Strategies for Sustainability

Peter A. Wilderer
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Klaus Mainzer *Editors*

Sustainable Risk Management

Springer

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Foreword

The Paris UN climate conference in the autumn of 2015 was a groundbreaking landmark for responsible and future-oriented climate policy. A positive side effect of the pervasive atmosphere of global responsibility were the accompanying conversations, discussions, panels and workshops with leading members of the research, business and policy community. One thought in particular came up again and again: a consensus on the necessity of risk management that builds on the fundamentals of sustainability. Climate protection is actually precisely that: weighing up the risks of taking action, but also those posed by inaction. There was also agreement that the complexity and urgency of this matter require a scientifically based and broad discourse in society. This is also the case because climate change is a major—but by far not the only—risk to our earth system, and consequently to us. This is also expressed in Pope Francis' Encyclical Letter "Laudato Si", issued in 2015: by the Vatican, Italy.

Only a few months later, the Institute for Advanced Studies on Earth System Preservation (IESP) addressed these same issues in a three-day international workshop in April 2016, thereby laying the foundations for this book.

Never before have the global challenges been as formidable as they are today: Climate change and its impacts, seen against the backdrop of a growing world population and increasing globalization, give us a sense of the risk-inclined and unsettled times that lie ahead. First portents of things to come are, for example, worldwide refugee displacement, the increasing number of geopolitical conflicts and the ensuing system-relevant ecological crises that have the potential to turn into global environmental catastrophes which would inevitably cause a further rift in society. The accompanying societal challenges are certainly resulting in the presently more or less latently palpable sense of insecurity in society, which is also an expression of individual overwhelmed-ness in the face of globally unfolding crises. The latent fears that this creates, but also many well-founded concerns, are warning signs to be taken seriously when it comes to recognizing risks in their full extent and managing them in responsible manner, even as they interact. In other words: Now more than ever, we need a translation of scientifically validated findings into a form and language that society will understand. This creates the willingness to assume responsibility and the capacity for action in place of paralyzing fear. Well-founded concerns can contribute towards preparing the ground for unselfish solidarity in the interest of the common good. The task at hand is to overcome the difficulties facing human society, which has always been molded by selfishness, which leads us to the central question of this book: How can we manage risk in a sensible and responsible manner? How can we transform risks into what in essence they are as well, namely opportunities?

As a citizen and politician, I am extraordinarily grateful that the expert network IESP and the authors of this book have taken on this question and have, in conjunction with top-level representatives of the scientific, business and policy communities, examined it from various perspectives. In addition to the most important results and assessments, this book contains both general and specific guidance for action aimed at decision-makers in business, society and politics. Hence, in accordance with sustainable risk management based on scientifically validated findings, a contemporary way to manage the looming risk scenarios and effectively limit their extent is rendered comprehensible and recognizable. At this point I would like to express my special thanks to all those involved, for making a substantial contribution to this difficult but extremely important subject. Environmental policy in terms of the protection of our livelihood is, above all, one thing: an essential component of our global security architecture.

Munich, Germany

Ulrike Scharf
Bavarian State Minister for Environment and
Consumer Protection

Preface

The contents of this book refer to the workshop on “Sustainable Risk Management: How to manage risks in a sensible and responsible manner?” held in Feldafing at Lake Starnberg on April 14–16, 2016. Forty scientists, entrepreneurs, administrators and politicians gathered at the International Training Centre operated by the German Association for International Cooperation (GIZ). The workshop was organized by the Institute for Earth System Preservation (IESP) in cooperation with the Emeriti of Excellence of the Technical University of Munich and the Institute for Sustainability Studies (IASS) at Potsdam, Germany. IESP is a non-profit organization of the European Academy of Sciences and Arts: headquatered in Salzburg, Austria.

The topic of the workshop was chosen in response to the uncertainties that often render decision-making a very challenging task at any level of our societies. This is certainly not a new phenomenon. But the risk of taking a wrong decision has gained particular importance due to the rapidly increasing complexity of almost all aspects of our contemporary world. Guidance based on well-founded science is needed to keep our societies and economies on a balanced track towards a state of resilience and sustainability.

