OPERATIONAL SAFETY ECONOMICS

A Practical Approach focused on the Chemical and Process Industries

GENSERIK L. L. RENIERS • H. R. NOËL VAN ERP

WILEY

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Preface

With this book, it is our intention to fill the existing gap between the academic literature on operational safety economics within organizations, on the one hand, and the industrial situation and needs regarding the topic, on the other. The gap is wide and the bridge is difficult to construct due to the complexity and broadness of the topic and the variety of different viewpoints, perceptions and stakeholders.

The economic concepts, models and theories are explained in this book as simply as possible, but – of course – no simpler than necessary. Nevertheless, it was often a challenge to strip down the existing academic insights into clearly understandable and user-friendly practical know-how. We have provided straightforward theoretical examples and exercises and illustrated with industrial usable and credible examples wherever possible.

The book is written from the perspective of microeconomics, i.e., the single company wishing to bring more economic-related knowledge into the company's decision-making process with respect to safety. The objective is to improve decision-making based on economic approaches, models and information. Risks are considered relative, and decisions need to be made to decrease risks or certain aspects of risks, relative to other risks, or aspects of risks. Hence, this book is intended to guide the user into how risk decision-making can be improved from a single organization's viewpoint. Even if a company's safety figures are already very good, there is very often leeway for further improvement, i.e., more efficiency with the same effectiveness, or vice versa. In brief, excellence needs to be strived for. To achieve this, adequate company-specific economic considerations are required.

This book is thus not intended as a macroeconomic work. Topics such as wage differentials, inter-country or inter-company macroeconomic aspects of risks, societal cost–benefit analyses, psychometric studies of risks and so on are not discussed. The book follows the observation that in this age of technology, communication and need for respect among people, new products are being ever more cleverly engineered to accomplish incredible feats of precision and economy, but the methods and approaches used to produce them often remain stuck in an old-school, mechanistic age of production. However, the safety needs of employees, like those of customers, also require innovation and adaptation to the twenty-first century. An important way to further improve safety within many organizations is for safety managers to use economic analyses more effectively. Economic analyses, if carried out correctly, almost always show that safety investments are a no-brainer (i.e., they should be carried out), and that investing in prevention and avoiding accident costs actually is a business strategy leading to long-term profitability and to sustainable and intrinsically healthy organizations.

In summary, the purpose of *Operational Safety Economics: A Practical Approach Focused on the Chemical and Process Industries* is to investigate the complexity of operational risk with respect to economic issues and considerations from a single organization perspective, to provide dimensions and definitions that encompass and describe topics in operational safety economic topics. A variety of theories and methods for dealing with economic analyses in an organizational environment are thus addressed. To accomplish this purpose, previous work in the field is revisited, studied and discussed, and new ideas and innovative theories are conceptualized and debated. In the end, the objective is to clarify the economics surrounding operational safety and, where possible, to provide techniques useful for addressing operational safety decision-making while considering economic issues. There are no final answers, only some clues and paths to follow to where and how such answers might be obtained by a company's safety manager.

We wish the reader of this book an interesting read, as well as economic innovative thinking with respect to operational safety.

Prof. Dr. Ir. Genserik L.L. Reniers

Drs. H.R. Noël Van Erp

Disclaimer

The authors of this work take no responsibility whatsoever for incidents directly or indirectly, alleged or not, related to any form of application or use of methods, models, approaches, information, or any other knowledge presented and discussed in the book.

