Chapter

# Introductory Chapter: Risk Management

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## 1. Introduction

The notion of risk presents itself, nowadays, as one of the most dynamic scientific areas, capturing the attention of researchers from a wide group of disciplines. Studies about the probability of occurrence of an event and its possible consequences are followed by answers that guide the concerns about interventions in relation to the health and safety of populations and the environment. This is why a fundamental question, related to the human perception of risks, arises.

There is a reasonable consensus to consider the age of Renaissance, the discoveries, and the long-distance maritime trade as milestones in the initial consolidation of risk analysis. In the Modern Age, a catastrophe in a European capital, the 1755 earthquake in Lisbon, sparked a debate in Europe around ideas about providence and destiny. This event triggered, from the political power, the implementation of a set of measures to mitigate its social effects as well as protective actions against future earthquakes. The decisions that were made then are a historical example of a response to a natural disaster and an organization model of a first crisis management.

Controlling risk in its various forms, for example, management, analysis, evaluation, and mitigation or treatment, among others, has now become a normal act, almost indispensable in proper governance. In the society of risk, the greater awareness of risk inevitably leads to its assessment and a search for answers, with the objective of implementing an adequate management. Whether risks are natural, technological, or other, the inclusion of perception studies in the risk management processes has become a priority for public policies. We can already ask ourselves how we could face the challenges of the present and the future without these operational instruments.

Protection against hazards that may affect the public or the environment has become a right, recognized and demanded by the public opinion, and an indicator of the quality of life and citizenship. From the resigned acceptance of events, we have moved to a phase of intervention by citizens and states to regulate life and public and private activities in defense of public health and safety.

Increasing social responsibility allows recognizing the effects resulting from the impact of different hazards, whether they are natural or anthropogenic. Politicians also started to use the concept of risk as a support device for the control of society and as a complementary device to ensure security.

Associated with risk comes the concept of vulnerability that characterizes the potential for loss derived from the impact of hazardous events on a given asset. In certain situations and conditions of uncertainty, the credibility or validity of a quantitative risk analysis based on estimated probabilities becomes problematic. In these circumstances, the vulnerability analysis and management can be an appropriate and effective alternative.

The concept of uncertainty, in turn, is always presented with our incomplete knowledge, namely related to successive "futures," and it has always been recognized as a permanent burden which should be avoided and that, for a long time, has been frequently ignored. Due to the object and nature of risk analysis, the uncertainty in the results and elements on which risk management decisions are based can be very significant and has important consequences. Thus, this chapter presents a summary of some relevant issues raised by the concepts of risk, vulnerability, and uncertainty.

## 2. Defining risk

Risk is increasingly present in today's society. Despite evidences that date back to several centuries, the level of risk awareness has become progressively higher since the last decades of the twentieth century. This has resulted in a higher exposure of people, built-up structures, and human activities to the potential negative effects of hazardous phenomena. In turn, the proximity of people and assets to the occurrence of hazardous events has enabled access to empirical knowledge from the population, valuable for scientific development, and the globalization processes contributed to a greater disclosure about risk from social media.

We live in a society of risk due to the difficulty in quantifying, preventing, and excluding risks from our lives due to their global nature and magnitude. Risk society refers to a type of settlement that is currently more exposed to frequent changes and uncertainty, therefore becoming more demanding and with less guarantees.

However, the attention and treatment given to the concept of risk was not always like today, having evolved over centuries. According to Covello and Mumpower [1], the first risk concerns (although it was not dealt with by this term) occurred around 3200 BC in the Tigris-Euphrates valley, where a group called *Asipu* practiced the analysis and advice on risk based on repeated events and motivated by divine forces, thus providing support to local populations.

The notion of risk, which is closer to the one currently used, emerged in the fourteenth century and was associated with sea expeditions and the events that could occur and jeopardize their success. In the sixteenth century, the term *rischio* started to be used in Roman languages to report situations of uncertainty. It was during this period, and from the seventeenth century on, that the risk concept acquired expression through Portuguese and Spanish navigators.