A good example of the need to address the theme of sustainable risk management are the conflicts around attempts to solve the problems of health, energy generation, and food and water supply, as well as problems involved in digitalization, big data management and robotics. The sometimes hysterical blind-faith rejection of innovations in agriculture, pharmacology and medicine is to be replaced by responsible information transfer prior to and during technology development. Likewise, robotics is sometimes damned as putting people under tutelage, while the same people excitingly embrace novel methods of internet communication and autonomous driving.

In awareness of humanity’s responsibility for the preservation of creation, and based on consolidated knowledge of causes and effects, the workshop was intended to delineate ways that lead to a strengthening of the willingness of decision makers and their concerned populations to overcome unwarranted fears and to elaborate policies based on scientific evidence.

To this end, four focus areas were chosen for in-depth discussions:

1. The scientific basis of risk management.
2. Risk management in the area of environmental and ecological policy.
3. Risk management in radiation medicine.
4. Risk management in the context of digitalization and robotics.

The recommendations derived from the discourses are summarized and elaborated by the authors of the book which you are holding in your hands.

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Introduction

Webster's Dictionary and Thesaurus of the English Language defines risk as "the possibility of danger, injury or loss". Basically, risk is a part of human life. If a loss of goods or property values is concerned, risk management is the means for compensating such losses—by insurance policies, for instance. However, when it comes to loss of physical health, social status or even human life, specific pre-emptive, precautionary action is required, other than filing an insurance contract. For example, a self-reliant mountain climber knows that a wrong grip may have fatal consequences. Consequently, he or she completes rigorous professional training before scaling the highest peak. Similarly, the application of innovative practices concerning the economy, medicine or cyber-physical systems requires—prior to the implementation of such practices—a thorough investigation not only of the functionality of the respective technologies, but also of the effects of uncertainties, dangerous side effects or lack of public acceptance.

The perception of risk and the development of risk management methods constitute cognitive processes. As such, they are restricted to creatures possessing the capacity for deductive reasoning—in short, human beings. It goes definitely beyond the instinct widespread in the animal world. Therefore, risk management focuses primarily on humans and human society, including its economy. It would be shortsighted, however, to exclude the effects on and reactions from ecosystems within which the human civilization is embedded. A "transboundary" view and subsequent considerations are necessary to avoid secondary risk. Therefore, sustainable risk management focuses on effects leading to long-lasting ecological, economic and societal well-being.

Risks occur in a multitude of areas of human activities; each niche requires a tailored, sustainable risk management approach. Attempting to of cover all possible aspects risk and sustainable risk management would far exceed the pages of a single book. In the following three focal areas were selected to stress possibilities and limits of a sensible and responsible dealing with risks, namely:

- Ecological and environmental considerations
- Radiation medicine

- Cyber-physical systems

These three focal areas are framed by two sections (Parts I and V):

- Fundamental Thoughts, and
- Memorandum

Three overarching aspects are presented and discussed under the heading "Fundamental Thoughts". The chapter written by Markus Vogt deals with important ethical considerations. The chapter presented by Andreas Klinke and Ortwin Renn adds the principle of responsibility and accountability in the political decision-making processes. Finally, Michael von Hauff concentrates on the question of whether economic growth leads to opportunities rather than to systemic risks.

The Memorandum refers to the outcome of the workshop on Sustainable Risk Management mentioned in the Preface. The document resolved by the participants of that workshop is considered the backbone of all the chapters on Ecological and Environmental Considerations, Radiation Medicine and Cyber Physical Systems.

The chapters compiled in of the Parts II, III and IV were written as further elaboration of the various points of the Memorandum, namely the general and the specific recommendations for decision makers acting in political, economic and scientific institutions being in charge of responsible and sustainable risk management.

The readers of this book are recommended to read the Memorandum first, including the explanations of the individual points of the recommendations. This document explains the overarching contribution made by the authors of the chapters compiled in the three focal areas.

