Introduction

So long as you write what you wish to write,
that is all that matters; and whether it matters
for ages or only for hours, nobody can say.

Virginia Woolf (1882–1941) in *A Room of One's Own*

Why we have written this book. For many years, we have taught courses on probability, statistics, insurance and financial mathematics and the modeling of extremes and quantitative risk management. Our students come from a wide range of disciplines. Beyond these, we have also offered courses and seminars to practitioners and regulators. Over the recent years, an increasing awareness of risk-related issues has become omnipresent in society. This no doubt is in part due to the continuous streaming of news bulletins through diverse electronic media. Transporting knowledge down from the academic ivory tower remains a difficult task that far too often is neglected by academics; see Figure 0.1 for a cartoon interpretation. This book offers a bridge between the world of scientific writing and that of everyday experience.

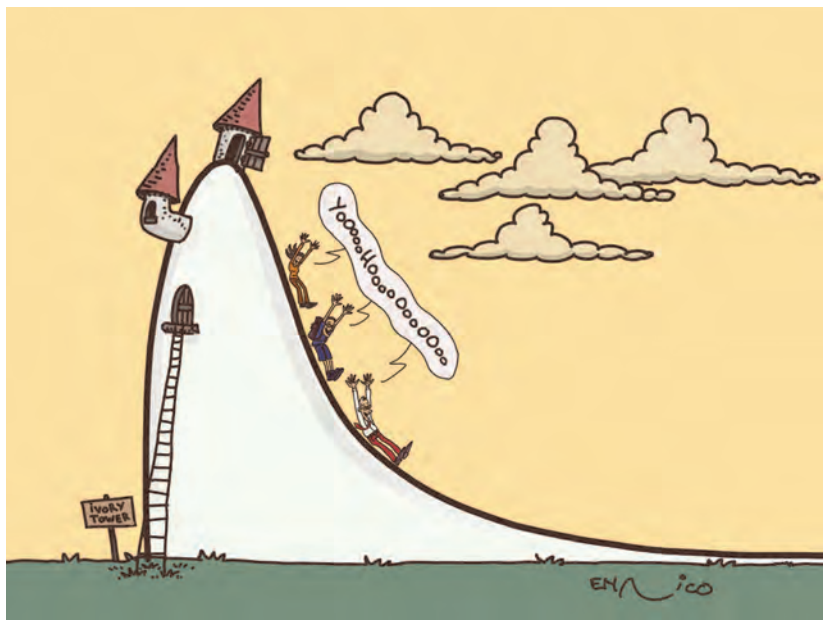

Figure 0.1 Coming down the academic ivory tower. Source: Enrico Chavez

We deliberately write *a* and not *the*, as our presentation is very much colored by our own scientific background as well as our personal experiences. Throughout, we address risks due to natural and man-made disasters, and we describe how such events and future risks can be understood, modeled and communicated. Much has been said and written about risk at the non-technical level, and more and more specialized literature concerning the modeling of risks is emerging. Our goal is to bridge this gap and provide a widely accessible treatment at a sufficiently technical level to appreciate the types of question mathematical modeling can answer. Clearly this is ambitious. We see our effort more as providing you, the reader, with a walking stick to discover the land of risk at your own pace. Occasionally we will encounter a more demanding path, but the experience of walking together is always more important than the ultimate goal of reaching a local summit. Of course, when we reach a local summit, it is worthwhile to look around and admire the view.

Whom we have written this book for. The book is written with a wide readership in mind. A unique feature is its mix of selected accounts of major historical disasters. Beyond these general presentations, we cover the understanding and mathematical modeling of risk described in an accessible way so that readers with only basic mathematics background (high school level, including, for example, the knowledge of limits, derivatives, integrals, elementary mathematical functions) should be able to follow our reasoning. Even the slightly more technical discussions are interspersed with historical comments and simple worked examples. Of course there exist several examples of researchers in the realm of risk who have contributed importantly to the public risk debate. The various chapters contain references to these personalities. One name that occurs often throughout the book is that of Sir David Spiegelhalter, the former Winton Professor of the Public Understanding of Risk in the Statistical Laboratory at the University of Cambridge. It is impossible to better the work done by David Spiegelhalter on risk communication and its understanding, aimed at a wider public. We do hope however that our book does justice to his efforts and offers complementary material on, as well as interpretations of, the multifaceted manifestation of risk.

