Core Subjects of Risk Analysis

Expert group members:

Terje Aven (leader)
Henning Boje Andersen
Tony Cox
Enrique López Droguett
Michael Greenberg
Seth Guikema
Wolfgang Kröger
Katherine McComas
Ortwin Renn
Kimberly M. Thompson
Enrico Zio

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CORE SUBJECTS OF RISK ANALYSIS

The Society for Risk Analysis (SRA) Specialty Group on foundational issues in risk analysis and the SRA Committee for Specialty Groups have established a group of risk analysis experts with the mandate to produce a list of core subjects for the risk analysis field.

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The term risk analysis is here used in line with the established tradition of SRA to include: risk assessment, risk characterization, risk perception, risk communication, risk management, risk governance, and policy relating to risk, in the context of risks of concern to individuals, to public- and private-sector organizations, and to society at a local, regional, national, or global level. Risk analysis addresses both negative (undesirable) and positive (desirable) consequences, but the main focus of the present work is on the negative part.

OBJECTIVES

The objectives behind the preparation of this document, including the list of core subjects of risk analysis, are:

1. To initiate and foster a discussion on what are the core subjects of risk analysis.
2. To provide guidance on what subjects should be covered in study programs on risk analysis, for example a two year master's program..
3. To offer a platform to identify key topics for study programs on specific risk analysis subjects like risk assessment or risk management, for broad overview courses on risk analysis, as well as for courses and programs on related areas such as safety and security.

In more general terms, the document gives a contribution to the overall goal of establishing the knowledge content pillars for risk analysis as a science in itself. Hopefully, the document will stimulate work providing further substance to this, with outcomes in the form of books, study programs, etc.

SCOPE, RATIONALE AND PROCESS

A suggestion for core subjects of the risk analysis field is presented below. The subjects and topics are not all 'owned' by the risk analysis field per se, for example the topic of probability; however, risk analysis is the main field for the understanding and use of probability in a risk analysis context. The list of subjects shown must be understood in this way: the concept of probability in a risk analysis context, decision analysis tools in a risk analysis context, etc. There is a lot of material related to probability and decision analysis, but only some of this provides input to the subjects and topics here defined.

How we should define the core of the field will also depend on the target group and level. There is a spectrum of needs, ranging from high school level (and even below) to graduates and professionals in the field. Based on the topics outlined below, we can develop requirements for a course for high school students, for more comprehensive courses for colleges/universities and for professionals, and even for (a two-year) master's program covering, in detail, the many issues addressed by the topics mentioned below. The total list included provides guidance for what topics that should be covered by a comprehensive study program in risk analysis, for example a two year master's program.

The document does not describe in detail the content of the subjects and topics listed. In some cases, the content is however clear and well defined from the topic title, as for example when referring to the use of event trees in risk assessment or the meaning of a probability model. However, for other cases, there could be different interpretations reflecting that the topic is under development or that there are different perspectives and views on what constitute the key issues. For example, on the topic of how to best conceptualize risk, the SRA Glossary provides a possible basis, but there is still a debate on this topic in the risk analysis community. The document acknowledges this by allowing for different interpretations. As the field and science of risk analysis is developing, stronger guidance can be provided. It

is a challenge to balance the need for authoritative guidance and solutions on the one hand, and the need for continuous debate, research and improvement on the other. This balance is sought by specifying the subjects up to some level of detail, but avoiding selecting and forcing a specific implementation or solution.

As for all fields and sciences, there will be a continuous discussion on what represents the core. Take statistics as an example. Looking at basic courses and textbooks in this field, we see some common topics and a number of issues that are included in some but not in others. Yet, no one would question the usefulness of having defined a core that all students and statistical trained analysts should cover. The core defines what it means to have competence in the field. You cannot label yourself as a statistician without having this knowledge base. It ensures that statistical work and training can progress from this core of subjects and do not need to start from scratch when statistical problems are to be tackled. The same should be for the risk analysis field. We need to build a platform that defines the core competence for the risk analysts and professionals.