However, the origin of the term itself is still unknown with absolute certainty, and Proske [2] points out as possibilities the Greek word *rhizia*, the Persian word *rozi(k)*, or even, the Spanish and African languages with the term *aresk*. These terms had in common a context where life was dependent on God and on a destiny that was impossible to predict and control. According to Ewald [3], risk emerged as an act of God, a force so great that no responsibility could be attributed to humans. They could do little, either in an attempt to predict future events or to reduce its impact.

An important contribution to the evolution of the concept of risk was made by the banking sector during the seventeenth century. In the beginning of its use, the risk concept only included the notion of space, whereas from the moment it started to be used by the banking system, it was linked to the notion of time since this was also essential to determine probable consequences regarding investments, both for creditors and debtors. The emerged idea stated that, in the past, society was concerned with external risk as a result of phenomena imposed by nature, such as droughts, pests, or poor harvests. Currently, the concern lies not only on this but also on the impact that technological development has on the environment.

During the eighteenth century, risk began to be addressed in the scientific community, especially in mathematics and probabilities. The development of the industry and its need to statistically define the degree of security of its decisions and activities have led to the use of calculus as a way to determine and even try to eliminate possible risks. According to Reddy [4], the advances observed in society over the years moved us toward the eradication of uncertainty, leaving the risk in its place. However, for Castel [5], this removal of uncertainty is not a given fact.

Risk prevention has become a fixation, yet the factor of unpredictability has continued to emerge frequently. The rational treatment given to the risk concept and the calculation carried out for its determination did not exclude completely the occurrence of unpredictable events. A clear evidence of the close relationship between unpredictability and risk can be found in the scope of activities in the insurance industry where the calculations for obtaining insurance values are based on correlative events and statistics accumulated over several years. Although the risk does not disappear, this is a way of people dealing with it and gaining a sense of control.

At the end of the last millennium, one can verify the intensification of the concerns about risk not only within the scientific community but also in the general public, creating the idea that at any moment a negative event can occur, causing disruptions at various levels and general confusion. According to Beck [6], all changes in the nature of risk made it more globalized, less identifiable, and with more serious consequences, creating anxiety in the populations. This state of greater alertness and apprehension regarding the existence of risks is a major reason for a stronger request to anticipate and warn about risk situations from those who are responsible for it. Prevention, when duly justified, can make the difference between worsening the risk or mitigating it.

The uncertainty associated with risk sometimes creates situations of alarmism, and/or of concealment of facts. When the risk is considered high and is highly publicized and when later it is found that the impacts were minimal, those involved in the prevention process are considered alarmists; on the contrary, when this risk is not properly taken care of and serious situations occur later, they are accused of underestimating the risk and of carelessness regarding the preparation to deal with it. Considering alarmism can be an instrument in favor of precaution when facing risks through the preventive action that promotes it and is instead only prized as a positive approach after the occurrence of events with negative consequences, referring to the preventive role it could have played.

In descriptive terms, the definition of risk has been the target of a disambiguation process over time. Professionals and decision-makers from the most diverse areas as well as the general public or communities in different sectors have approached this concept in an applied way, adapting it to their reality and objectives. The result of this practice is the formulation of different risk concepts. As a rule, risk is associated with the doubt about future events of a negative nature for humanity. Risk can be taken as a category of analysis associated *a priori* to the notions of uncertainty, exposure to danger, material damaging, economic and human life losses due to natural processes (such as exogenous and endogenous Earth processes), and/or those associated with the human actions.

In an integrated perspective, risk intends to characterize the possibility of disturbances that alter the existing or predicted balance and security state and cause negative impacts. Using mathematical concepts, risk is understood as the probability of occurrence of a specific event causing serious damage to humanity and/or the environment in each period and under certain circumstances. According to the same authors, and in a clear reference to the importance of the concept of risk for management, risk expresses the possibility of occurrence and the respective

quantification in terms of costs, serious damages, economic consequences, or even for the safety of people, triggered by a natural phenomenon or induced by anthropic activity. In the light of the variety of existing definitions, risk can also be seen as the probability of the occurrence of a dangerous process (or action) and the respective estimate of its consequences on people, property, or the environment, expressed in human casualties and/or material and functional damage, direct or indirect.