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Genserik L.L. Reniers

List of Acronyms

ALARA	As Low As Reasonable Achievable
ALARP	As Low As Reasonably Practicable
AZF	Azote Fertilisants
BACT	Best Available Control Technology
BAT	Best Available Techniques
BATNEEC	Best Available Technology Not Entailing Excessive Costs
BEST	Break-Even Safety Target
BN	Bayesian Network
CATNIP	Cheapest Available Technology Not Invoking Prosecution
CBA	Cost-Benefit Analysis
CEO	Chief Executive Officer
CER	Cost Effectiveness Ratio
CPT	Conditional Probability Table
D&O	Directors and Officers
DF*	Disproportion Factor where moral principles are considered
DF	Disproportion Factor
DF°	Disproportion Factor where the Net Present Value is equal to zero
DNA	Deoxyribonucleic acid
ERR	External Rate of Return
EV	Expected Value
FN	Frequency, Number of fatalities
FR	Failure Rate
HILP	High-Impact Low-Probability
HOFS	Human and Organizational Factors of Safety
HRO	High Reliability Organisation
HSE	Health and Safety Executive
ICER	Incremental Cost-Effectiveness Ratio
IRR	Internal Rate of Return
ISO	International Standardisation Organisation
LAC	Long-term Average Cost of production
LIHP	Low-Impact High-Probability
LIMID	Limited Memory Influence Diagram
LTI	Lost Time Injury
LTIFR	Lost Time Injury Frequency Rate

LTIIR	Lost Time Injury Incident Rate
LTISR	Lost Time Injury Severity Rate
MC	Markov Chain
MCA	Multi-Criteria Assessment
MGT	management
MJS	Maximum Justifiable Spend
MTIFR	Medical Treatment Injury Frequency Rate
NPV	Net Present Value
PBP	Pay Back Period
PF	Proportion Factor
PV	Present Value
QAAP	Quality-Adjusted Accident Probability
QALY	Quality-Adjusted Life Years
QRA	Quantitative Risk Assessment
RM	Risk Management
RSSB	Rail Safety and Standards Board
SAR	Social Acceptability of Risk
SFAIRP	So Far As Is Reasonably Practicable
SIC	Safety Investment Cost
SIO	Safety Investment Option
SIP	Safety Investment Project
SMART	Specific, Measurable, Achievable, Relevant, Time bound
STOP	Strategic, Technology, Organisational, Personal
TEAM	The Egg Aggregated Model
TOP	Technology, Organisational, Personal
TRIFR	Total Recordable Injury Frequency Rate
VaR	Value at Risk
VoL	Value of Life
VoSL	Value of Statistical Life
WF	Weight Factor
WTA	Willingness To Accept
WTP	Willingness To Pay

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Introduction

1.1 The "Why" of Operational Safety

In this book, safety within organizations, or safety linked with the operations of an organization (i.e., goods, services, installations, equipment, employees, and so on), is termed "operational safety." The term "operational safety," instead of "organizational safety," is employed to make it very clear that there is a distinction between, for instance, operational organizational safety, and finance-related organizational safety, health-related organizational safety, or public safety. Operational safety, for example, includes making strategic decisions on safety, or using tactical tools to deal with safety. The term "operational" merely indicates the relationship with the operations (all operations) of an organization, nothing more, nothing less.

Operational safety, or the lack thereof, is the result of a series of choices, great and small, within organizations. These choices are extremely complex and depend on a variety of factors within every organization. Important factors are legislation, available technology, socioeconomic aspects, ethical considerations, to name a few. Trade-offs often need to be made and, importantly, a diversity of assumptions need to be made and agreed upon within an organization prior to the safety-related choices. Uncertainties are involved and preferences may differ hugely between people making the decisions. Nevertheless, the goal is always the same: avoid losses! The idea is that by avoiding losses, non-tangible (because hypothetical) gains are realized. Gains can obviously be very small as well as very high, depending on the avoided losses. Determining the avoided losses quantitatively is often not simple, and qualitative aspects sometimes need to be considered when doing so. The ideas and mental models about how to achieve the end objective (i.e., to avoid losses) can thus be quite different, but the goal itself remains the same. In any case, operational safety is thus very much related to the fields of economics, management, and business, and it is therefore very important to be able to grasp and assess the prevention costs together with the level of avoided losses, preferences of decision-makers, assumptions to be made in relation to certain economic models, moral aspects of safety, and so on.

The father of industrial safety, H.W. Heinrich, in his seminal book *Industrial Accident Prevention*, the first edition published in 1931, starts the book by explaining why operational safety (and accident prevention) is important for company management and why he is in favor of a more scientific approach to this important phenomenon with substantial business impact.