Risk in its various disguises: a historical perspective. So far we have mentioned a couple of times the word *risk*, but which interpretation hides behind this word? Besides risk, we can equally well talk about chance, luck, or fate, say. For instance, we all have experienced "lucky escapes", or had good or bad luck in playing a game, or a lucky experience in daily life. But what is this elusive luck? In Roman and Greek mythology, Tyche (Greek) or Fortuna (Latin) personified the goddess of luck. Fortuna was much more important to the Romans than Tyche was to the Greeks, hence also the saying being "fortunate". We learn from Wikipedia (2020b) that "The Greek historian Polybius believed that when no cause can be discovered to events such as floods, droughts, frosts, or even in politics, then the cause of these events may be fairly attributed to Tyche." Especially for politicians this could be rather convenient. Whereas the goddess Fortuna mainly blessed citizens with beneficial events, Tyche embodied bad luck as well as good luck, and hence would address both sides of the risk medal. Etymologically, the word "risk" most likely derives from the ancient Greek word "$\rho\iota\zeta\alpha$" (rhiza). The word has many meanings, both literally as well as metaphorically. We concentrate on its translation to the root or branch of a tree – something that offers stability, something to hold onto. In this interpretation, we find the word back in Homer's account of Odysseus' passage through the

Strait of Messina between Scylla and Charybdis. The latter two are mythological sea monsters trying to kill Odysseus and his companions. A relevant detail in the story is that Charybdis lurked under a fig tree, the roots (hence rhiza) of which would assist Odysseus to pass. Later interpretations referred to Scylla as a rock and Charybdis as a whirlpool. In English, rhiza obtained a nautical translation as a hazard of sailing along rocky coasts. Nowadays, being "between Scylla and Charybdis" means being caught between two equally unpleasant alternatives; related to the advice "to choose the lesser of two evils". An excellent depiction of this interpretation is to be found in James Gillray's 1793 political cartoon "Britannia between Scylla and Charybdis"; see Figure 0.2. In the picture, on the summit of Scylla is a

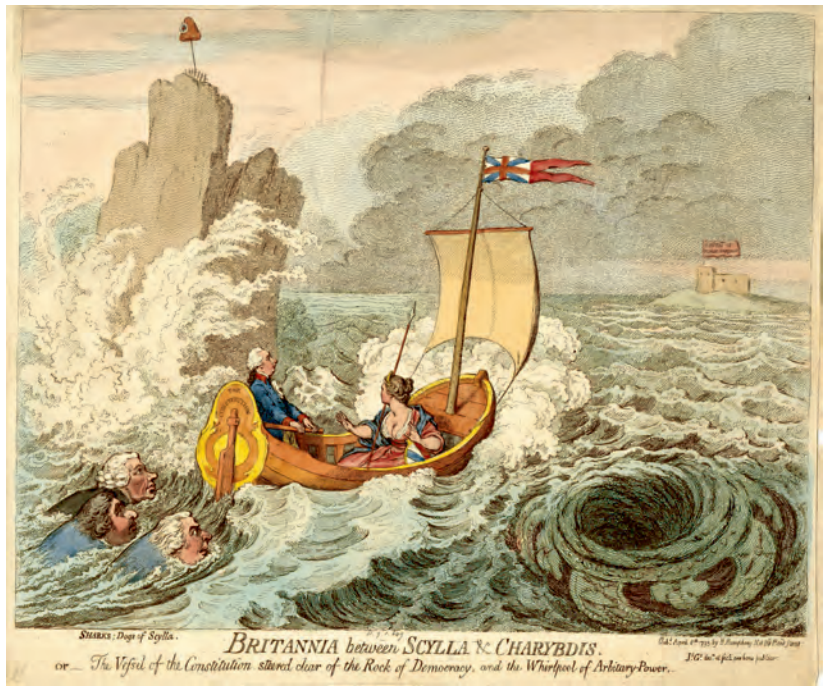

Figure 0.2 "Britannia between Scylla and Charybdis", James Gillray, 1793. The three sharks with human heads (Richard Brinsley Sheridan, Charles James Fox and Joseph Priestley) closely pursue the boat. Source: Wikimedia Commons

large bonnet rouge with a tri-colored cockade, symbol of the 1789 French Revolution, and on the right the inverted royal crown in Charybdis' whirlpool symbolizing arbitrary power.

Everyday language is not precise when it comes to possible differences between the usage and the philosophical loading of words like risk, chance, fate, fortune, luck, to name a few. In this book, we will gradually translate risk into more technical, mathematical language; see, for example, Sections 8.4.2 and 8.4.5. When doing so, we will always be very well aware of the words spoken by Hamlet to Horatio in Shakespeare's play "The Tragedy of Hamlet" (Act I, Scene 5): "There are more things in heaven and earth, Horatio, Than are dreamt of in your philosophy." For a most readable and informative historical overview of risk, see Bernstein (1996). An excellent talk on the concept of luck is to be found in the entertaining

BBC 4 presentation Spiegelhalter (2019). In it, David Spiegelhalter ends his discourse with the following words:

> After listening to all these stories what would I say luck is. I heard that your real luck happens before you were born and after that it's a mixture of chance and your attitude that determines what happens to you. But even hardened gamblers often can't help feeling that they're in the grip of some temporary external force [Tyche?] of good or bad fortune. So if we think of chance as simply unavoidable unpredictability, then I agree with David Flusfeder [see Flusfeder (2018)] that luck is chance taken personally.

