk type.

We have loosely organized the modeling methods into three categories:
- Methods based primarily on analysis of historical data
- Methods based on a combination of historical data and expert input
- Methods based primarily on expert input

<u>Methods Based Primarily on Analysis of Historical Data</u>

These methods are the most appropriate when there is enough historical data to apply standard statistical approaches to develop probability distributions. Typically several years of high-frequency data are necessary. These methods are most often used to model risks that are traded in the financial markets such as interest rate, foreign exchange, asset risks, claims and the like.

Empirical Distributions

The simplest and the most direct approach is to assume that the historical data fully defines the probability distribution. Then the data can be used directly to develop a discrete probability distribution. Of course the danger is in assuming that the data is complete and the time period over which the data is gathered is long enough to have "seen" or experienced the full range of outcomes.

Fit Parameters of Theoretical Probability Density Functions

An alternative to empirical distributions is to assume that the risk can be described by a theoretical probability density function. Then the data is used to estimate the parameters of the theoretical distribution. For example, for property/casualty claims, the frequency of claims is often assumed to follow either a Poisson or negative binomial distribution whereas the severity of claims is often assumed to follow a lognormal or a Pareto (for conditional claim or tail distribution).

Stochastic Differential Equations (SDE)

A Stochastic Differential Equation (SDE) expresses the difference (or change) in the value of a variable (e.g., interest rate) at time t and the value one time period later, t +1. It's a **stochastic** differential equation because the difference is expressed as a combination of a predictable change and an uncertain or random change during the time period. The random change is represented as a random variable with a specified probability distribution (typically normal distribution). Starting with an initial value, the SDE is used to iteratively determine a scenario of how the value changes over a forecast period (e.g., 10 years). Hundreds or possibly thousands of scenarios are generated in this way. The scenarios can then be summarized as probability distributions for each point in time over the forecast period. See the ERM bibliography for helpful publications that provide more detail on use of SDEs to model risk.

Extreme Value Theory

In risk management, often the most important part of a probability distribution is the tail representing the downside risk. The tail distribution is used to determine capital and shortfall risk constraints for optimizing strategies. However, most risk modeling methods focus on accurately representing the main body of the distribution. Extreme Value Theory (EVT) is a technique for increasing the accuracy with which to model the probability of large values in the tail distribution. EVT is devoted to the modeling and estimating the behavior of rare events. Different EVT models and techniques have been developed and applied to deal with some environmental issues like sea levels, wind speeds and pollution concentrations, where there is a potential for catastrophic results but it happens rarely. Recently, EVT has been used increasingly in finance and insurance.

The main difficulty of estimating rare events is that in most cases there is a small amount of, or even no, data available. The EVT approach is to develop models based on asymptotic theory. EVT models the limiting distribution of the extreme values of a random variable, which corresponds to the happening of rare events. A description of the method is beyond the scope of this document, however, several useful references are cited in the bibliography.

Regression

Often it's necessary and useful to develop a model of a variable by examining its drivers or causal variables. A regression equation expresses a dependent variable as a function of one or more predictor variables. Regression equations provide managers more information on the dynamics underlying a specific risk to help manage, insure or hedge the risk.

Methods Based on a Combination of Historical Data and Expert Input

Often there is not enough data to reliably quantify risks directly through data analysis. In these cases it's necessary to develop a model of the underlying dynamics that give rise to the data. This requires drawing on the experience and knowledge of domain experts to fill in the data gaps. The following methods attempt to model the dynamics of a system by using a combination of both historical data and expert input.

System Dynamics Simulation

System Dynamics is a robust modeling method that explicitly simulates the cause/effect relationships underlying the dynamics of system. The approach leverages both existing historical data and the knowledge and experience of senior managers to develop a stochastic simulation model. The model is used to run Monte Carlo simulations and develop probability distributions for the variable of interest.

The System Dynamics approach has several advantages over parametric approaches described above, particularly for modeling operational risks:

- It provides a systematic way to fill any gaps in historical data with input from experts relying on their knowledge and experience. This is applicable particularly for modeling operational risks where it's often the case that there isn't enough representative data to apply the statistical methods described above.
- It provides a way to determine how operational risks change as a function of changes in operations. Since the approach explicitly captures the cause/effect linkages, it is easier to develop effective ways to mitigate risk and measure their impact than with noncausal methods.
- As businesses become more complex, knowledge of their underlying dynamics becomes more fragmented and localized. Although many managers have a good understanding of their own functional areas, few have a solid grasp of the dynamics of the entire organization. Obtaining a complete picture, for example, of the sources of operational risks and how they affect financial performance, requires the combined knowledge of managers across functional areas. The system dynamics approach facilitates this interaction through a structured, participative modeling and decision-making process.