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He does so by giving an example of a conversation at a conference involving the CEO, the production manager, the treasurer, and the insurance manager of a large manufacturing company. The first five and a half pages of the book are devoted to them talking about money and how they would be able to cut a huge amount of their costs simply by being safer [1]. Remember, this is a time when safety was really in its infancy and the job/function of "safety manager" simply did not exist. Safety management in those days was a synonym to insurance management. Nonetheless, the direct and obvious reason for adding more importance to operational safety in any organization was clear, even in that era, at the very beginning of industrial safety: economic considerations and the profitability of a company.

Things have changed dramatically with respect to the "how" question of operational safety – the safety regulations and procedures, prevention management, techniques and technology available, and so on. However, things have stayed exactly the same regarding the "why" question of operational safety, the answer being to avoid losses to be more profitable as an organization and to be able to "stay in business." Of course, the benefits for people and society are also very welcome. Nonetheless, for example, in the seminal work by Lees on *Loss Prevention in the Process Industries* [2, 3], a book of over 3600 print pages on process safety and loss prevention in the chemical and process industries, only a mere 20 pages cover the topic of "economics and insurance." The literature in other industries is similarly lacking.

It is thus remarkable to note that economic issues have been important from the beginning of industrial safety, but the focus has been on technology (e.g., new risk assessment techniques and innovative ways of prevention), organizational issues (e.g., compliance, new procedures and safety management systems) and, most recently, psychological/sociological human factors issues (e.g., leadership, training and collaboration within groups, safety climate and culture). However, all these advancements should be linked, in some way, to economic assessments. At the end of the day, safety choices are made to be profitable (in some way, not necessarily according to a strict interpretation of the term), not "just to be safe." This assumes adequate economic assessments within an organization.

There have been attempts to bring more economics into the operational safety decision-making process, but these have not (or hardly) been successful. The reason for their limited success is that they focus on one aspect of economic assessment (e.g., a cost-benefit analysis) but fail to develop the "big picture" of operational safety economics, where all aspects are considered by an integrated economic assessment. Moreover, most economic attempts have focused on macroeconomic issues and have tried to depict operational safety within a macro environment. Such a macroeconomic picture and theory are not interesting or applicable to concrete and microeconomic industrial practice and operational safety decision-making.

Furthermore, even in the present era there is still too much unproductive competition between "objective" and "subjective" as labels to attach to beta science and technology activities on the one hand, and social science activities on the other. However, one should recognize that people, in essence, only wish to distinguish between what is experimentally reproducible within certain limits of uncertainty, and what is either unknown or unpredictable. Looking at the objective–subjective debate in this way leads to the insight that the difference between exact sciences and social sciences is actually rather small, as some risk calculations (of so-called type II risks – see Chapter 2) as well as their rational assessment (using the best risk assessment techniques available to date) are not experimentally reproducible within certain limits of uncertainty. Hence, it is not a question of "or", but rather one of "and": the

use of "objective" and "subjective" as pejorative terms is counter-productive, and risk experts should understand that risks need to be considered by all kinds of disciplines to improve the decision-process. These disciplines then need to work together based on, among other things, technological, economic, and moral aspects to inform the decision process.

1.2 Back to the Future: the Economics of Operational Safety

One theory proposes that the word "risk" is derived from the Greek word "*riza*," which means, amongst others, "cliff" [4]. In Ancient Greece, most transactions were done via shipping. If a ship sank after running into a cliff, it was lost. For an individual shipowner this was obviously a disaster, but a number of shipowners agreed that the possible misfortune should be shared among them, and that an individual shipowner should be compensated for his lost ship by the joint budget of the shipowners. In this way, the future became less uncertain for individual shipowners due to an increased confidence in doing business. This ancient version of insurance is possibly the root cause of the propensity to take risks, and the willingness to loan more for commercial undertakings, as a result of an increased confidence in the future. Hence, risk has, since its origins, been linked with economics.