Secondly, it is suggested to read the background papers to better understand the approach taken by the authors contributing to the various aspects addressed in the three focal areas.

Peter A. Wilderer
Editor-in-Chief

Part I
Fundamental Thoughts

Chapter 1
Risk Management from the Perspective of Catholic Social Ethics

Markus Vogt

Preliminary Remarks

Each title implies certain expectations, of which I consider two to be in need of explanation in the present text in order to emphasize how I want to approach the topic. The given title does not consider risk, but risk management. This is a specific point of view on the situation of uncertainty, which only partly does justice to the theological perspective. The theological perspective assumes that there are existential uncertainties in our existence, which cannot be solved through management. The theological term therefor is contingency.

According to Niklas Luhmann, the central mission of religion is to overcome contingency, meaning to keep awake the consciousness about paradoxes and uncertainties that cannot be solved. To me that seems fundamental, especially with regard to current technological, ecological and political risks.[1] A concept that shortens the risks to matters of management tends to suggest one-sided technocratic solutions. This is a highly explosive scientific and political topic, as Rudolf Stichweh shows in a reaction to the paper of the science council "Great Challenges of Society".[2] Risk management is a term which belongs to the conceptual idea of the *homo faber* as the "can-do type". Theology, or humane disciplines in general, do not deny the importance of management questions, but first, they take a step back and ask about the complex causes and manifestations of uncertainty. Theology and philosophy open a perspective which insists that there are existential crises,

[1]Cf. Luhmann (2008).
[2](Stichweh 2016).

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ambivalent experiences, uncertainties and risks, for which management recipes for frictionless functioning are not an adequate answer.[3]

A Christian risk ethic is neither a pure management theory nor a discourse about fear bound to certainty. It is, in a certain way, the opposite of a promise of security. In a biblical sense, the picture of the decampment into a new, uncertain land, as the story of Abraham tells, is paradigmatic. A Christian risk ethic assumes that from time to time, a radical dare is necessary and that failure is part of life. This is to be answered by willingness for solidarity with those in need and by awareness of their own limits. Not certainty, but resilience, robustness in situations of crisis and transition, is a suitable guiding concept for a Christian risk ethic.[4]

A second remark about the title concerns the characterization "Catholic". The subject of social ethics is traditionally anchored in the law of nature, which is pursued in rational law, and therefore aims for general rational ethical judgment rather than a specific Catholic moral. Christian social ethics in theological education is traditionally part of the "philosophicum" and therefore is a theological discipline, which provides information about their reasons via philosophical compatible arguments.[5] It is always compatible with pluralism on a dialogue that expands over church and theology. This seems important to me for an audience, in which I do not presuppose a Christian creed, so that the interest of the majority does not die from reading the word "Catholic" in the title. What I aspire to is an ethical-systemic and contingence-critical point of view on risk.

From an ethical viewpoint, risk is the decision-theoretical side of complexity. In a specific socio-ethical perspective, the regulatory dimension is added. My lecture, therefore, is about decisions and institutions that are adequate for the complexity of the twenty-first century. A decisive aspect within that is the uncertainty of morality itself. You can correlate "normative risks" to the risk of infringements or—what I will concentrate on—to the corrosion of moral systems with regard to their justification as well as their individual and social validity. If morality today should help with overcoming risks, it has to prove itself under the conditions of value pluralism and individualism.

The following outline of my lecture results from the remarks above:

1. Contingency as a challenge for ethics
2. Patterns of unresolved complexity in politics and society
3. Risk maturity in light of systemic ignorance
4. Theological models for dealing with informed unknowing

[3](Schirach 2014).

[4]For concepts of resilience in social sciences, ethics and theology, cf. Endreß and Maurer (2015), Vogt and Schneider (2016).

[5]Cf. Vogt (2013c, 229–326) (about the relationship of God's law and human rights); (Vogt 2015, 50–53).

