Operational Risk
with Excel and VBA
John Wiley & Sons

Founded in 1807, John Wiley & Sons is the oldest independent publishing company in the United States. With offices in North America, Europe, Australia, and Asia, Wiley is globally committed to developing and marketing print and electronic products and services for our customers’ professional and personal knowledge and understanding.

The Wiley Finance series contains books written specifically for finance and investment professionals as well as sophisticated individual investors and their financial advisors.

Book topics range from portfolio management to e-commerce, risk management, financial engineering, valuation and financial instrument analysis, as well as much more.

In loving memory of my mother-in-law,
Lydora.
Her devotion and wisdom nurtured my wife
into becoming the encouraging source
of strength that she is today.
These qualities have inspired
and enabled me to complete this work.
Contents

Preface xiii
Acknowledgments xv

CHAPTER 1
Introduction to Operational Risk Management and Modeling 1
What is Operational Risk? 1
The Regulatory Environment 3
Why a Statistical Approach to Operational Risk Management? 5
Summary 6
Review Questions 6
Further Reading 6

CHAPTER 2
Random Variables, Risk indicators, and Probability 7
Random Variables and Operational Risk Indicators 7
Types of Random Variable 8
Probability 9
Frequency and Subjective Probability 11
Probability Functions 13
Case Studies 16
Case Study 2.1: Downtown Investment Bank 17
Case Study 2.2: Mr. Mondey’s OPVaR 20
Case Study 2.3: Risk in Software Development 20
Useful Excel Functions 24
Summary 24
Review Questions 25
Further Reading 26
CHAPTER 10

The Law of Significant Digits and Fraud Risk Identification 113

The Law of Significant Digits 113
Benford’s Law in Finance 116
Case Study 10.1: Analysis of Trader’s Profit and Loss
  Using Benford’s Law 116
A Step Towards Better Statistical Methods of Fraud Detection 118
Summary 120
Review Questions 120
Further Reading 120

CHAPTER 11

Correlation and Dependence 121

Measuring Correlation 121
Dependence 132
Stochastic Dependence 134
Summary 136
Review Questions 136
Further Reading 136

CHAPTER 12

Linear Regression in Operational Risk Management 137

The Simple Linear Regression Model 137
Multiple Regression 148
Prediction 153
Polynomial and Other Types of Regression 155
Multivariate Multiple Regression 155
Regime-Switching Regression 157
The Difference Between Correlation and Regression 158
A Strategy for Regression Model Building in Operational Risk Management 159
Summary 159
Review Questions 159
Further Reading 160

CHAPTER 13

Logistic Regression in Operational Risk Management 161

Binary Logistic Regression 161
Bivariate Logistic Regression 165
Case Study 13.1: Nostro Breaks and Volume in a Bivariate Logistic Regression 172
Other Approaches for Modeling Bivariate Binary Endpoints 173
Contents

Summary 176
Review Questions 177
Further Reading 177

CHAPTER 14
Mixed Dependent Variable Modeling 179
A Model for Mixed Dependent Variables 179
Working Assumption of Independence 181
Understanding the Benefits of Using a WAI 184
Case Study 14.1: Modeling Failure in Compliance 184
Summary 185
Review Questions 186
Further Reading 186

CHAPTER 15
Validating Operational Risk Proxies Using Surrogate Endpoints 187
The Need for Surrogate Endpoints in OR Modeling 187
The Prentice Criterion 188
Limitations of the Prentice Criterion 191
The Real Value Added of Using Surrogate Variables 193
Validation Via the Proportion Explained 196
Limitations of Surrogate Modelling in Operational Risk Management 200
Case Study 15.1: Legal Experience as a Surrogate Endpoint for Legal Costs for a Business Unit 201
Summary 202
Review Questions 202
Further Reading 202

CHAPTER 16
Introduction to Extreme Value Theory 203
Fisher-Tippet–Gnedenko Theorem 203
Method of Block Maxima 205
Peaks over Threshold Modeling 206
Summary 207
Review Questions 207
Further Reading 207

CHAPTER 17
Managing Operational Risk with Bayesian Belief Networks 209
What is a Bayesian Belief Network? 209
Case Study 17.1: A BBN Model for Software Product Risk 212
Creating a BBN-Based Simulation 215
Until a few years ago most banks and other financial institutions paid little attention to measuring or quantifying operational risk. In recent years this has changed. Understanding and managing operational risk are essential to a company’s future survival and prosperity. With the regulatory spotlight on operational risk management, there has been ever-increasing attention devoted to the quantification of operational risks. As a result we have seen the emergence of a wide array of statistical methods for measuring, modeling, and monitoring operational risk. Working out how all these new statistical tools relate to one another and which to use and when is not a straightforward issue.