Furthermore, as Bernstein put it [5], probability theory seems to be a subject made to order for the Ancient Greeks, given their zest for gambling, their skill as mathematicians, their mastery of logic, and their obsession with proof. Yet, although the Greeks were the most civilized of all the ancients, they never ventured into that fascinating world. Only in the Renaissance period, some thousands of years later in the seventeenth and eighteenth centuries, were the laws of probability conceptualized and developed in contemporary Europe. All the great scientists of this era were in some way involved in the development of probability theory. Gambling and insurance were the fields in which the laws of probability were derived, and where they were used and applied.

A new insight into risk science came in 1738 with the St. Petersburg paper [6]. The author was Daniel Bernoulli, from the famous family of mathematicians. From the late 1600s to the late 1700s, eight Bernoullis had been recognized as celebrated mathematicians. The founding father of this remarkable tribe was Nicolaus Bernoulli of Basel, a wealthy merchant whose Protestant forebears had fled from Catholic-dominated Antwerp, nowadays Belgium, around 1585. The St. Petersburg paper is truly important on the subject of risk as well as on human behavior, because it establishes that people ascribe different values to risk and introduces a pivotal idea: "Utility resulting from any small increase in wealth will be inversely proportionate to the quantity of goods previously possessed." In the paper, Bernoulli thus converts the process of calculating probabilities into a procedure for introducing subjective considerations into decisions that have uncertain outcomes, and for the first time in history measurement was applied to something that could not previously be counted. In this paper, the intellectual groundwork was laid for many aspects of microeconomic theory and decision theory.

Many improvements have been made since Bernoulli, with the introduction of operational risk management, including risk analysis and risk assessment methods, in the mid-twentieth century, mainly in the aftermath of the Second World War and the beginning of the atomic era. Due to many consistency problems with risk analysis, utility theory, and risk acceptability in general, it has been difficult to link existing theories and methods in a practical way. Nonetheless, as expressed by Reith [7], the utility of the notion of "risk" lies not necessarily in its ability

to correctly predict future outcomes (at which, on the level of the individual, it is currently not particularly successful), but rather in its ability to provide a basis for decision-making.

The mandate of the economics of operational safety can be interpreted in two different ways. Instead of predicting the exact future for every individual or for an organization as a whole, the economics of operational safety should be seen as an instrument to make decisions that are as good as possible, or optimal, for the organization. Alternatively, the economics of operational safety should aim to resolve the consistency problems with risk analysis, utility theory, and risk acceptability in general, so that it may serve as a predictive instrument for the future for every individual or for an organization. In this book, both views of the role of the economics of operational safety are discussed. The current state of the art, discussed in Chapter 4, sees the economics of operational safety as a non-normative decision support tool. The advantage is that the approach is user-friendly for organizations, while the downside is that the approach gives the perception of accuracy, although it only has a limited predictive resolution, depending on the information available and on the assumptions made. The Bayesian decision theory, a neo-Bernoullian utility theory which is introduced in Chapters 7 and 8, goes beyond the state of the art and sees the economics of operational safety as a powerful normative decision support tool with considerable predictive resolution. However, the disadvantage of this approach is that its user-friendliness, in terms of easy to use and readily available software modules, needs to be improved for it to be widely employed by companies. In any case, organizations may opt to use either or both approaches to adequately deal with operational safety economics. Most importantly, the approaches need to be used correctly. This book aims to provide the background knowledge and know-how for interested readers to be able to use economic approaches with respect to operational safety.

Economic considerations have led to the development of risk theory and indirectly to operational safety, and they will also lead to its further advancement. Until some decades ago, operational safety was a field in which autonomous action was taken and certain objectives were pursued without considering the economic impact on the company. In recent years, interest in economic considerations and the financial impact of operational safety decisions has been growing. Hence, you could say that the story of the economics of safety is one of going back to the future.