Contingency as a Challenge for Ethics

Uncertainty as a Component of the "Cognitive Infrastructure" of Postmodern Morality

The increase of risks is actuarially measurable. That does not mean though that life has become more uncertain, but only that many things that used to be fate are now insurable. The expansion of knowledge and opportunities to have influence extend the radius of responsibility, and change tolerable fate into risk that depends on choice. With that, there is a link to significant shifts in perception and social classification of uncertainties. Talk of risk most often implies a negative evaluation.

Herrmann Lübbe criticizes the common risk communication as a biased pre-shaped thinking pattern that generates the tendency for excessive certainty expectations and a moralism that often manifests itself in accusations.[6] It chases politicians into a "declamatory responsibility overload"[7] because they get elected if they promise a mastery of risk that exceeds their occupational competence.[8] The talk of critical uncertainty is usually used to legitimize or de-legitimize certain interests of power.[9] It is a call for social debates. The use of the term crisis is therefore not necessarily an indicator for growing uncertainty but a method of observation: It indicates that well-known solution patterns are stretched to their limits and are often linked to the demand to depict given courses of action as especially urgent and without any alternative. The boom of the topic crisis as an interpretation category of modern societies[10] does not only point to an existential uncertainty but to a prior argument about interpretation and action patterns of social development. Against this background, a certain distance to alarmist risk, uncertainty and crisis rhetoric is advisable.[11]

In the ethical discussion, the experience of uncertainty is relevant in several ways: it refers to the consequences of action in complex coherences as well as the grounding and responsibility for certain decisions. In pluralistic societies, a consensus regarding the grounding, validity and range of a moral posit often cannot be found, which might create enormous uncertainty within the individual. That is not only a problem of social disagreement, but also a limitation to moral rationality, for which there seems to be no ultimate grounding and no complete coherence under modern conditions.

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[6](Lübbe 1994, 297). He defines moralism as an attempt to solve urgent problems of civilization via pleas to the collective of uninvolved individuals; cf. ibid. 298.

[7]Cf. Lübbe (1994, 293–297).

[8]This is how Ulrich Beck analyzes "risk society" and its globalization as a "global risk society" with regard to basic deficits of political controllability and the illusion of promised but not redeemable responsibility. Cf. Beck (1986), Beck (2007).

[9](Schulze 2011).

[10](Wilhelms and Wulsdorf 2012, 3).

[11](Schulze 2011; Wilhelms and Wulsdorf 2012, 3–7; Renn 2014).

Thus, you can expect an irreducible pluralism of characterizations and evaluations of problems and attempts at a solution in morality, because the different social subsystems and theoretical approaches observe the decisional choices with their own rationality.[12]

The late modern shift of ethics to contingence and pluralism of different types of rationality and inherent logic of social subsystems[13] demands its own type of strategies to overcome the associated increase of complexity. It is necessary to face up with fundamental (not only subjective and thus conquerable) ignorance as well as the logic of open decisions and process operations. Even though humankind has never had so much information about worldwide developments and future events, there is at the same time a rapid loss of knowledge due to accelerated innovations, which outdate knowledge in every field in ever shrinking half-lives.[14]

In the field of know-how, it might be possible to compensate the decay of knowledge with even faster gain of knowledge. With regard to orientation knowledge, which can only grow slowly, because it results from the relation to a whole, there are fundamental methodical problems, so that the development of ethical knowledge seems to lag behind many social developments enormously. For such times of social upheavals, a high degree of uncertainty in ethical judgment is characteristic. Ethical knowledge in many aspects does not exist but has to be gained and opened. In this searching process, knowledge about one's own ignorance and the productive doubt about alleged securities are constituent for responsible and future-oriented actions.

"Moral in Doubt": Productive Meaning of Informed Unknowing

In Spanish scholasticism, the first comprehensive and practical moral systems of casuistry were developed as a classification of decision criteria for moral actions in the conditions of uncertainty. Those are, as Rudolf Schüßler carves out in his two-volume book on "Moral in doubt", to be considered as a reaction to the corrosion of orientation knowledge in the upheavals of the beginning of the modern era.[15] One was confronted with new complex challenges, could no longer rely on

[12]Cf. Lyotard (1989).

[13]On the problem of multicriterial decisions from a rational theoretical viewpoint cf. Hausmanninger (2009).