## 3. Types of risks

The presence of risk, or the notion of its existence, is noticed in different areas and realities. Ewald [7] referred that the notion of risk has been extended in its scope to other domains and is no longer centered solely and exclusively on nature. In fact, the globalization and scope of application of the concept of risk is felt in the daily life of modern society, being associated with work, personal security, health, housing, economy, or environment, among others.

Currently, the concept of risk applies both to uncertainties in the security of technological systems or products (technological risks) and to natural systems and catastrophes (natural risks). Technological risk does not only concern systems of technology and dangerous and manipulated products but also living beings, especially humans, either because of the direct relationship in terms of design and use or because of the exposure to a certain level of risk. An error in a design or project of an artificial or technological system created by people can bring risks and result in harmful consequences, which can become a disaster or catastrophe. Thus, technological risks are those that result from accidents, often sudden and unplanned, triggered by human activity (e.g., floods due to rupture of dams, accidents in the transport of dangerous goods, and radiological emergencies).

Advances and new approaches to science, the exploration and application of the concept of risk to different sectors of society have generated new types of risks such as social risk or environmental risk.

Social risk is related to the gaps in the life of an individual or community, restricting to some extent the access to means, goods, and basic care which provide him with the minimum acceptable level of comfort in his daily life. One can define it as the result of social needs that hinder the full human development and contribute to the degradation of living conditions. As indicators for determining the degree of social risk, one can suggest the conditions of habitability and hygiene, access to drinking water, and even in the long term, the conditions of employment, income, or technical skills. These are elements capable of demonstrating the level of dignified and sustainable human development.

As a rule, and although any individual is subject to risks, it has been verified throughout history that those who are most exposed to it are the most disadvantaged social groups. Individuals of poor financial condition, the elderly, the sick, or even children, among others, are usually the most exposed to social shortages and are most sensitive to the recovery process. We can also refer to social risk as damage caused by a society or part of it, emphasizing armed conflicts and military actions, among others. Wisner [8] approaches social risk differently, focusing on extreme natural phenomena as events that demonstrate the greater vulnerability of unprotected individuals to these occurrences.

As for the definition of the environmental component of risk, it is relatively recent, at least in the light of new theories. The definition of environmental risk, as a consequence of its designation, has been applied several times under the designation of natural risk due to the fact that the term environment is associated with nature, with all its integrated and interacting living and nonliving beings. The increasingly

sharp and complex interaction of human activities with the functioning of natural systems led to the introduction of the concept of environmental risk, which includes phenomena such as desertification, environmental pollution, and forest fires.

Currently, the concept of environment is more complex and goes beyond the basic life support structures and living beings, encompassing as well a set of extremely diverse and interactive components. These components are connected, so even subtle modifications to one of them can generate changes in the others.

Given this change in the conceptual environment toward a reality that functions with the close relationship between complex and dependent systems, the concept of environmental risk followed the same direction, assuming itself as a risk that is a mix of several others.

The distinction between different types of risks has become increasingly fuzzy, as human influence over the natural environment has grown in association with technological development. The concepts risk and hazard are often misused as synonyms for the same definition. For Cutter et al. [9], hazard is considered as the threat to people and the things they value. The threat arises from the interaction between the social, natural, and technological systems and is often described according to its origin, although the author recognizes that this classification loses strength within the scientific community since many of these threats have a complex origin.

Social and technological hazards affect the natural environment, producing different hazards, including quasi-natural hazards, which have a dimension of the physical environment modified or determined by social or technological elements. Mixed hazards are the result of the interaction of social and technological phenomena, while environmental risks are the result of the interaction of the three elements (natural, social, and technological) in a more contemporary perspective of analysis.

## 4. Risk quantification

As expected, in concepts associated with complex entities, there are always different definitions and philosophical perspectives to characterize risk as a credible object of analysis and decision. It can be said, however, that the notion of risk is based on a subtle combination of possible knowledge and uncertainty. That is, it always involves a combination of knowledge and ignorance. This turns out to be the major practical difficulty but also the biggest interest of analysing risk as a theoretical concept.

From the point of view of the concept's intrinsic nature, there are two substantially different approaches for risk. First, risk is an objective reality that exists independently of peoples' subjective values and opinions—as in other situations, the application of a scientific methodology will allow the identification of the relationship between facts, quantification, forecasting, and control—a positivist perception of risk. Second, there is human construction in the face of uncertain events with harmful consequences. In this case, risk can even be considered as a subjective reaction to a phenomenon coming from personal and social experiences—a relativistic perspective of risk.