1.3 Difficulties in Operational Safety Economics

The process of making optimal economic assessments with respect to operational safety, and the use of these assessments as a background for company policy-making, offers a large number of difficult challenges. For instance, no widely accepted method is available to give a monetary value to certain aspects of health, or to human life. Also, the result of any economic assessment method is only as good as the data available. As many costs are either unknown or incalculable, this can pose a serious problem. Furthermore, operational safety is a productive factor, but enhanced productivity is difficult to include in cost-benefit analyses of operational safety. Moral and ethical aspects need to be taken into account when carrying out economic assessments related to operational safety. For example, those people who bear the risks are not necessarily the same as the ones taking the risks, posing equity problems. Another problem is the fact that decision-makers often have a difficult choice to make between short-term real (safety investment) costs and long-term hypothetical (related to avoided accidents) benefits. As many decision-makers are responsible (and accountable) only for a brief period for safety budget allocations, and the accident probability of possible disaster scenarios

is often extremely low ("once in a million years"), depending on a myriad factors such as the macroeconomic circumstances, they sometimes will opt for budget cuts and safety downsizing, regardless of the outcome of economic assessments for operational safety. Psychological biases present within humans (such as the principle of loss aversion; see Chapter 4) may also lead to difficulties in adequate operational safety economics. As an example, probability neglect among laypeople in general leads to a remarkable disparity between the views of the public and the views of experts, as explained by Sunstein [8], leading to consistency problems.

Fischhoff *et al.* [9] further remark that the reduction of risk typically entails the reduction of benefits, thus posing dilemmas for society. At first glance, this is of no interest in this book focusing on risk and economics only at the level of the organization. However, the question at the root of this remark is the same for society and for any company: is this product, activity, technology, etc., acceptably safe? Classic methods such as "revealed preference" or "expressed preference" (see also Chapter 4) are difficult to implement in a single organization, and, if applied, would only allow one to get an idea of the perceived risk and benefit. For operational safety decision-making to be successful, more is needed than merely perception. Based on company information available, and all other information that can be found in the academic and professional/industrial literature, and on company preferences within the wider context of societal aspects and the regulatory framework in which the company is operating, decisions need to be made about safety investments to avert operational losses. Besides the need for optimization of decisions through the use of economic analyses (where perception and moral aspects are also considered), if something goes wrong, decisions need to be defensible vis-à-vis top management, shareholders, citizens, politicians, and – sometimes forgotten – the company's employees. This seems a nearly impossible task, but the theories and concepts explained in this book, if applied correctly, may help towards achieving this task.

1.4 The Field of Operational Safety within the Profitability of an Organization

Any organization tries to be profitable, and to be healthy in the long term. Adequate managerial decisions should be taken about uncertain outcomes to achieve this goal. Hence, uncertainties, whatever they are, should be well managed within organizations. In this regard, it is important that managers realize that the results of decisions are double-edged: they may have a positive outcome, and they may have a negative outcome. Furthermore, there are essentially two fields of uncertainty that are important for organizations, and decisions are taken in these fields to make a company profitable or to continue its profitability: financial uncertainties and operational uncertainties. Figure 1.1 provides an idea of the different fields in which adequate or optimal managerial decisions matter for the long-term viability of any organization.

As can be seen from Figure 1.1, operational risks should be seen as an essential domain of any organization, to increase profitability. Similar to the fact that good decisions should be taken in the fields of financial uncertainties and profit-related operational uncertainties (e.g., production investments and innovation), good decisions should be taken to avoid operational losses. In other words, this book takes the viewpoint that operational safety is actually a domain fully contributing to the profitability of a company by generating hypothetical benefits (through the avoidance of real losses via the use of adequate operational safety). Organizations, and managers within organizations, should genuinely look at operational safety in this way. Operational safety is not part of the cost structure of a company; on the contrary, it is a