Although a handful of books explain and explore the concept of operational risk per se, it is often quite difficult for a practicing risk manager to turn up a quickly digestible introduction to the statistical methods that can be used to model, monitor, and assess operational risk. This book provides such an introduction, using Microsoft Excel and Visual Basic For Applications (VBA) to illustrate many of the examples. It is designed to be used “on the go,” with minimal quantitative background. Familiarity with Excel or VBA is a bonus, but not essential. Chapter sections are generally short—ideal material for the metro commute into and from work, read over lunch, or dipped into while enjoying a freshly brewed cup of coffee. To improve your understanding of the methods discussed, case studies, examples, interactive illustrations, review questions, and suggestions for further reading are included in many chapters.

In writing this text I have sought to bring together a wide variety of statistical methods and models that can be used to model, monitor, and assess operational risks. The intention is to give you, the reader, a concise and applied introduction to statistical modeling for operational risk management by providing explanation, relevant information, examples, and interactive illustrations together with a guide to further reading. In common
with its sister book *Applied Statistical Methods for Market Risk Management* (Risk Books, March 2003), this book has been written to provide the time-starved reader, who may not be quantitatively trained, with rapid and succinct introduction to useful statistical methods that must otherwise be gleaned from scattered, obscure, or mathematically obtuse sources. In this sense, it is not a book about the theory of operational risk management or mathematical statistics per se, but a book about the application of statistical methods to operational risk management.

Successful modeling of operational risks is both art and science. I hope the numerous illustrations, Excel examples, case studies, and VBA code listings will serve both as an ideas bank and technical reference. Naturally, any such compilation must omit some models and methods. In choosing the material, I have been guided both by the pragmatic “can do” requirement inherent in operational risk management, and by my own practical experience gained over many years working as a statistician and quantitative analyst in the City of London, on Wall Street, at the quantitative research boutique StatMetrics, and in academia. Thus, this is a practitioners’ guide book. Topics that are of theoretical interest but of little practical relevance or methods that I have found offer at best a marginal improvement over the most parsimonious alternative are ignored. As always with my books on applied statistical methods, lucidity of style and simplicity of expression have been my twin objectives.
Many people have helped considerably during the process of researching and writing this text. I particularly would like to thank StatMetrics for providing me with the time and financial resources to complete this project. I would also like to express my sincere appreciation to Angela Lewis for her wonderful cooperation, understanding, and support throughout the period of this research. The inspiration for this text came from a discussion I had with an organization keen to set up an operational risk department. It became clear by the end of my discussion that their analysts and senior management lacked even a basic understanding of what can and cannot be achieved using statistical methods.

Following this conversation I decided to “act out” various roles to gather information about the approach, tools, and techniques of operational risk. The most enjoyable role was as a job seeker, in which my resume would be forwarded to potential employers who were seeking a analyst to model their operational risk. Almost inevitably, I would be offered an interview and would then play the role of a badly informed candidate or a super knowledgeable expert. Through this process it became clear that there is little consensus on how operational risk should be modeled and very little understanding of the role statistical methods can play in informing decision makers. I particularly wish to thank and at the same time apologize to those anonymous individuals who interviewed me as a real candidate for a position in their operational risk departments. I am deeply indebted to them all.
Operational Risk
with Excel and VBA
Operational risk (OR) is everywhere in the business environment. It is the oldest risk facing banks and other financial institutions. Any financial institution will face operational risk long before it decides on its first market trade or credit transaction. Of all the different types of risk facing financial institutions, OR can be among the most devastating and the most difficult to anticipate. Its appearance can result in sudden and dramatic reductions in the value of a firm. The spectacular collapse of Barings in 1995, the terrorist attack on the World Trade Center in September 2001, the $691 million in losses due to fraud reported by Allied Irish Bank in 2002, and the widespread electrical failure experienced by over 50 million people in the northeastern United States and Canada in August 2003 are all concrete but very different illustrations of operational risk. The rapid pace of technological change, removal of traditional trade barriers, expanding customer base through globalization and e-commerce, and mergers and consolidations have led to the perception that OR is increasing. Indeed, although many functions can be outsourced, OR cannot. Increasingly, banks and other financial institutions are establishing OR management functions at the senior executive level in an effort to better manage this class of risk. In this chapter we discuss the definition of OR, outline the regulatory background, and describe the role of statistical methods in measuring, monitoring, and assessing operational risk.

WHAT IS OPERATIONAL RISK?