[14]Wolfgang Frühwald talks about "scientific fright", and analyzes the various ambivalences of an accelerated society as basic scientific and ethical challenges; (Frühwald 2009, 9–10). (Böschen et al. 2004, 7–13), talk about the "end of the myth", "safe knowledge" and a "shattered science".

[15]Cf. Schüßler (2006). What is new about Schüßler's interpretation is, among others, that he links the problems of uncertainty reflected by Catholic moral casuistry with the resurrection of skepticism in the renaissance era. He assumes that the "negation of uncertainty in the 'maximum security unit' of philosophy of Descartes and Kant" is no longer fully satisfying in important

the conventional catalogues of virtues and so drafted differentiated rules of decision-making for different individual cases.

Here, the lex dubia principle, according to which a dubious law is not binding, has led to a century-long ongoing discussion.[16] A rule which has been deduced from that and is still valid in law today is "in dubio pro reo"—"in doubt, for the accused". Schüßler characterizes this as "freedom-centered probabilism".[17] The reflective confession of ignorance and doubt regarding the verifiability of actions, motifs and consequences of actions is a strong and sensible reason for constituting freedom. The abstention from judgment and tolerance of different opinions in uncertain situations is rooted in the logic of dealing with ignorance which is constitutive for the reasoning of ethical decisions. One can build on various traditions here, whether it is the Socratic "I know nothing except the fact of my ignorance" as the root of philosophical wisdom or the "docta ignorantia" of Nikolaus von Kues. The knowledge about one's own ignorance is an important virtue for acting under uncertain conditions.

The Limits of Rational Choice Considering Complexity and Uncertainty

In a liberal and pluralistic society, free space for pursuit of what the individual believes to be his greatest benefit or his greatest happiness has become a political principal. Modern societies in their daily practice are highly influenced by different varieties of economic and utilitarian ethics. Thinking in categories of benefits that are linked to specific goods and situations can be understood as a reaction to ethics reasons which write up rules of "ought" and become uncertain. The high affinity for practical questions, for integration of empirical research (e.g. in medicine) as well as individual and situation-specific differentiation are big strengths of the utilitarianism of ethics basic approaches.[18] It is yet commented on that ethics that internalize a calculation of benefit lead to a sellout of morals and overwhelm the individual when it comes to knowledge and complex requirements of stable cooperativeness.[19]

The limitation of comparability of benefit validity in complex situations limits at the same time its applicability as an ethical category. The teleological approach (which takes the results of an action as a starting point of its moral evaluation)

aspects today and, therefore, in a new form, is especially current for ethics today, which egresses over the limits of enlightenment (ibid. 96–100). For the moral dealing with doubt about the validity of moral systems, also cf. Arntz (2009, 125–141).

[16]Cf. Schüßler (2006, 96–100).

[17]Ibid., 96–100.

[18](Wolbert 1992; Schüßler 2006, 284–295; Zichy and Grimm 2008, 87–116). 153–183; (Nida-Rümelin 2015).

[19]Here esp. Spaemann (1999).

reaches its methodological limits regarding postmodern complexity of social and technological developments: Many individual and social conflicts of choice have such a high and specific degree of complexity that the prognostic calculation's type of rationality does not seem to ensure rational choices.

The question about choice criteria for complex situations in which the problem-solving pattern of utilitarian impact analysis reaches its limits is an essential testing area for ethics in their access to current social problems. That is especially true for the field of evaluating technological consequences, which is essentially a question of adequate dealing with complexity, risk and lack of knowledge. The classical method of actuarial risk evaluation fails when it comes to extremes of very low probability of occurrence and very high possible extent of damage, as it is the case, for example, in nuclear energy production. New analyses of the accidents in Chernobyl and Fukushima have shown that this method is much too abstract and does not stay abreast of the "risk factor human".[20]

The modern "techno-ethical tutiorism" of promising or postulating a zero risk or a neglectable "remaining risk" turns out to be delusional in the light of the dilemma situation, in which every version is linked with risky side effects and non-action also contains significant risks.[21]