Fuzzy Logic

In spite of its name, fuzzy logic is a well-established engineering science used successfully in control systems and expert reasoning. It is an approach to modeling complex systems, where much of the complexity comes from the ambiguous, uncertain or undecided representation of the variables of the system. Traditional quantitative models tend to interpret reality in binary terms. For example, imagine a device that identifies if a person has a fever. Given the temperature of an individual, a quantitative model programmed in the device will use a discrete, binary rule, such as: "if the temperature is at or over 103°F then person has a fever, else normal". Even if it has other categories in between, such as "light fever", it will still use a discrete binary rule to determine whether a person falls in the "light fever" category or "fever" category. However, in reality it's clear that there is no precise cut-off for determining whether someone has a fever and the boundary between "normal" and "fever" is fuzzy. Fuzzy set theory was developed to recognize these gray areas. According to fuzzy set theory, a person with a temperature of 101.5°F would be classified as having some membership in both categories "normal" and "fever". Fuzzy logic is the reasoning based on fuzzy set theory.

Fuzzy logic has advantages in modeling complex business problems where linguistic variables are used to express the logic rules, the information is subjective, incomplete or unreliable, and the problem spaces are often nonlinear. A fuzzy system is closer to the way people reason and is therefore often used to build expert systems. The fuzzy nature of the rule spaces makes it easy to model multiple, often different or conflicting expert views toward the same model variables. In terms of risk modeling and assessment, fuzzy logic shows potential to be a good approach in dealing with operational risk, where the probability assessment is often based on expert opinion and the risk space is multidimensional and highly nonlinear.

Estimating Probabilities through Expert Testimony

In extreme cases, there aren't any data at all. In these cases, one must rely on the knowledge and experience of domain experts. Probability distributions for events for which there is sparse data can be estimated through expert testimony. A naive method for assessing probabilities is to ask the expert, e.g., "What is the probability that a new competitor will enter the market?" However, the expert may have difficulty answering direct questions and the answers may not be reliable. Behavioral scientists have learned from extensive research that the naive method can produce unreliable results because of heuristics and biases. For example, individuals tend to estimate higher probabilities for events that can be easily recalled or imagined. Individuals also tend to anchor their assessments on some obvious or convenient number resulting in distributions that are too narrow. (See Clemen, 1996 and von Winterfeldt & Edwards, 1986 in the bibliography for further examples). Decision and risk analysts have developed several methods for accounting for these biases. Several of these methods are described below.

Preference among Bets

Probabilities are determined by asking the expert to choose which side she prefers on a bet on the underlying events. To avoid issues of risk aversion, the amounts wagered should not be too large. For example, a choice is offered between the following bet and its opposite:

Bet	**Opposite Side of Bet**
Win \$*x* if a new competitor enters the market Lose \$*y* if no new competition	Lose \$*x* if a new competitor enters the market Win \$*y* if no new competition.

The payoffs for the bet, amounts \$*x* and \$*y*, are adjusted until the expert is indifferent to taking a position on either side of the bet. At this point, the expected values for each side of the bet are equal in her mind. Therefore,

$$\$x\mathrm{P}(C) - \$y[1-\mathrm{P}(C)] = -\$x\mathrm{P}(C) + \$y[1-\mathrm{P}(C)]$$

where $\mathrm{P}(C)$ is the probability of a new competitor entering the market. Solving this equality for $\mathrm{P}(C)$:

$$\mathrm{P}(C) = \$y \,/\, (\$x + \$y)$$

For example, if the expert is indifferent to taking a position on either side of the following bet:

Win \$900 if a competitor enters the market
Lose \$100 if no new competition

then the estimated subjective probability of a new competitor entering the market is \$100/(\$100 + \$900) = 0.10.

