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Risk Assessment in Business

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Abstract

Risk assessment and management have been recognized as a scientific discipline for approximately 30–40 years. The foundational principles and methods for conceptualizing, assessing, and managing risk were developed during this period and continue to underpin the field today. Despite this, significant advancements have been made in both theoretical frameworks and practical models. This paper reviews these advancements with a focus on the core concepts and ideas driving the evolution of risk assessment and management. It explores trends in perspectives and approaches, and reflects on areas where further development is necessary and should be promoted. This review is intended for a broad audience, including those without specialized expertise in risk management.

Keywords: Risk assessment, Risk management, Foundational issues, Review

1. Introduction

The concept of risk and risk assessments has a deep historical context. Over 2400 years ago, the Athenians demonstrated their capacity to assess risk before making critical decisions (Bernstein, 1996). However, risk assessment and management as a formal scientific field is relatively young, emerging only within the past 30–40 years. During this time, the first scientific journals, papers, and conferences addressing fundamental ideas and principles on risk assessment and management were established.

These foundational ideas and principles still underpin the field today, serving as the building blocks for the risk assessment and management practices that have evolved since the 1970s and 1980s. Despite this, the field has undergone significant development. More sophisticated analytical methods and techniques have been introduced, and risk analysis is now employed across various societal sectors. For example, the Society for Risk Analysis (www.sra.org) features specialty groups focusing on diverse areas such as Dose Response, Ecological Risk Assessment, Emerging Nanoscale Materials, Engineering and Infrastructure, Exposure Assessment, Microbial Risk Analysis, Occupational Health and Safety, Risk Policy and Law, and Security and Defense.

Recent advances in the field have also addressed fundamental issues that hold broad relevance and potential to impact a wide range of applications. This paper aims to review these recent advances with a focus on the core ideas and theories that form the foundation of risk research and development.

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The field of risk assessment and management encompasses two primary tasks: (I) applying risk assessments and management practices to specific activities, such as the operation of offshore installations or investment decisions, and (II) conducting generic risk research and development to refine concepts, theories, frameworks, approaches, principles, methods, and models for understanding, assessing, characterizing, communicating, and managing risk (Aven and Zio, 2014; SRA, 2015b). The generic aspect (II) provides the essential concepts and tools for addressing specific risk assessment and management problems (I). In essence, the risk field is about comprehending the world in relation to risk and developing strategies for understanding, assessing, and managing it effectively.

This paper seeks to review recent advancements in the risk field, with a particular focus on the fundamental ideas and theories that underpin generic risk research (II). Given the broad scope of this review, selecting relevant works from the many seminal contributions made in the past 10–15 years has been a challenging task. Only those works that contribute meaningfully to the foundational aspects of the field have been included.

2. The Risk Field and Science

Generic risk research (II) largely defines the field of risk science. However, applications of type (I), which involve applying risk assessments and management practices to specific activities, can also contribute scientifically if they offer new insights or improvements in practice. Despite this, there has been relatively little discussion on the intersection between science and risk fields. Recently, several fundamental discussions have emerged that clarify the content and scientific basis of the risk field (Hansson and Aven, 2014; Hollnagel, 2014; Hale, 2014; Le Coze et al., 2014; Aven, 2014). Here are some key points from these discussions:

1. **Distinguishing Risk Disciplines:** It is important to differentiate between the risk field as characterized by the collective body of risk-related educational programs, journals, papers, researchers, research groups, and societies (referred to as a risk discipline) and the risk field as it pertains to knowledge generation in both (I) specific applications and (II) generic research.

2. **Science and Knowledge Generation:** This understanding aligns with Hansson's (2013) perspective on science, which argues that science is the practice of providing the most epistemically warranted statements about subject matters covered by knowledge disciplines. By publishing research, we contribute to the development of risk science.

3. **Overlapping Levels of Research:** The boundaries between levels (I) and (II) are not rigid. Level II research and development are often generic for the risk field, but the relevance of research can vary. Some research is broadly applicable to all types of applications, while other work may focus on specific areas but still provide fundamental insights for those areas. For instance, research on conceptualizing risk in a business context might be less relevant outside that context but still valuable within it.

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4. **Case Study - Supply Chain Risk Management:** An example of this intersection is the emerging field of supply chain risk management. Recent developments in this area, such as the review by Fahimnia et al. (2015), illustrate how quantitative and analytical models contribute to both application-specific research (I) and generic risk research (II). These contributions are relevant not only to supply chain management but also have implications for other areas of risk management.