Risk analysis as a field is built on two main knowledge-generating pillars (analogous to statistics):

A. Risk knowledge related to an activity in the real world (interpreted in a wide sense to include, for example, also natural phenomena), for example the use of a medical drug, the design of a bridge or the analysis of climate change.
B. Knowledge on concepts, theories, frameworks, approaches, principles, methods and models to understand, assess, characterize, communicate, manage and govern risk.

To perform the type A analysis, different approaches are used and issues raised, including:

a. Descriptive analysis: What has happened previously in terms of losses, failures, etc.? What do the data indicate is (not) worth worrying about? What has changed that seems worth worrying about?
b. Predictive analysis - knowledge and uncertainties: What will happen if a specific activity is realized, a specific system is operated? What might go wrong? Why and how might it go wrong? What are the consequences? What will happen if we (do not) intervene? How soon, with what consequences? What do we know; what do we not know? What are the uncertainties and likelihoods?
   Causal analysis - knowledge and uncertainties: What will happen if we intervene in different ways? What do we know; what do we not know? What are the uncertainties? Likelihoods?
c. Prescriptive analysis and decision optimization - management: What should we do next, given the resources, risk, uncertainties, constraints and other concerns? Who should do what? Who should use what decision rules? What are intolerable or unacceptable risks? How can the public participate? How to be prepared in case of an event? How to build robust and resilient systems?
d. Communication: Who should say what to whom? How to address uncertainties? How to interpret probabilities?
e. How are perceptional aspects, like fear or prejudice, influencing risk judgments and decisions?
f. Evaluation analysis: How well is the risk analysis working? What have the consequences of our actions and policies actually been?
g. Learning analysis: How might we do better? What should we try next, and for how long? When should we stop exploring and commit to a policy?
h. Collaborative analysis: How might we do better together?

The knowledge production of type B covers development of concepts, principles, methods, models, etc., for these activities. For example, the development of the SRA Glossary is an example of a B-type of activity. It provides guidance on how to define and understand basic concepts that can be used for different types of applications (A). Another example is theoretical work clarifying the meaning and use of the precautionary principle in a risk management context. The A activities are multidisciplinary and interdisciplinary; for example when predicting the impact of a medical drug, the work could be a result of collaboration between natural sciences, medicine, statistics and risk analysis. Also, A activities may include modeling and theoretical analysis; however, the aim is to produce knowledge about the specific activity studied (the drug, the nuclear power plant, etc.), and not to improve the models and methods as such, which is the driver for B.

One may refer to A as applied risk analysis (in the sense that risk analysis concepts and methods are put in practical use to obtain knowledge about a specific activity) and B as generic risk analysis (in the sense that it produces knowledge on concepts, principles etc., which is general and relevant across different applications).

Insights from A activities can lead to developments in B and, of course, findings in B could influence the practical work of A. Developments in other fields, like psychology, statistics and operations research, can provide useful contributions also to risk analysis, directly or adjusted to fit the risk analysis context. The core subjects of risk analysis need to cover both A and B types of activities.

The list of subjects is divided into five main categories:

1. Fundamentals
2. Risk assessment
3. Risk perception and communication
4. Risk management and governance
5. Solving real risk problems and issues

There is some overlap between these five categories, but not much. The first category covers fundamental issues, concepts and principles of risk analysis as a field and science, for example subjects related to what science means in a risk analysis context, and what risk and risk analysis actually mean. The second category is risk assessment, which covers in more detail this particular tool used in risk analysis, to understand, describe and evaluate risk. The third category covers issues related to perception and communication of risk, whereas the fourth addresses measures and activities carried out to manage and govern risk, balancing developments and exploring opportunities, on the one hand, and avoiding losses, accidents and disasters on the other. The fifth category of subjects addresses how to solve risk problems, challenges and issues in real practice, by integrating theories and methods from the other four categories of topics, and using concrete, practical cases.