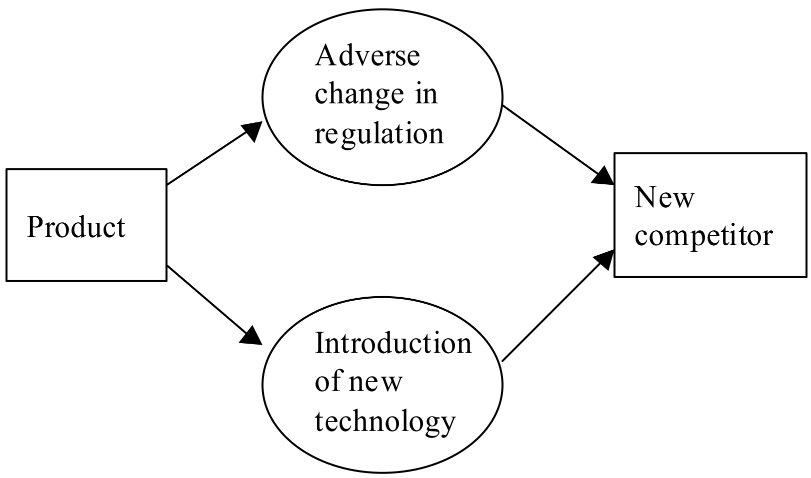
Judgments of Relative Likelihood

This method involves asking the expert to provide information on the likelihood of an event relative to a reference lottery. The expert is asked to indicate whether the probability of the event occurring is more likely, less likely or equally likely compared to a lottery with known probabilities. Typically a spinning wheel (a software implementation of the betting wheels in casinos) is used on which a portion of the wheel is colored to represent the event occurring. The relative size of the colored portion is specified. The expert is asked to indicate whether the event is more, less or equally likely to occur than the pointer landing on the colored area if the wheel was spun fairly. The colored area is reduced or increased as necessary depending on the answers until the expert indicates that the two events are equally likely. This method is often used with subjects that are naive about probability assessments.

Decomposition to Aid Probability Assessment

Often, decomposing an event into conditional causal events helps experts assess risk of complex systems. The structure of the conditional causal events can be represented by an **influence diagram.** Influence diagrams illustrate the interdependencies between known events (inputs), scenarios and uncertainties (intermediate variables) and an event of interest (output). An influence diagram model comprises risk nodes representing the uncertain conditions surrounding an event or outcome. Relationships among nodes are indicated by connecting arrows, referred to as arcs of influence. The graphical display of risks and their relationships to process components and outcomes helps users visualize the impacts of external uncertainties.

While this approach increases the number of probability assessments, it also allows input from multiple experts or specialists, and helps combine empirical data with subjective data. For example, a new competitor entering the market may be decomposed using an influence diagram such as this one:



The probability of a new competitor, P(C) can be estimated, using a **Bayesian approach**. The approach uses "Bayes' Rule" which is a formal, optimal equation for the revision of probabilities in light of new evidence contained in conditional or causal probabilities.

$$P(C) = \sum_i P(C_i \mid R_i, T_i)\, P(R_i, T_i)$$

where i is a product index, P(R_i, T_i) is the joint probability of an adverse change in regulation and introduction of new technology, and P(C_i | R_i, T_i) is the conditional probability of a new competitor entering a market for product i. This formula is useful when assessing the conditional probabilities P(C_i | R_i, T_i) and is easier than a direct calculation of P(C).

Several different experts may be asked to assess the conditional and joint probabilities. For example, one expert (or group of experts) may assess the probability of adverse regulation for a specific product, another expert may assess probability of introduction of new technology and a third may assess the probability of a new competitor given the state of new regulation and technology.

The Delphi Technique

Scientists at the Rand Institute developed the "Delphi process" in the 1950's for forecasting future military scenarios. Since then it has been used as a generic strategy for developing consensus and making group decisions, and can be used to assess probabilities from a group of individuals. This process structures group communication, and usually involves anonymity of responses, feedback to the group as collective views, and the opportunity for any respondent to modify an earlier judgment. The Delphi process leader poses a series of questions to a group; the answers are tabulated and the results are used to form the basis for the next round. Through several iterations, the process synthesizes the responses, resulting in a consensus that reflects the participants' combined intuition, experience and expert knowledge.

The Delphi technique can be used to explore or expose underlying assumptions or information leading to differing judgments and to synthesize informed judgments on a topic spanning a wide range of disciplines. It is useful for problems that can benefit from subjective judgments on a collective basis.

Pitfalls and Biases

Estimating subjective probabilities is never as straightforward as implied in the description of the methods above. There are several pitfalls and biases to be aware of:

None of the methods works extremely well by itself. Typically, multiple techniques must be used. To increase consistency, experts should be asked to assess both the probability of an event and, separately, the probability of the complement of the event. The two should always add up to 1.0; however, in practice they seldom do without repeated application of the assessment method. The events must be defined clearly to eliminate ambiguity. "What is the probability of a new competitor entering the market?" is an ambiguous question. "What is the probability that a new competitor will take more than 5% market share of product A in the next two years?" is much less ambiguous and more clearly defines the event. When assessing probabilities for rare events, it is generally better to assess odds. Odds of event E is [P(E) / P(complement of E)].

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Note: This appendix was reproduced from the Tillinghast – Towers Perrin monograph *RiskValueInsights®: Creating Value Through Enterprise Risk Management*, (http://www.tillinghast.com).

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