In both perspectives, it is interesting to define a threshold that mirrors the concept of risk and allows its quantitative analysis in a generalized way. In fact, inspired by human behavior in the face of dangers, risk analysis can be considered a construction of the human mind.

One of the difficulties in defining the magnitude of risk consists of the characterization of uncertain events that are threats to a certain objective or societal state. They are frequent future events or possibly exceptional, unique, and of great intensity, with variable, tangible, and (or) intangible consequences. Risk intends to

measure the uncertainty of an activity and the severity of its consequences, that is, the effect of uncertainties on existing or planned conditions.

The quantification of risk could then be determined by relating hazard and consequences. For the purposes of presenting the fundamental components of natural risk, the model that follows will be a derivation of the original expression, where consequences are represented by vulnerability and exposed elements. In practical terms, the two approaches are similar. In this sense, concepts such as hazard, vulnerability, exposed elements, and consequences will be addressed, as well as other supporting concepts required for the full understanding of the components of risk and the multiple aspects it involves, such as susceptibility and severity.

Risk is a comprehensive, motivating, and ambiguous concept with different dimensions and a special potential for characterizing uncertain occurrences associated with deviations from baseline situations. Risk justifies options and actions as a decision variable in face of potential threats, encourages the protection of people and assets, and thus, improves the quality of life and enables a symbolic representation of the contemporary world.

One of the fundamental concerns of this construction, considering the decision-making processes, arises from the need to compare, in the present, certain effects whose future occurrences are considered with different degrees of uncertainty. The concept of probability arises, therefore, associated with the quantitative analysis of risk.

Knight [10] strongly defended the principle that risk implies knowledge with probabilities (measurable); otherwise it is ignorance or uncertainty in a restricted sense. Thus, the construction of quantitative risk analysis implies grading the plausibility of uncertain events through the assessment of probabilities. For some lines of thought, the probability of the hazardous event is so important that it is almost confused with the notion of the associated risk (probabilistic conception). In the dominant conceptual construction process, practice and reflection allowed the reduction of the three intervening factors—uncertainty, intensity, and consequence—to only probabilities and consequences.

The estimated value of the consequences is "mitigated," depending on the degree of uncertainty and by multiplying by the respective probability of occurrence. Therefore, the risk variable has a quantifiable value that can be compared with others in a quantitative assessment and decision process. Risks of a different nature (quantitative risk units indicate the type of value: victims/year or euros/year, for instance) can thus be compared by consequence classes.

It must be recognized that the solution found is simple and almost brilliant: the concept has resisted for centuries. De Moivre, in his book *De Mensura Sortis*, published in 1711, explains for the first time about this concept of risk: the measure of the risk of loss of an amount is the product of the amount put at stake by the probability of loss [11].

With the canonical definition, quantitative risk analysis allows the consideration and internalization of risks in cost-benefit analyses and in multi-criteria decision-making processes. This ability is appreciated in the design of complex technological systems or in the planning of costly protection measures against natural risks.

Regardless of the origin of the phenomenon, the concept of risk encompasses the probability of hazard. This concept is often used as synonym of the concept of risk. Therefore, it is important to add that hazard can be defined as a natural, technological, or mixed process (or action) capable of producing identified losses and damages. The United Nations definition of risk, dated of 1979, addresses this concept only in its natural aspect, describing it as the probability of the occurrence of a specific natural hazard with a specific level of severity and in a certain period [12]. The idea of associating this concept to the time and space of occurrence is evident,

since at a more general level, danger is understood as the probability of occurrence (assessed qualitatively or quantitatively) of a phenomenon with a certain magnitude (associated to a destruction potential) in a certain period and in a given area. Hazard represents the probability that a territory will be affected by a natural or technological event or a process due to parameters such as magnitude and severity.

The exposed elements, also called elements at risk or vulnerable elements, are, according to Dilley et al. [13], the population, properties, structures, infrastructure, and economic activities, among others, exposed to a hazardous process in a certain area. The intrinsic characteristics of the exposed elements, in relation to other factors, determine whether they are predisposed to suffer impacts when affected by a certain hazard, thus contributing to the occurrence of damage or total loss.