Also, the subject categories 1-4 include cases and examples, but these are simpler. The point in 1-4 is to illustrate the concepts, theories, principles and methods. An engineer who is to learn about statistics will not benefit from detailed studies in statistical analysis in, for instance, health and finance, although simple illuminating examples from these applications could be useful. We would have the same situation for risk analysis. For an engineer who is to study risk, simple cases from different applications can be informative, but, if they are too detailed, they will not serve the purpose of the study. For subject category 5, the focus is on solving real risk problems, hence of type A knowledge generation, but also practical issues related to the link between A and B are addressed, for example practical issues caused by unsuitable risk analysis methods.

If specific areas of applications are to be highlighted, for example safety, security, reliability or resilience, tailor-made theories and methods can be added to the subject list here provided. For instance, if safety is the application, accident theories will be a topic to include.

The target audience for the list of subjects is all individuals who have an interest in risk analysis, SRA members or not, ranging from risk analysis professionals and practitioners, to researchers, students, decision makers, bureaucrats, regulators, journalists and curious lay people who would like to get an overview of what are key topics of the field of risk analysis.

The plan for the development of this list of subjects is defined by the following milestones:

- Presentation of plans for the SRA Council (June 22, 2016)
- Establishment of the expert group (July 2016)
- A first draft of the list of subjects is produced (July, 2016)
- Discussion and agreement on a draft list of subjects (Nov. 20, 2016)
- Presentation of a draft list of subjects at the SRA meeting in San Diego at the SRA council meeting there (December 2016)
- Sending the draft to SRA members and the Specialty Groups for comments (Feedback before March 1, 2017)
- Revision of the document (March - April 2017)
- Committee conclusions (May 1, 2017).
- Presented for SRA Council May 15, 2017. List to be published on the SRA website
- Presentation of the work at the SRA Annual Meeting in Arlington in December 2017.

The list is planned to be updated from time to time to reflect the ongoing discussion, addressing comments and

suggestions made. Please contact terje.aven@uis.no if you have some ideas.

The committee is grateful to the many professionals who have provided insightful and improving comments and suggestions to earlier versions of this document.

SUBJECTS AND TOPICS DEFINING THE RISK ANALYSIS FIELD

1. FUNDAMENTALS

This area covers fundamental issues related to risk analysis as a field and science, basic concepts and principles, including ways of representing and expressing uncertainties. The SRA Glossary represents a possible basis for this category of subjects.

More specific topics:

What is risk analysis? Different analysis approaches used and issues raised (such as a-h listed above). The risk analysis field and science. The distinction between A and B types of risk analysis knowledge generation (applied risk analysis and generic risk analysis, see above). The risk concept (basic ideas, alternative definitions with discussion). Risk metrics. Coherent risk metrics. Risk and knowledge. Surprises and the unforeseen (black swans). Risk and utility. Risk aversion. Why risk is not expected value or variance. Representing and expressing uncertainties. Different types of uncertainties (epistemic, aleatory). The probability (likelihood) concept. Variation and probability models. Frequencies. Understanding and using subjective probabilities to reflect epistemic uncertainties and degrees of belief. Why the use of probability to represent uncertainties? Bayesian analysis. Generalizations of probability theory. Interval (imprecise) probabilities and related “non-probabilistic” characterisations and metrics. Risk problem categorizations (e.g., simple, complex, uncertain, ambiguous). Fundamentals about modeling of systems and processes in a risk context. Different types of models (structural models, physical models, logic models, probability models). Model uncertainty. Causality, uncertainties and risk. Sensitivity analysis and importance measures analysis.

Related concepts like hazards, threats, opportunities, danger, vulnerabilities, resilience, safety, security, risk source, reliability, etc.; commonalities and distinctions.

2. RISK ASSESSMENT

This area covers principles, approaches and methods for identifying risk sources, threats, hazards and opportunities; understanding how these can occur and what can be their consequences including adaptive behavior and recovery; representing and expressing uncertainties and risk; and determining the significance of the risk using relevant criteria.

More specific topics:

Stages and processes in a risk assessment: planning, identification, cause analysis, consequence analysis, uncertainties and beliefs, evaluation. Main categories of assessment approaches, including statistical approaches and system analytical approaches; qualitative, quantitative and semi-quantitative; dynamic and semi-dynamic/static; linear and non-linear approaches. Models for analyzing failures, events, survival, causation, frequency-severity, interactions, etc. Dose-response functions. Meta analyses. Methods for addressing potential surprises and the unforeseen. Reflecting signals and warnings. Adaptive risk assessments. Quality of risk assessment (validity, reliability criteria).