The risk field encompasses both the applied and theoretical aspects of risk assessment and management. The ongoing development of risk science is shaped by contributions across both these dimensions, reflecting a dynamic interplay between practical applications and foundational research.

3. Risk Conceptualization

Efforts to establish widely accepted definitions for key terms in the risk field have been ongoing, as evidenced by Thompson et al. (2005). For a scientific field to be robust, it must be based on well-defined and universally understood terms and concepts. However, achieving a unified set of definitions has proven challenging. Recent work by an expert committee of the Society for Risk Analysis (SRA) led to the development of a new glossary that acknowledges the diversity of perspectives on fundamental concepts while striving for authoritative definitions (SRA, 2015a).

Key Points from the SRA Glossary:

1. **Different Perspectives:** The glossary accommodates various viewpoints on fundamental risk concepts. It distinguishes between qualitative definitions and their associated measurements, recognizing that while unified definitions may not be realistic, authoritative and logical definitions can be established.

2. **Criteria for Definitions:** Definitions included in the glossary must meet certain criteria, such as being logical, well-defined, understandable, and precise (SRA, 2015a).

Overall Qualitative Definitions of Risk:

- **Possibility of an Unfortunate Occurrence:** Risk is the chance that an undesirable event may happen.
- **Potential for Realization of Unwanted Consequences:** It refers to the likelihood of negative outcomes resulting from an event.
- **Exposure to Uncertain Propositions:** Risk involves uncertainty about potential losses or adverse events.
- **Consequences and Associated Uncertainties:** It includes the impact of activities and the uncertainties surrounding those impacts.

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- **Uncertainty and Severity of Consequences:** Risk encompasses the uncertainty about and the severity of impacts on valued elements.
- **Occurrences of Specified Consequences:** It involves the likelihood of specific consequences and the uncertainties tied to them.
- **Deviation from Reference Values:** Risk can be seen as the deviation from a standard or reference value and the uncertainties related to this deviation.

These definitions aim to provide a comprehensive understanding of risk by addressing its various dimensions, including uncertainty, potential impacts, and deviations from expected outcomes. The glossary serves as a tool for aligning discussions and analyses in the risk field, despite the inherent complexities and variations in definitions.

4. Uncertainty in Risk Assessments

Uncertainty plays a pivotal role in risk conceptualization and assessment, as highlighted in Section 3. The challenge of understanding and managing uncertainties has been a significant topic since the early days of risk assessment, and it remains central to contemporary discussions. Flage et al. (2014) offer a recent perspective on how to represent and express uncertainty in risk assessments, identifying concerns, challenges, and future directions.

Types of Uncertainty:

1. **Aleatory Uncertainty:** This represents inherent variation or randomness in the system or process being studied. Probabilistic analysis, using probabilities with a limiting relative frequency interpretation, is widely accepted for handling aleatory uncertainty.
2. **Epistemic Uncertainty:** This arises from a lack of knowledge or incomplete information about the system or process. Unlike aleatory uncertainty, epistemic uncertainty is more complex to address. Common approaches include Bayesian subjective probability, interval probabilities, possibilistic measures, and qualitative methods.

Challenges and Approaches:

- **Subjective Probability:** Bayesian approaches are commonly used to represent epistemic uncertainty. However, when background knowledge is weak, assigning a specific subjective probability may be problematic. In such cases, the assigned probability might imply more precise knowledge than is actually available. For instance, if the only known information about a quantity xxx is that it lies within the interval [0,1][0, 1][0,1] and the most likely value is 12\frac{1}{2}21, it is challenging to specify a precise probability distribution. Possibility theory can be a useful alternative in such scenarios (Aven et al., 2014).

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- **Alternative Approaches:** Aven (2010) suggests that the aim should be to represent the available knowledge and express expert beliefs. This perspective acknowledges the subjectivity of these beliefs but argues that they are valuable for decision-making. Thus, probability and alternative approaches can complement each other.
- **Five Levels of Uncertainty Expression:** Spiegelhalter and Riesch (2014) propose expressing uncertainty at five levels:
    - **Event Uncertainty:** The uncertainty about the occurrence of specific events.
    - **Parameter Uncertainty:** The uncertainty regarding the values of parameters within models.
    - **Model Uncertainty:** The uncertainty about the adequacy of the model itself.
    - **Acknowledged Inadequacies:** Recognized limitations and potential errors in the modeling process.
    - **Unknown Inadequacies:** Unidentified or unexpected issues in the modeling process, including disagreements about problem framing.