We will return to the interpretation of chance as "unavoidable unpredictability", such as the result of tossing a fair coin, in our discussion on probability theory in the more mathematical Chapter 8.

It is perhaps no coincidence that representatives of the animal kingdom are often used in idioms related to risk. You have surely heard of "the elephant in the room", "bear and bull markets" or "crying wolf". The latter epitomizes the problems faced by early warning systems, for example in tsunami or earthquake-prone regions, or false negative reporting in case of a pandemic. Together with Nassim Taleb's "black swan", see Taleb (2007), we could also have added a "gray rhino" (Wucker (2016)) as well as Didier Sornette's double metaphor "dragon kings" (Sornette (2009)). It may be our hunter–gatherer distant past that coded the animal link to risk into our genes.

Two examples from daily life. Before we delve a bit deeper into the structure of the book, we would like to recount two lighthearted examples where risk was involved. The stories below we learned from a close friend of ours, Agnes Herzberg, Professor Emeritus of Statistics at Queen's University, Kingston, Ontario, Canada. Since 1996, Agnes has organized international conferences on the topic of statistics, science and public policy. These annual conferences bring together a diverse mix of scientists, politicians, civil servants and journalists. The second conference in the series took place in 1997; see Herzberg and Krupka (1997) for its proceedings. The stories underscore two important aspects: (1) giving a precise and multipurpose definition of the concept of risk is difficult, if even possible, particularly as (2) any definition very much depends on personal attitude and historical perspective. Throughout the book, we will of course offer you some more technical 'translations'. For the moment, we leave you with the following quotes from Agnes' opening remarks to the above conference:

> [. . .] I returned to Kingston on a small plane from Toronto. I was in an aisle seat and just before take-off a woman arrived, wanting the window seat beside me. She was carrying many bags and a large cup of tea. I held the tea for her as she settled in her seat. Still holding the cup, I sat down, but did not realize that the lid was not secure. The movement caused the tea to spill everywhere. I began to read the book Risk by John Adams. [. . .] When I was asked "What is Risk?" I suggested it was perhaps risky to go on this airplane and go to Kingston. I returned to reading, only to be interrupted again and again for more examples. Finally, in exasperation, I replied, "Suppose you get on an airplane and someone gives you a cup of tea to hold and then it spills all over you; that is taking a risk!" No more was said.

The opening remarks end with:

> Professor Lewis Wolpert, a biologist and writer, used the following example [he presented at a] Royal Society meeting in London [on science, policy and risk]. His office is in the basement of a building at University College London. The hallways are made of brick and there are glass-covered signs stating that because of the fire hazard, no paper may be posted unless it is under glass. He then enters his office where every surface is covered with paper! Our attitudes toward risk are contradictory at best.

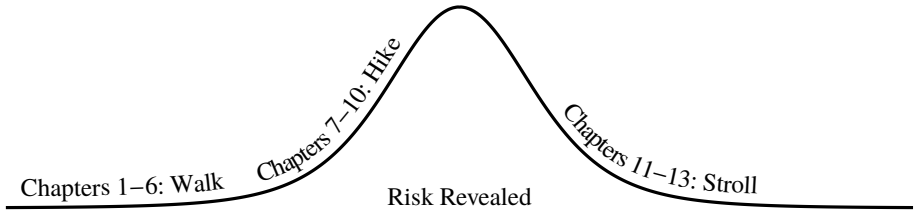

Figure 0.3 A walk, a hike and a stroll through the landscape of risk. Source: Authors

How the book is structured. We will take you for a guided tour through different terrains in the multifaceted world of risk. Our tour will consist of a *walk*, a *hike* and a *stroll*; see Figure 0.3. We start with several cautionary tales, which are presented in a non-technical, widely accessible way; hence this part of the book is just a *walk*. These tales also serve as motivation for the second part of the book, where we introduce you to some basic mathematical techniques from the realm of probability and statistics. The usefulness of these techniques is highlighted in several applications where we return to some of the cautionary tales. Our focus in the second part of the book is on obtaining a basic understanding of the mathematical modeling of risk and what types of questions mathematical methodology allows us to answer. This more technical *hike* requires a bit of stamina but only very rarely additional oxygen. We finish the book with a final, hopefully pleasant and relaxing *stroll*. Chapter 7 has a somewhat special character as it sits between the cautionary tales and the more mathematical, technical hike. Its aim is to offer you, the reader, a brief glimpse of the beauty of mathematics. As such, Chapter 7 acts as a bridge that we cross together before we start on the more serious hike.