There is no generally accepted definition of OR in the financial community. This lack of consensus relates to the fundamental nature of operational risk itself. Its scope is vast and includes a wide range of issues and problems that fall outside of market and credit risk. A useful starting point is to acknowledge that OR encompasses risk inherent in business activities across an
organization. This notion of OR is a broader concept than “operations” or back and middle office risk and affords differing definitions. For example, Jameson (1998) defines OR as “Every risk source that lies outside the areas covered by market risk and credit risk.”

Typically, this will include transaction-processing errors, systems failure, theft and fraud, “fat finger” trades, lawsuits, and loss or damage to assets. Jameson’s definition is considered by many as too broad in the sense that it includes not only operational risk but business, strategy, and liquidity risks as well. An alternative provided by the British Bankers’ Association (1997) states, “The risks associated with human error, inadequate procedures and control, fraudulent and criminal activities; the risk caused by technological shortcomings, system breakdowns; all risks which are not ‘banking’ and arising from business decisions as competitive action, pricing, etc.; legal risk and risk to business relationships, failure to meet regulatory requirements or an adverse impact on the bank’s reputation; ‘external factors’ include: natural disasters, terrorist attacks and fraudulent activity, etc.”

Another frequently quoted definition of OR is that proposed by the Basel Committee on Banking Supervision (2001b): “The risk of loss resulting from inadequate or failed internal processes, people systems or from external events.” In this categorization OR includes transaction risk (associated with execution, booking, and settlement errors and operational control), process risk (policies, compliance, client and product, mistakes in modeling methodology, and other risks such as mark-to-market error), systems risk (risks associated with the failure of computer and telecommuni-
cation systems and programming errors), and people risk (internal fraud and unauthorized actions).

However we choose to define OR, our definition should allow it to be prudently and rigorously managed by capturing the business disruption, failure of controls, errors, omissions, and external events that are the consequence of operational risk events.

**THE REGULATORY ENVIRONMENT**

Traditionally, financial institutions have focused largely on market and credit risk management, with few if any resources devoted to the management of operational risks. The perception that operational risk has increased markedly over recent years, combined with the realization that quantitative approaches to credit and market risk management ignore operational risks, has prompted many banks to take a closer look at operational risk management. Indeed, the fact that the risk of extreme loss from operational failures was being neither adequately managed nor measured has prompted many regulators to issue guidelines to their members. In the United States, as early as 1997 the Federal Reserve Bank issued a document entitled “The Framework for Risk-focused Supervision of Large, Complex Institutions.” In June 1999 the Basel Committee (1999) signaled their intention to drive forward improvements in operational risk management by calling for capital charges for OR and thereby creating incentives for banks to measure and monitor OR: “From a regulatory perspective, the growing importance of this risk category has led the committee to conclude that such risks are too important not to be treated separately within the capital framework.”

The New Capital Adequacy Framework (also referred to as the New Capital Accord) proposed by the Basel Committee exposed the lack of preparedness of the banking sector for operational risk events. Indeed, in a consultative document issued in January 2001, the Basel Committee reflected (2001a): “At present, it appears that few banks could avail themselves of an internal methodology for regulatory capital allocation [for OR]. However, given the anticipated progress and high degree of senior management commitment on this issue, the period until implementation of the New Basel Capital Accord may allow a number of banks to develop viable internal approaches.”

By the early 2000s regulators were beginning to “get tough” on failures in operational risk management. Severe financial penalties for failing to monitor and control operational procedures are now a reality. Two examples from the first quarter of 2003 illustrate the new regulatory environment.
BASEL COMMITTEE ON BANKING SUPERVISION

The Basel Committee on Banking Supervision represents the central banks of Belgium, Canada, France, Germany, Italy, Japan, Luxembourg, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom, and the United States. It was established at the end of 1974 and meets four times a year to develop supervisory standards and guidelines of best practice for national banking systems. Although the committee does not possess any formal supranational supervisory authority, its recommendations shape the international banking system. In 1988, the committee introduced a capital measurement system (commonly referred to as the Basel Capital Accord, or Basel I) that provided for the implementation of a risk measurement framework with a minimum capital charge. In June 1999, the committee issued a proposal for a New Capital Adequacy Framework (known as Basel II) to succeed Basel I. Basel II began the process of institutionalizing operational risk as a category for regulatory attention. Operational risk was required to be managed alongside other risks. Indeed, the proposed capital framework required banks to set aside capital for operational risk.