Each type of exposed element is related to a specific set of damages and to particular factors that enhance them. The same natural phenomenon can cause different damages to people and housing or infrastructure. The outcome of the hazardous phenomenon, in complementarity with the characteristics of the elements, is influenced by factors such as the magnitude, duration, location, and time of the event. Personal and material losses always result from the interaction between the event and the characteristics of the affected elements that make them more or less susceptible to negative impacts.

It should be noted that the distinction between exposure (still undamaged or vulnerable in potential) and physical vulnerability (damage operator in action), depending on the intensity of the impact in each scenario, is of great operational efficiency and is a basis for framing mitigation measures.

## 5. Risk management

There is an old saying that states that "is better to prevent than to fix." This aphorism can be a good example of practical and popular philosophy. Almost everything that is essential for sensible human behavior is stated in this general sentence and it is applicable to all hazardous situations.

The aphorism presupposes the possibility of perceiving a hazard that can be structured and materialized in different levels of risk (hypothetically), but which can supposedly be mitigated by an anticipated action. In fact, every human being applies tactics to assess situations of risk or hazardous situations, in a more or less conscious way, in the decision-making processes associated with their survival and development.

This automatic possibility is no longer the normal feature in contemporary society. Hazards have become diffuse and are hardly perceived in a society that is heavily dependent on systems of such complexity that most citizens cannot fully understand the vulnerabilities and associated threats. It is one of the aspects of the so-called society of risk [6] and the subject of cultural analysis. Structuring the process, from identification to decision, and the implementation of measures are then necessary. This is the function of risk analysis and management.

This structure was strongly influenced by the developments in the areas of financial and insurance management during the twentieth century. As a curiosity, it should be noted that the term risk management is proposed in 1956 in the Harvard Business Review in an article by Russel Gallagher [14], and since then, a general organizational framework has been imposed, which includes risk analysis and crisis management.

According to the international standard, International Organization for Standardization (ISO) 31,000, Risk Management Guidelines [15], risk management comprises the set of activities to guide and control an organization with respect to risk. In the future behavior of a natural or built system (e.g., a technological product), we are led to admit a normal pattern of expectations, a reference, or a set

of objectives to be fulfilled. Experience tells us that these conditions, these expectations, are not always fulfilled. Events, predictable or not, can occur in the more or less near future and cause deviations to what was expected with the consequences (positive or negative). According to this conceptual framework, the aforementioned ISO standard defines risk as the effect of uncertainty on objectives. This definition alerts us, in an elegant way, to the need to identify the objectives intended to achieve (e.g., the preservation of human life) the uncertainties to consider (epistemic and random) and the likely effects or consequences.

Risk management does not predict the future that will occur, but several possible or plausible future scenarios are considered and the respective probabilities of occurrence and the potential consequences, tangible or non-tangible, are evaluated. The risk management process comprises a set of procedures and components and a relatively consensual quantitative analysis formalism (**Figure 1**).