We need a form of rationality, which does not assume predictability and calculability of the consequences, but calculates with open variables and can react to surprises; a form of rationality, which considers systemic effects and non-linear reciprocity as a starting point for the incalculable and takes horizontal coherences into account; a form of rationality, which does not only define goals, but also optimizes choice and communication processes, which envisages the unexpected and designs systems in a way so that they can catch them elastically in buffer zones (in ecology, the term used is "resilience").[22] "Resilience" is currently founding as an interdisciplinary key term, which transforms traditional concepts of progress, risk and security and carries forward the sustainability discussion from the point of view of crisis management strategies and the quest for criteria for changing sturdiness in an innovative way.[23]

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[20]Cf. Kersten et al. (2012), esp. 41. It is widely unknown that the experts of MunichRe, a worldwide leading reinsurer with an expert committee for stochastic calculation of damage, decided in the 1970s, due to theoretical risk problems, not to insure nuclear power plants at all. Today, especially the comparison of risks of nuclear energy and fossil fuels and the question if and how those two can be compared, leads to basic risk ethical problems of method.

[21]For juridical aspects of this debate, cf. Kersten (2014); for the controversial debate about ethical aspects, cf. Korff (1979), Spaemann (2011).

[22]Cf. from a scientic theoretical viewpoint: Böschen et al. 2001; from a socio-ethical viewpoint: (Vogt 2013a, 347–372); from a sociological viewpoint: Beck (2007; Renn 2008).

[23]There is a Bavarian research group with the title "Fit For Change" (which is a central scientific background of this paper); cf. http://www.forchange.de; about the relation between resilience, security and risk vgl. (Schneider 2015).

Patterns of Unresolved Complexity in Politics and Society

The Declamatory Overload of Responsibility in Politics

In the complex interaction systems of modern society, actions quite often have consequences that cannot be predicted by the individual and therefore cannot be assigned to the specifically responsible person. The predictable non-calculability of risks in highly complex effect coherence, in which the probability of occurrence is not predictable, finally leads to a situation where it is neither enforceable nor legally insurable.[24] As a form of moral compensation for that deficit, politics, as a form of superior authority, are assigned with a far-reaching responsibility. The consequence is an overload of responsibility that rather stands in the way of real problem solving.

The Logic of Failure

Action in the systemic interweaving of modern, fully differentiated society often follows a "logic of failure", as psychologist and system theorist Dietrich Dörner from Bamberg, Germany analyzed in several experiments as typical strategy errors when faced with complex problems.[25] These can be summarized in four types.

1. Poor target recognition: Targets are not clearly identified or drafted and not weighted. Intermediate targets or sub-goals can therefore develop a momentum of its own. Action for the sake of its own develops, which takes shape in repairing any deficiency that can be found and overcome. The criteria therefore are at times one's own capability for which adequate problems can be detected.
2. Poor systemic thinking: Perception of details predominates, so that the large coherences and interactions, meaning positive and negative feedback mechanisms, are blocked out and side effects are not considered. Often, the process character, meaning the sense of passages of time with inherent logic and different paces, is ignored. Normally, that leads to oversteer, because it is not recognized that the system reaction is delayed or non-linear.
3. Getting out of touch with reality: Analysis of cause and situation are either pushed to extremes, what creates uncertainty and paralyzes, or are neglected. Changes are hardly considered, actions not evaluated and self-criticism is absent. One lives in a self-created model and forgets that actions take place in reality.

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[24]Cf. Lübbe (1994, 296f. and 293f). The use of moral categories in complex historical processes would therefore be assumed.

[25]Cf. Dörner (1992); for following socio-ethical criteria about controlling complex adaptive systems, cf. Vogt (2013a, 347–372).

4. Trailing away in subtopics: In complex situations, actors can quickly reach their limits. They encapsulate in a (sub)topic. With the first obstacle, the topic is changed, there is a swinging forwards and backwards between different areas or a behavior like "ad hocism". Other reactions to excessive demands are cynical resignation, dictator-like behavior or "delegation", meaning foisting responsibility onto others, who are often all the more lacking in the necessary competences.