Mis-selling: In April 2003, Lincoln Assurance Limited was fined £485,000 by the United Kingdom’s Financial Services Authority (FSA) for the mis-selling of 10-year savings plans by its appointed representative, City Financial Partners Limited, between September 1, 1998, and August 31, 2000. The operational risk event of mis-selling occurred because Lincoln Assurance Limited failed to adequately monitor City Financial Partners Limited and so failed to ensure that City Financial Partners Limited only recommended 10-year savings plans where they were appropriate for customers’ needs.

Systems failure: In February 2003 the Financial Services Authority fined the Bank of Scotland (BoS) £750,000 for the failure of one of its investment departments to administer customers’ funds appropriately. Between November 1999 and August 2001 problems with BoS systems used to administer personal equity plans (PEPs) and individual savings accounts (ISAs) implied that the bank could not be sure how much money it was holding on behalf of individual customers.

The above examples underscore the fact that as a prerequisite to good operational risk management, firms must have good processes and procedures in place. Systemic failings in internal procedures such as staff training and
information systems management and control put investors at risk and increase the risk of fraud going undetected and the possibility of catastrophic operational losses. In today’s regulatory environment systemic failure also results in heavy regulatory fines. Good operational risk management makes sound commercial sense.

WHY A STATISTICAL APPROACH TO OPERATIONAL RISK MANAGEMENT?

The effectiveness of operational risk management depends crucially on the soundness of the methods used to assess, monitor, and control it. Commercial banks, investment banks, insurance companies, and pension funds, recognizing the central role of statistical techniques in market and credit risk management, are increasingly turning to such methods to quantify the operational risks facing their institutions. This is because modern statistical methods provide a quantitative technology for empirical science; they offer the operational risk manager the logic and methodology for the measurement of risk and for an examination of the consequences of that risk on the day-to-day activity of the business. Their use can improve senior management’s awareness of the operational risk facing their institution by highlighting the expected losses due to operational failures, identifying unexpected losses, and emphasizing the risk associated with starving key business units of their institution of resources. In the language of senior management, statistical methods offer a mechanism for the assessment of risk, capital, and return. Given this, the continued search for value by customers and shareholders, and regulators seeking to force banks to set aside large amounts of capital to cover operational risks, a sound understanding of applied statistical methods for measuring, monitoring, and assessing operational risk is more than an optional extra, it is now a competitive imperative.

DISTINGUISHING BETWEEN DIFFERENT SOURCES OF RISK

Consider a bank that holds bonds in XYZ Corp. The value of the bonds will change over time. If the value fell due to a change in the market price of the bond, this would be market risk. If the value fell as a result of the bankruptcy of XYZ Corp, this would be credit risk. If the value fell because of a delivery failure, this would be operational risk. In each of the three cases the effect is a write-down in the bonds’ value, but the specific cause is a consequence of different risks.
SUMMARY

Operational risk has been described as the oldest of risks, yet the application of statistical methods to operational risk management is a new and rapidly evolving field. This is because regulators have now elevated operational risk management to the forefront of risk management initiatives for banks and other financial institutions. The outcome is likely to be tighter internal controls and a drive toward better measurement, monitoring, and modeling of operational losses. Virtually all financial institutions are now paying attention to the application of statistical methods to their OR. In the remaining chapters of this book we focus attention on what statistical method to use and how these methods can improve a firm’s overall management of OR events. As we shall see, there are significant benefits to be gained from the use of statistical methods. Of course, the careful use of statistical methods in itself is not an assurance of success, but it is a means of calculating in advance the probability and possible consequences of an unknown future OR event, allowing managers to make better-informed decisions.

REVIEW QUESTIONS

1. What do you consider to be the weaknesses of the definitions of OR discussed in this chapter? What alternative definitions would you consider more appropriate?
2. Despite being the oldest risk facing financial institutions, OR is the least monitored. Why?
3. What are the potential benefits to the firm, customers, and shareholder of monitoring OR? In your opinion, do these benefits outweigh the costs?
4. In what way could VaR be used in an OR context?
5. Why should statistical methods play a central role in the analysis of OR?

FURTHER READING

Operational risks are endogeneous in the sense that they are based on an institution’s internal operational environment. As such, they will vary significantly from organization to organization. Although market and credit risk can be managed to some degree through the capital markets, OR is fundamentally different because it can only be managed by changes in process, people, technology, and culture. Given this and the continual reshaping of the business landscape through mergers, restructuring, and rapid technological and regulatory change, how can we capture the complex uncertainty surrounding future OR events? The notion of random variables, OR indicators, and probability described in this chapter provides us with some of the tools we require. Probability offers a formal structure for describing the uncertainty in the business environment. Through its use, despite the reality that OR does not lend itself to measurement in the same way as market or credit risk, we can gain valuable insights into the nature of the uncertainty surrounding future OR events. In this chapter we outline the basic concepts of applied probability and demonstrate how they can be useful in an OR setting.