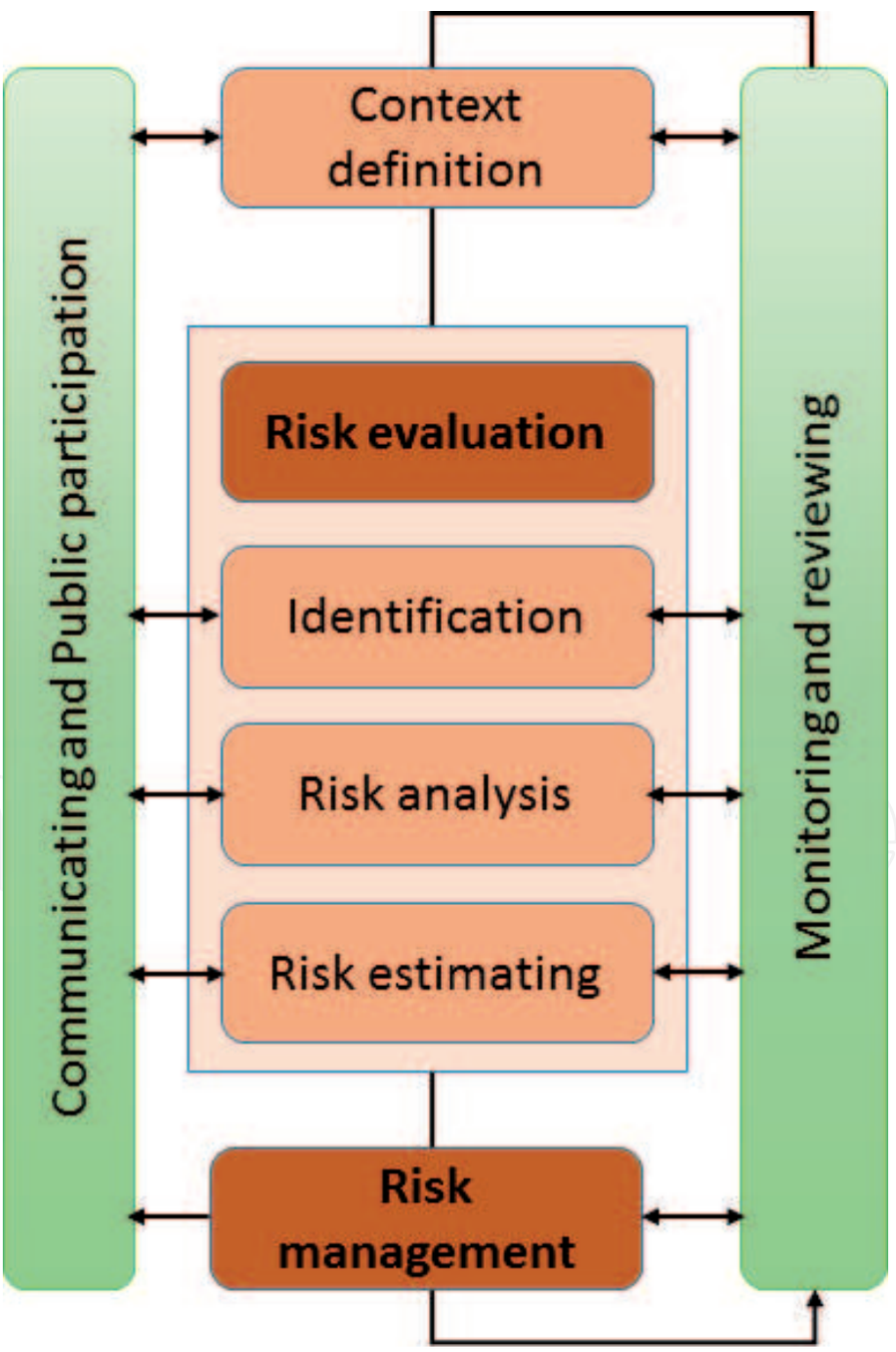


**Figure 1.**
*General risk management process. Adapted from ISO 31000 [15].*

## 6. Conclusions

The risk concept is based on the combination of expected consequences and probabilities/uncertainties dimensions. Quantitative risk analysis, despite the great benefits of its application in certain contexts, should not be considered as a panacea to guarantee absolute security. Qualitative or semiquantitative analyses may prove to be more appropriate in specific circumstances.

The risk management and analysis methodologies have in their favor the positive fact of placing the consequences or uncertain effects resulting from the exposure to a hazard, at the center of decisions. They can thus contribute to avoid irreparable damage or loss and, overall, improve the safety of a community, a company, or an enterprise.

Risk analysis and management should not be ruled by rigid or dogmatic methodologies and structures, which generate illusions or myths related to rationality and efficiency without limits. In some circumstances, it may be advisable to adopt the management of two of the variables that jointly provide the quantitative definition of risk in addition to the probability of the event, the exposure level, and in particular, the vulnerability. The probabilities are not always the most useful tool to characterize the uncertainties.

In any case, the characterization of the uncertainties involved in the risk assessment calculations must be carried out, considering the possibility of making more suitable decisions with the available knowledge. Without an analysis of the epistemic uncertainties embedded in the calculations, the apparent rigor of the results of a quantitative risk assessment can lead to disproportionate decisions.

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