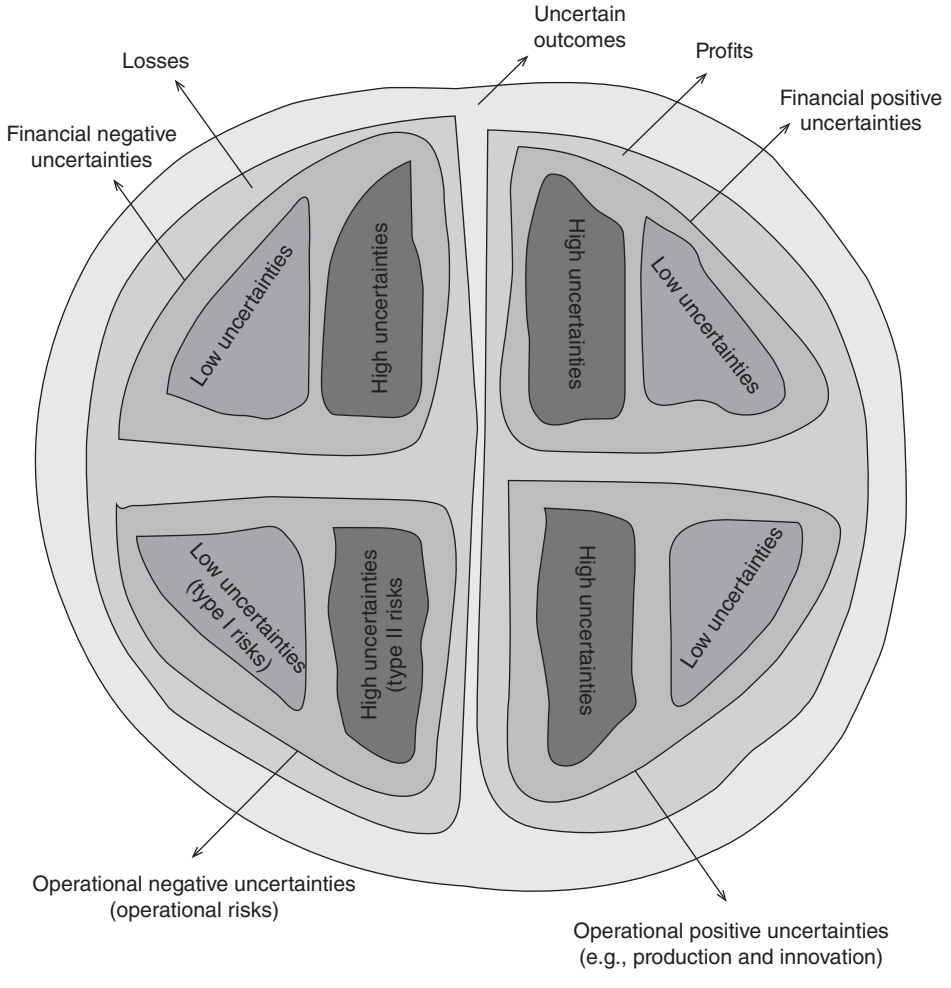

Figure 1.1 The position of operational risks within the mind of the manager.

domain that truly leads to making profits (in both the short and long term). Similar to financial uncertainties, one needs to be careful with high-uncertainty decisions (related to so-called type II risks; see later in this book), and one needs to focus on making profits via low-uncertainty decisions (related to so-called type I risks). This book will treat the risk phenomena that are fundamentally different due to the highly diverging levels of uncertainty (type I and type II) separately wherever needed.

1.5 Conclusions

Traditionally, economists are not much occupied with operational safety. Microeconomics is usually focused on well-known research fields, such as production and technology, profit and

cost, utility and consumer preference, demand and supply, choice theory and game theory, to name but a few. Operational safety is thus not at all a common field of study within the economic sciences, and, in the rare cases where it is studied at universities, most academics take a macroeconomic viewpoint. This is a regretful observation, which it is not easy to explain, as operational safety is an important aspect of production and can lead to economic optimization within organizations and also within society. It is also highly relevant at all levels of society and within all subgroups and professions. Newspapers are filled with news related to operational safety and to microeconomics; it is merely the combination of the two that is lacking attention. Based on previous observations, the overlap of operational safety and microeconomics is clearly important and of interest to universities and research institutions. The field of operational safety economics within organizations therefore deserves much greater attention, from academics as well as practitioners.