**Random Variables and Operational Risk Indicators**

Underlying all statistical methods are the concepts of a random experiment, or experiment of chance, and a random variable. A random variable is a variable that can take on a given set of values. A random experiment is the process by which a specific value of a random variable arises.
EXAMPLE 2.1  NUMBER OF TRADES THAT FAIL TO SETTLE WHEN EXPECTED AS A RANDOM VARIABLE

The number of trades that fail to settle when expected varies from one day to the next. In the language of statistics, the number of failed trades on any specific business day is a random variable, the settlement process is an experiment, the passage of time from one day to the next is a trial, and the number of failed trades at the end of the day is the outcome. At the start of business on a particular day, the experiment begins. At this stage the outcome of the experiment is unknown. Will the number of failed trades be 0, 1, 5, or 200? At the end of the business day the outcome of the experiment, the observed number of failed trades, is known.

The costs incurred through mistakes made in carrying out transactions, such as settlement failures, and the loss of business continuity when operations are interrupted for reasons such as electrical failure or the failure to meet regulatory requirements, are all examples of random variables. The key point to note is that a random variable is actually a function that associates a unique numerical value to every outcome of a random experiment. In writing, we denote a random variable by $X$ and the value it takes by $x$.

When a random variable $X$ is observed on $N$ occasions, we obtain a succession of values denoted by \{ $x_1, x_2, x_3, \ldots, x_N$ \}, each of which provides us with a realization of $X$ at specific points in time. We may have observed the number of failures on the five days, for example, from August 19 to August 23 as \{5, 0, 0, 1, 0\}. We also may write this sequence as \{ $x_1 = 5, x_2 = 0, x_3 = 0, x_4 = 1, x_5 = 0$ \}.

TYPES OF RANDOM VARIABLE

There are two fundamental types of random variable, discrete and continuous. A discrete random variable may take on a countable number of distinct values. These are usually measurements or counts and take on integer values such as 0, 1, 2, 3, and 4. In Example 2.1 the number of trades that fail to settle when expected is a discrete random variable because it can only take on the values 0, 1, 2, 3, and so on. A continuous random variable is one that can take on any real value, that is, a variable that can take any real number in a given interval. An example of a continuous random variable of interest to OR managers is the value of trades that fail to settle when expected. In this example, we observed that the discrete random variable (the number of trades that failed to settle) on the five days from August 19 to August 23 as \{5, 0, 0, 1, 0\}; the value of these trades was \{ $250,000, 0, 0, 500,000, 0$ \}.

Since the number of trades that fail to settle when expected and the value of trades that fail to settle when expected are random variables that
Random Variables, Risk Indicators, and Probability

can be used to provide information on a OR event, they are called operational risk indicators.

**OPERATIONAL RISK INDICATORS**

Operational risk indicators are random variables that are used to provide insight into future OR events. For example, a rising number of trades that fail to settle may be indicative of failing settlement or back office procedures. There are numerous risk indicators that firms can monitor to assess future OR events. Losses due to the failure of a vendor to perform outsourced processing activities correctly and unauthorized transfers of money by employees into their personal bank accounts are examples of OR events for which we seek to find suitable OR indicators. Some risk indicators may generally be applicable to all businesses, while others will be specific to a particular business. The key objective of risk indicators is to provide insight into future problems at their earliest stages so that preventive action can be undertaken to avert or minimize a serious OR event.

**PROBABILITY**

We use probability to help characterize risk indicators, the number of OR events, and the size of OR losses. Intuitively, a probability should lie between 0 and 1. An outcome or event that cannot occur should have a probability of 0, and an event that is certain to occur will have a probability of 1. What is the probability that the number of trades that fail to settle when expected today will be the same as yesterday, equal to yesterday, or more than yesterday? Since one of these outcomes is certain to occur, the probability is 1. Probability values indicate the likelihood of an event occurring. The closer the probability is to 1, the more likely the event is to occur. For example, suppose completion, within the next three days, of projects A and B is uncertain, but we know the probability of completion of project A is 0.6 (60 percent) and the probability of completion of project B is 0.25 (25 percent). These probability values provide a numerical scale for measuring our uncertainty in the sense that they inform us that project A is more likely to be completed within the next three days’ time than project B. More formally, we say that probability provides a numerical scale for measuring uncertainty.

If E is an event of interest (for example a high settlement loss), we denote Prob(E) to be the probability of E. We also write Prob(¬E) as the probabil-