A recurring theme. Throughout we ask questions of the *if* and *what if* variety. For example, on July 18, 2021, the catastrophic low-pressure system Bernd ravaged parts of Germany, Belgium, The Netherlands and Austria, causing several hundred deaths and a massive material loss. Also at that time, untold high temperatures, just short of 50 °C, scorched Northwestern USA and Canada. An *if* question corresponds to asking for the probability that a low-pressure zone like Bernd gets stuck for several days above a relatively small geographic area, as it did above the states of Rheinland-Pfalz and Nordrhein-Westfalen in Germany, inundating these areas with massive amounts of rain. The word "rain bomb" entered the journalistic vocabulary. Similarly, what is the probability of a high-pressure zone settling for an unusually long time above the west coast of Canada? One explanation that climate experts offer is the slowing down of the jet stream, forming local cusps and trapping highs and lows rather than moving them faster along its path. Putting a statistical estimate on such events, as well as proving climate change causality, is very difficult. It is precisely here that a *what if* scenario analysis becomes highly relevant. Skeptics may say that, before the event under discussion, the *if* event is deemed so rare that the *what if* stress scenario should not enter our risk radar. Our answer invariably is that this is not the point nor the question. We as individuals and society ought to consider the consequences of such a rare *if* event as much as possible beforehand. This is the essence of the *what if* thinking and related methodology like extreme value theory, a topic we will cover in Chapter 9. Skeptics may still object that this is all

rather academic and quote that "after the event we always know better". This surely holds some truth and is related to the so-called hindsight bias corresponding to a "we always knew" attitude. The chapters to follow contain numerous examples through which we hope to convince you that there is hope for scientists and skeptics to meet each other and achieve a mutual understanding. We admit that we have set the bar rather high. The threats we face do not justify a lower one, however. We very much hope that you have already learned a first concrete lesson from our book: when faced with a discussion on risk, it does not suffice to ask the *if* question; we always need to ask the *what if* question, too. It will invariably broaden your understanding of the underlying topic.

Reader guidelines. From our brief discussion of its walk, hike and stroll structure, it should be clear that this book is not necessarily to be read in one go from cover to cover, though you are of course welcome to do so. Enjoy the material presented at your own pace. On occasion, the book's language may be deemed somewhat scholastic, in that even in the less technical parts we try to be precise on sources used and quotes included. However, we always try hard to keep the language used at a narrative level, and this despite the interspersed referencing. The references form an important part of the book. They are carefully chosen to offer you the possibility of delving deeper into a specific topic of interest. Also important to us is that the less technically versed among readers should not be frightened by the use of mathematical formulas in the more technical chapters. Even in those chapters you will always find some pedagogical and historically motivated examples to assist you in following the main exposé. The book is primarily oriented to individual readers, but it can certainly be used as a guiding text for a graduate course on the understanding and communication of risk. The various chapters can easily be structured into part self-study, part *ex cathedra* teaching as well as accompanying classroom projects.

A picture is worth a thousand words. In a somewhat different formulation, this famous quote goes back to the Norwegian writer and playwright Henrik Ibsen (1828–1906). If you flip through the pages of our book, you surely will notice the various graphs, figures and even cartoons. Those graphs and figures produced by us were made by Marius Hofert with the free software R (for statistical computing and graphics), LaTeX (a typesetting software) or, occasionally, Google Drawings (a web-based drawing software). When a graph has been produced by us, we have always taken great care to present it in its best, hence most informative, format. We have also made history come to life by inserting photographs of important risk-related events as well as of the personalities who played a key role in the stories told. A special feature is the several cartoons drawn by Enrico (Kiko) Chavez, the husband of Valérie Chavez-Demoulin. As a professional statistician, Kiko regularly provides cartoons for statistical publications such as *Significance* and the *Bulletin of the Swiss Statistical Society*. Like any cartoons, their main message is somewhat hidden in the presentation. Do spend some time looking at them in detail and discover the deeper insights that this contemplation typically will offer you on the topic under discussion.

Intelligibility versus correctness. When discussing the probabilistic modeling of extremes in Chapter 9, the name of Emil Julius Gumbel will frequently appear. He wrote an early classic on the field of extreme value theory; see Gumbel (1958). From that book's Summary section

we quote the following headline: "A book should either have intelligibility or correctness. To combine the two is impossible." With all respect for the greatness of Gumbel, on this issue we beg to differ. At least we have tried hard to achieve this combination. It is for you, the reader, to judge our efforts.