These levels highlight the multifaceted nature of uncertainty and emphasize the importance of addressing both model and parameter uncertainties, as well as the broader issues of inadequacies in the modeling process.

While probabilistic methods are predominant in managing aleatory uncertainty, addressing epistemic uncertainty involves a range of approaches, from Bayesian methods to possibility theory. Understanding and managing these uncertainties are crucial for effective risk assessment and decision-making.

5. Risk Management Principles and Strategies

Understanding and applying risk management principles and strategies is crucial for effectively managing risks. This section provides an overview of established strategies and the structure of the risk management process.

Risk Management Strategies

There are three primary strategies for managing risk, each with its own approach and application:

1. **Risk-Informed Strategy:**
    - **Definition:** This strategy involves making decisions based on a comprehensive understanding of risks, including their likelihood and potential impacts. It integrates risk assessment findings into decision-making processes to balance risk and reward.

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- **Application:** Used when detailed risk assessments are available, and decisions can be made with a clear understanding of the associated risks.

2. **Cautionary/Precautionary Strategy:**
   - **Definition:** Also known as the strategy of robustness and resilience, this approach focuses on minimizing potential adverse impacts by being cautious and proactive. It involves implementing safety measures even in the absence of full scientific certainty.
   - **Application:** Applied in situations where there is high uncertainty or potential for severe consequences, requiring precautionary measures to mitigate risks.
3. **Discursive Strategy:**
   - **Definition:** This strategy emphasizes open dialogue and stakeholder engagement to understand and address risks. It involves discussing risk perceptions, values, and concerns with stakeholders to reach consensus on risk management approaches.
   - **Application:** Useful in contexts where stakeholder perspectives and values play a significant role in decision-making.

In practice, an effective risk management approach often involves a combination of these strategies, tailored to the specific context and nature of the risks.

Structure of the Risk Management Process

The risk management process can be broken down into several key steps, as outlined in standards like ISO 31000 and various risk analysis textbooks (e.g., Aven, 2015a; Meyer and Reniers, 2013; Zio, 2007a):

1. **Establish Context:**
   - **Purpose:** Define the objectives and scope of the risk management activities, including the goals and criteria for assessing and managing risks.
   - **Example:** Setting up a risk management framework for a new project, specifying what risks will be assessed, and identifying the criteria for evaluating them.
2. **Identify Situations and Events:**
   - **Purpose:** Identify potential hazards, threats, and opportunities that could impact the objectives. This involves recognizing what can go wrong or right.

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- **Methods:** Use techniques such as checklists, Hazard and Operability Study (HAZOP), and Failure Modes and Effects Analysis (FMEA) to systematically identify risks.

3. **Conduct Cause and Consequences Analysis:**
    - **Purpose:** Analyze the causes and potential consequences of identified events to understand their impact on objectives.
    - **Techniques:** Employ Fault Tree Analysis (FTA), Event Tree Analysis (ETA), and Bayesian Networks to model and analyze risk scenarios.
4. **Make Judgements of Likelihood and Consequences:**
    - **Purpose:** Assess the probability of risk events occurring and their potential consequences to establish a risk description or characterization.
    - **Example:** Estimating the likelihood of a system failure and its impact on operations.
5. **Evaluate Risk:**
    - **Purpose:** Judge the significance of the risk based on the likelihood and consequences, determining whether it falls within acceptable levels or requires further action.
    - **Example:** Comparing risk levels to predefined risk criteria to decide on the need for risk treatment.
6. **Risk Treatment:**
    - **Purpose:** Develop and implement strategies to manage the identified risks, aiming to mitigate, transfer, accept, or avoid them as appropriate.
    - **Example:** Implementing safety controls, purchasing insurance, or redesigning processes to reduce risk.

Implementation Issues

Effective implementation of the risk management process requires attention to various practical considerations, including:

- **Integration with Organizational Processes:** Ensuring that risk management is embedded into organizational processes and decision-making.
- **Communication and Reporting:** Providing clear communication about risks and risk management actions to stakeholders.

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- **Monitoring and Review:** Regularly reviewing and updating the risk management process to adapt to new information and changing conditions.

For further details on implementation issues, refer to resources such as ISO (2009b), Banks and Dunn (2003), and Teng et al. (2012, 2013).