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2

Operational Risk, Operational Safety, and Economics

2.1 Defining the Concept of Operational Risk

A "risk" is defined by ISO 31000:2009 as "the effect of uncertainties on (achieving) objectives" [1]. Our world can indeed not be perfectly predicted and life and businesses are always exposed to uncertainties, which have an influence on whether objectives will be reached or not. Risks are double-sided: we call them negative risks if the outcome is negative, and positive risks if the outcome is positive. It is straightforward that organizations should manage risks in a way that minimizes the negative outcomes and maximizes the positive outcomes. Such management is called risk management RM) and contains, among other things, a process of risk identification, analysis, evaluation, prioritization, handling, and monitoring (see, e.g., Meyer and Reniers [2]), aimed at controlling all existing risks, whether known or not, and whether they are positive or negative. In this book, to make it workable, "operational risks" are assumed to arise from involuntary undesirable events within an organizational context. The rest of the book will thus be concerned with taking decisions regarding the management of these undesirable events and thereby considering economics-related issues.

The adoption of consistent risk management processes within a comprehensive framework can help to ensure that all types and amounts of risk are managed effectively, efficiently, and coherently across an organization. As mentioned, the economics of operational risks are focused upon. Operational risks imply unwanted events with possible negative consequences resulting from industrial operations. The economics implies approaches (concepts, models, theories, etc.) linked to financial considerations, whatever they are and in whatever form they occur. Evidently, economic considerations are very important while dealing with operational risk. Managing risks always demands making choices and allocating available budgets in the best possible way. This is not an easy task; on the contrary, it can be extremely difficult.

These days, companies and their safety managers are usually overwhelmed with tasks concerning the operational safety policy of a company. The number of tasks is huge, as are the responsibilities accompanying the decisions and choices that have to be made. Economic considerations are only one part of the larger domain of risk management. Other elements

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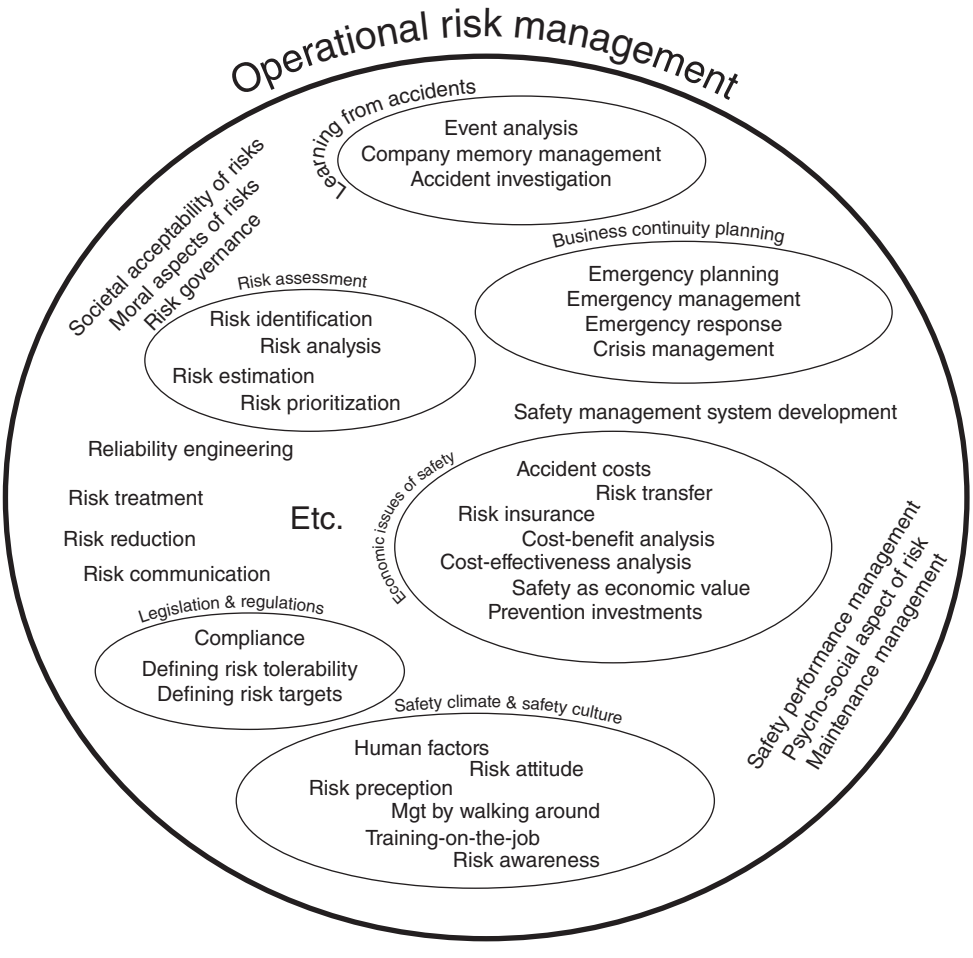