Specific approaches, methods and models

Risk source identification and qualitative analysis methods such as databases, brainstorming, Delphi methods, interviews, surveys, check¬lists, Structured What IF Technique (SWIFT), HAZard Operability studies (HAZOP), Anticipatory Failure Determination (AFD), red teaming, etc. Basic analysis tools such as block diagrams, fault trees, event trees, Bayesian belief networks, Bow-tie diagrams and Monte Carlo simulation. Advanced analysis tools like complex network theory, agent-based modeling, etc. Expert judgments, including heuristics and biases. Deriving and using different types of models such as counting processes (e.g., Poisson), marked point processes (e.g., Compound Poisson process), survival models (e.g., Weibull), times series models, artificial intelligence models, causal models, logistic regression models, game theory models, etc. Related statistical analysis (including Bayesian).

Design of the analysis

Characterization of the problem and associated analysis tasks. Evaluation of strengths and weaknesses of assessment approaches and methods. Choosing the proper approaches and methods for assessing the risk, including approaches and methods for representing and treating interdependencies, uncertainties and knowledge. Protocol for dealing with complexity, uncertainty

and ambiguity, as well as potential surprises and the unforeseen.

Evaluation

Presentations of the results of the risk assessments, with characterization of knowledge, uncertainties and limitations. Decision criteria. Tolerability limits and acceptance criteria. Risk-risk comparisons. Differences in risk perspectives between analysts and decision-makers. Decision frameworks; integration with other types of analyses, such as social impact analyses, technology assessments, and cost-benefit analysis. Risk valuation.

3. RISK PERCEPTION AND COMMUNICATION

This area covers issues related to perception and communication of risk, how affect and trust influence risk perception and behavior, and how exchange or sharing of risk-related data, information and knowledge between and among different parties (such as regulators, experts, consumers, media, general public) can be provided.

More specific topics:

What is risk perception? Risk perception and feelings/affects. Reactions to real or perceived threats: System 1 vs. System 2. What are the determinants of perceived risk? The difference between expert versus lay judgments of risk. How and why do laypersons' perceptions of risk differ from those of the experts? Heuristics, biases, beliefs and risk perception. Social and cultural factors shaping risk perception. How social trust and credibility relate to risk perception. Risk perception and behavior/decisions. The psychometric model. The cultural theory of risk perception. Social amplification of risk.

What is risk communication? Different models and theories of communication related to risk. Risk information seeking and processing. Sources of risk information, including unofficial. Message design and the effects of different message elements, such as probabilities, comparisons, statistics, narratives, fear appeals. Media coverage of risk. Different types of stakeholders and audiences. Strategic risk communication. Visuals in risk communication. Framing effects on risk perceptions and behaviors. Persuasive and balanced messages. Source credibility and its influence on message effects. Public engagement to inform risk analysis. The analysis-deliberation paradigm.

4. RISK MANAGEMENT AND GOVERNANCE

This area covers measures and activities carried out to manage and govern risk, balancing developments and exploring opportunities, on the one hand, and avoiding losses, accidents and disasters on the other. A main emphasis here is on providing insights and guidance on multi-dimensional, multi-actor, multi-institutional decision and policy making and on resolving emerging trade-offs.

More specific topics:

Risk management strategies and processes. Risk avoidance, optimization, reduction, transfer, sharing, retention, acceptance and tolerability. What risky prospects to accept? How to allocate resources across risky opportunities? Different types of risk problems. Decision mistakes and how to avoid them. Preferences, goal setting and performance measures. Risk trade-offs. Enterprise risk management. Insurance.

Different instruments and tools. Multi-criteria, multi-attribute, multi-actor types of analyses. Cost-benefit analysis. Value of a Statistical Life (VSL). Bayesian decision analysis. Expected utility theory. Alternatives to expected utility theory (including Prospect theory).