6. The Future of Risk Assessment and Management

The future of risk assessment and management involves addressing new challenges and evolving methodologies to keep pace with emerging risks and uncertainties. Key areas of focus and development are discussed below:

Challenges and Directions for Development

1. **Knowledge and Uncertainty Characterization:**
    - **Current State:** Risk assessments have traditionally relied on statistical and probabilistic methods, which work well when data is ample and boundaries are clearly defined.
    - **Emerging Needs:** As situations with large uncertainties and emerging risks become more common, there is a growing need to focus on knowledge and lack of knowledge characterizations rather than solely on accurate risk estimations and predictions. Developing frameworks and tools to handle such scenarios is crucial.
2. **Dynamic Risk Assessment:**
    - **Traditional vs. Dynamic Approaches:** Traditional risk assessments often rely on static methods that may not account for evolving conditions and uncertainties. The future direction is towards dynamic risk assessment and management, which addresses the fluid nature of risks and incorporates continuous updates and adjustments based on new information and changing circumstances.
3. **Emerging Risks:**
    - **Concept and Analysis:** The concept of emerging risks has gained prominence. These are risks associated with activities where background knowledge is limited, but there are indications that new types of events could occur with potentially severe consequences. Flage and Aven (2015) highlight the challenge of dealing with weak background knowledge and difficulty in specifying consequences and scenarios.
4. **Black Swan Events:**
    - **Relevance:** Emerging risks often relate to "black swan" events—rare and unpredictable occurrences with severe consequences. Understanding and preparing

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for such events, despite their low probability, is a key area of research and development.

7. Conclusions

This review highlights several important conclusions about the state and future of risk assessment and management:

1. **Foundation and Development:**
    - The scientific foundation of risk assessment and management is still developing. Although there are established principles and methods, some theoretical and practical aspects remain shaky and could potentially misguide decision-makers. Continuous refinement and adaptation of these principles are necessary to ensure they remain relevant and effective.
2. **Future Focus:**
    - **Advances in Methods:** There is a need for continued research and development in risk assessment methods, particularly those that address dynamic and emerging risks.
    - **Integration with Practice:** Bridging the gap between theoretical advancements and practical applications is essential for effective risk management. Ensuring that new methods are applicable and useful in real-world scenarios will be crucial for future progress.
3. **Research and Development:**
    - Ongoing research should focus on improving our understanding of risk, particularly in areas characterized by high uncertainty and emerging risks. Developing new frameworks, tools, and methodologies will be key to advancing the field and supporting decision-making in increasingly complex and uncertain environments.

2. Integrative Research and Broader Perspectives

Recent research efforts have focused on integrating various aspects of risk assessment and management to establish a unified scientific platform for the field. Key areas of this integrative approach include:

- **Concepts and Terms:** Clarifying and standardizing fundamental concepts such as risk, vulnerability, and probability. Establishing well-defined and universally understood terms is essential for creating a cohesive framework for risk science.
- **Knowledge and Lack of Knowledge Descriptions:** Emphasizing the importance of describing and characterizing both the knowledge available and the uncertainties in risk

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assessments. This approach aims to enhance the understanding of risk in situations where data may be incomplete or ambiguous.

- **Treatment of Uncertainty:** Exploring different methods for representing and managing uncertainty in risk assessments. This includes probabilistic approaches as well as alternative methods like interval probabilities and possibilistic measures.
- **Robustness and Resilience:** Integrating principles of robustness and resilience into risk management. This involves developing strategies that not only address known risks but also prepare for unexpected or emergent challenges.
- **Managerial Review and Judgment:** Acknowledging the role of managerial judgment in risk management. This involves recognizing that decision-making often requires human insight and interpretation beyond purely quantitative analyses.

3. Revitalization of Foundational Issues

There has been a renewed interest in foundational issues within the risk field, which is crucial for addressing the complex challenges faced by society and emerging technologies. This revitalization is necessary to ensure that risk assessment and management methodologies remain relevant and effective in the face of:

- **Societal Problems:** Addressing risks that impact communities and societies at large, requiring a broad and integrative approach to risk management.
- **Complex Technological Risks:** Managing risks associated with advanced technologies, which often involve complex interactions and uncertainties.
- **Emerging Risks:** Preparing for and mitigating risks that are not fully understood or anticipated, highlighting the need for adaptable and forward-looking risk assessment methods.

Future Directions

The review and discussion aim to inspire further research and development in the risk field. Building a stronger foundation for risk assessment and management involves:

- **Encouraging New Research:** Attracting researchers with passion and enthusiasm to advance the field and tackle current and future challenges.
- **Addressing Large/Deep Uncertainties:** Developing methodologies and frameworks that can handle situations with significant unknowns and emerging risks.
- **Advancing the Field:** Continuously refining and expanding the principles and methods of risk assessment and management to keep pace with evolving challenges and opportunities.

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