Figure 2.1 The operational risk management set. (Source: Meyer and Reniers [2]. Reproduced with permission from De Gruyter.)

that form part of risk management, and which are, in a way, also related to economic considerations, include safety training and education, on-the-job training, management by walking around, emergency response, business continuity planning, risk communication, risk perception, psycho-social aspects of risk, emergency planning, and risk governance. Meyer and Reniers [2] define operational risk management as "the systematic application of management policies, procedures, and practices to the tasks of identifying, analyzing, evaluating, treating, and monitoring risks." Figure 2.1 illustrates the operational risk management set.

Although economic issues of risk may only be one part of the risk management set, as can be seen in Figure 2.1, it is a very important part, being interconnected with all other parts of the risk management set, affecting the effectiveness of a company's safety policy as a whole, and, by extension, of a company's profitability in the long term. Therefore, this domain deserves to be well elaborated, both in theory and in practice. This book provides practitioners as well

as the academic community new insights into this very interesting and challenging research domain, and offers practitioners concrete approaches and models to improve their risk management practice from an economic perspective.

2.2 Dealing with Operational Risks

As defined by the Center for Chemical Process Safety [3], operational risk can be seen as an index of potential economic loss, human injury, or environmental damage, which is measured in terms of both the incident probability and the magnitude of the loss, injury, or damage. The operational risk associated with a specific unwanted event can thus be expressed as the product of two factors: the likelihood that the event will occur (L_{event}) and its consequences (C_{event}). Therefore, such an operational risk index, as calculated according to Eq. (2.1), represents the "expected consequence" of the undesired event (see also Chapters 4 and 7):

$$R_{\text{event}} = L_{\text{event}} \times C_{\text{event}}. \tag{2.1}$$

However, the risk estimation always refers to specific scenarios in which the perception and the attitude to the consequences of the decision-maker may also differ in an important way. For example, most people judge a high-impact, low-probability HILP) event as more undesirable than a low-impact, high-probability LIHP) event, even if the expected consequence of the two events is exactly the same (e.g., a fatality). By introducing a risk preference parameter, the previously formulated risk index, taking into account decision-makers' preferences, can be re-formulated into:

$$R_{\text{event}} = L_{\text{event}} \times (C_{\text{event}})^{\text{a}}, \tag{2.2}$$

where the parameter a represents the attitude of the decision-maker to the consequences. If a decision-maker is consequence-averse (also called "risk-averse"), $a > 1$; if risk-neutral, $a = 1$, and if risk-seeking, $a < 1$. It is obvious from this that the way a risk is calculated, which depends on preferences of people, has an influence on the resulting index outcomes. The risk index as calculated according to Eq. (2.2), should thus be seen as the "calculated perception of risk reality" by a person or a group of persons using a certain calculation method that they agreed upon. In any case, the index outcomes allow us to distinguish between different types of risks.

Hence, in general, a "risk" calculation includes four terms: likelihood, consequences, risk aversion, and what can go wrong, in terms of "the event" (sometimes also called "the scenario"). To have an idea of the accumulated risk in an organization, the risks of different events (or scenarios) thus need to be summed.

Furthermore, as companies face many risks, especially when operating in high-risk environments, but also in "low-risk" environments, operational risks are usually classified into the following three categories:

- very small risks where no further investments in risk reduction are necessary;
- very large risks with an outcome so unacceptable that these risks need to be reduced immediately;
- risks that fall between the previous two risk categories.