Examples for such strategy errors are the Assuan reservoir dam, the mass starvation in Sahel, bioenergy generation at the rainforest's cost or essential parts of the war against terrorism in Iraq, Afghanistan and Syria. Their common characteristic is that complex interactions are not adequately considered, so that short-dated problem solutions cause increases in a long-dated problem. Indirectly, a whole range of criteria for more promising risk management can be deduced from such a system-theoretical analysis of characteristic patterns of failure.

In business consultancy today, planning optimism of the 1960s and 1970s has long disappeared in favor of models for optimizing communication and context-based adaption. For such a change of strategies, which considers momentum and interaction of different developing factors in a context-based way, a connection can be made to the subsidiary principle in the Catholic socio-ethics.[26]

Underrating of the "Risk Factor Human"

The experience with commercial risks teaches that the most underrated factor is the human behaviour.[27] The Chernobyl disaster can be traced back to a deliberately precipitated experiment and neglect of multiple basic security measures. There had been experience with tsunamis in Japan and the nuclear power plant of Fukushima should not have been built so close to the sea. Societies and people often act far less rational than they should for the responsible management of technological risks. Risk assessment needs a stronger consideration of social and cultural contexts. Without those, risk scores often stay abstract and are not significant for reality.

Technical control can contribute enormously to the minimizing of risks, for example, in driverless cars or trains, which cause fewer accidents. But a human society needs an error-tolerant technology, because technology without such error tolerance would incapacitate the human as a carrier of responsibility and choices. Technical assistance in order to minimize mistakes makes sense. But it cannot

[26](Vogt 2013a, 473–475); with regard to strategies of sustainability ibid. 134–179. 347–372; with regard to the question of systemic risks and respective adaption cf. OECD 2004.

[27]Cf. Vogt (2013b, 307–332).

substitute responsibility, which always is individual and situational. The ideal of a perfect technology and unlimited possibilities should not let us forget the need for "limits realism".[28]

Risk Maturity in Light of Systemic Ignorance

Wolfgang Kersting calls the responsible dealing with uncertainty "risk maturity": "Thinking in possibilities, the weighing up of several possibilities belongs to cognitive infrastructure of modern times, because "modern times" is the era of the just relative, certainty-free rationality. (…) That is why we have to become risk mature in a technological respect as well as in a moral respect."[29]

Risk maturity is the ability to come to reasonable and responsible decisions, even in situations characterized by high complexity and uncertainty. The uncertainty refers to the consequences of actions, to different valuation standards of the respective people, and to the limits of moral rationality, for which there cannot be ultimate grounding and complete coherence under modern circumstances.

Methodologically, there are three criteria which have to be considered:

1. If a moral assessment does not want to contort and reflect the factual choice situation in a one-sided way, it has to systemically take into consideration the consequences of not taking action.[30] Hans Jonas, for example, seems to neglect that in his "not-utopian responsibility ethic" which primarily seeks to minimize risks with the law "if in doubt, priority for the worst case scenario" (heuristics of fear).[31] Due to the excessive uncertainties in complex systems, however, this would lead to a complete paralysis of actionability. Strict risk avoidance would lead to loss of innovation and could thus turn out to be a strategy which blocks potential action and creates more risks than it prevents; it would thus be equivalent to the logic of failure. "Risk maturity" does not aim for the absolute minimization of any risk, but for the avoidance of a critical threshold of risks and for the enhancement of flexible problem-solving potentials.
2. A clear risk and danger hierarchy when assessing complex situations and weighing incomparable immediate risks belongs to risk maturity. Systemic risks, such as climate change or in the sector of financial services, which are

[28]Cf. Drobinski 2014, 4.

[29](Kersting 2005, 317).

[30]For methods of moral assessment cf. Korff (1979, 68–90).