Cooperative risk management. Principal-Agent (P-A) model of risk management. Negotiation and Bargaining. Games. Adversarial risk analysis. Risk psychology for groups, organizations, crowds, and markets. Group-thinking and dynamics. Consensus. Building a risk culture. High reliability organisations (HRO).

Cautionary and precautionary principles. Robustness and resilience-based approaches. ALARP (As Low As Reasonably Practicable). Adaptive risk management. Black swans. Emergency preparedness planning. Disaster planning. Policy analysis and risk. Risk governance issues (e.g., regulatory styles, regulatory regimes, risk governance capacity building, risk governance performance). The analysis-deliberation paradigm.

Modes of collective decision making. How to reach consensus on difficult conflicting values and trade-offs? Stakeholder involvement. Public participation. Law and risk management (the legal context). Risk regulation. Standards, inspection and certification. Risk analysis and politics. Ethical aspects.

5. SOLVING RISK PROBLEMS AND ISSUES

This category of subjects addresses how to solve risk problems, challenges and issues in real practice, by integrating theories and methods from the other four categories of topics, and using concrete, practical cases. Risk analysis as a multidisciplinary and interdisciplinary field is demonstrated, and special attention is devoted to the added value of risk analysis relative to the contributions from other fields and sciences. Organizational capacity (human resources, knowledge, etc.) needed for achieving high quality risk analysis is a key topic.

Cases are considered, highlighting

1. Clarification of the problem, challenge or issue, such as (see also a-h in the scope section):
   a. Support decision making on choice of alternatives and measures
   b. "Prove" that an activity is safe
   c. Empower people with risk related knowledge
   d. Reduce concerns and increase trust and confidence
2. Approaches for knowledge generation and management
   a. Frameworks and processes (including standards)
   b. Methods and tools
3. Execution and results obtained. Challenges and reflections, covering issues like
   - The degree to which the risk assessment is engaged effectively in the risk management decision process
   - The risk characterization has a format suitable for the decision making situation
   - The degree to which disclosure of the actual role of the analysis, e.g., advise vs. defend, is practiced
   - The degree to which assumptions and caveats, and the implications of these for the decision making, has been stated
   - Potential surprises are addressed and relevant management strategies implemented
4. Institutional responses to risk challenges. Role of risk regulation. Capacity building for risk assessment, management and governance; dealing with transboundary risks, international cooperation and legal requirements

Examples of cases that could be included:

- Accident risk analysis of engineering systems such as nuclear power plants, offshore installations, aircrafts and spaceships, critical infrastructures. First, second, and third party risks. How safe is safe enough? Probabilistic risk assessment (PRA). Quantitative Risk Assessment (QRA).
- Consumer product safety. Perceived vs. historical data. Examples: Plastic baby bottles, silicon breast implants, seatbelts, etc.
- Food and drug safety. Contaminants (deliberate or accidental) in foods and drinks. Microbial safety and microbial risk assessment. How sure can we be? GMO safety. BSE.
- Occupational safety. Framework: Asymmetries in information and costs of care. How much care should employers and employees be required to take? Hazardous occupations. Industrial Hygiene.
- Transportation safety. Maritime safety, aviation safety, railroad safety, automobile safety.
- Public health risk assessments. Epidemic, pandemics. Exposure modelling and analysis. False positives. Risk management policy paradigms: Command/control; Nudge: Information and incentives; and Adapt: Experiment, learn, and share successes.
- Environmental and ecological risk analysis. Climate change. Acid rain. Conserving biodiversity. Sustainable management of natural resources
- Financial risk analysis. Credit risk analysis. Investment risk analysis. Financial portfolio risk analysis. Financial market risks. Corporate financial risk management. Personal financial risk management.
- Security and terrorism. Cyberterrorism and cyber-security risk. Alternative analysis frameworks. Risk and uncertainty conceptualisation and characterisation.
- Habitual risk. Smoking, different lifestyles, measure activities, cultural practices.
- Social risks: lack of social coherence, growing inequities, crime, war, civil war, violence.