[31](Jonas 1984), 63 f. also cf. 385 (for anthropological error of utopia) and 390–392 (for the relation of fear, hope and responsibilty), (Hasted 1991, 172) in a critical approach. A final opinion on this very complex question is hardly possible. Jonas' critiques on utopia keep their validity, even if he hardly thinks about the consequences of not taking action.

essentially defined by systemic interaction, are especially problematic.[32] Traditionally, risk analyses limit the assessment of unwanted effects to numeric likelihood, which are normally based on relative frequency and the respective damage potential. Central technological conflicts of our times are, however, characterized by the anonymity of probability of occurrence, and public risk assessment significantly varies from that of experts, or the experts cannot agree themselves. Additional assessment criteria (besides probability of occurrence and amount of damage) are, among others, ubiquity (geographical range), persistency (temporal extent) and reversibility (especially with delayed effects).[33] Risk maturity demands systemic thinking and a hierarchy of problems or opportunity of action.

3. "Precisely because risk perception is not characterized by the grammar of absolute rationality, but embedded in a perception behavior balanced by plural, different value perspectives, it has to stay embedded in participatory choice models."[34] Because many situations of complex coherences are so context-sensitive, vitally significant is the judgment of the immediate actors and the parties concerned as opposed to the extern experts. Risk maturity implies democratic procedures, which constantly reflect the relevant limits of knowledge with representative involvement of the parties concerned. Risk maturity needs democratic procedures, which include the different responsibilities as well as the affected people. With that background, Nida-Rümelin suggests a new social contract "for dealing with collective risks, especially those caused by technology".[35] He speaks out for an institutionalized collective choice procedure, because risk control just via the market is not sufficient.

Theological Models for Dealing with Informed Unknowing

Theology: The Science of Known Ignorance

Theology is a science at the limits of knowledge, where the paradox and complex, the not-to-be-known, mysterious and rationally uncatchable has a systematic

[32]About the problem of systemic risks cf. OECD (2003), Renn (2008), Vogt and Ostheimer (2008, 186–191).

[33](Renn and Klinke 2003, 29). Behind the discussed paradigm change of modeling risks or uncertainties there are also mathematical problems. Today's chess computers, for example, do not only calculate the consequences of single moves regarding the question which man can beat which, but also optimize an assessment of the positions with regard to their attack possibilities and weaknesses on a meta-level. Accordingly, in ethics, one should switch in complex situations from individual good assessment to assessment of action laws on a meta level.

[34](Kersting 2005, 318).

[35](Nida-Rümelin 1996, 827).

significance.[36] For each Christian, divine speech knowledge about one's own ignorance is constituent, as God by definition exceeds any knowledge. Theology, consequently, is designed to be open for the not knowable and the not predictable. The "informed unknowing"[37] marks the scientific distinctiveness of theology, which yet has been reflected in context of dogmatics, but which should be evolved for Christian ethics in the same way. Here, the late modern rediscovery of contingency[38] could be brought into discussion profitably with theological traditions of dealing with not knowing, uncertainty and paradoxes.

In a completely different way, the discrepancy between suppressed or unreflected ignorance (that limits the validity of the respective theory) and the informed unknowing (that is included in the form of variables or factors kept open) is constitutive for theological traditions and modern complexity theories. Informed unknowing is the basis for curiosity and willingness to learn. The different forms of dealing with complexity, uncertainty and ignorance can be mutually complementary and critically expanded. A conclusion that is especially critical for ethics is the recognition of possible omission of different perspectives and, therefore, the recognition of the law of pluralism.

Trust is one of the most important resources for a communicative dealing with known ignorance. It is an essential form of complexity reduction which is also and especially indispensable under the terms of modernity.[39] It is based on communicative reason and does not exclude the ability for criticism. It draws its certainty not from objective knowledge about something, but from interpersonal relationships. Action under uncertainty demands a compensation of the limits of individual knowledge via communicative ability for a critical and trustworthy interweaving with other knowledge carriers and perspectives. There is a fundamental link here to the form of knowledge of faith. Faith according to biblical comprehension is a relationship of trust in its core (Hebraic *aman* = to believe, to trust).

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[36]Cf. Halík (2012), esp. 9–33 and 290–319. He links in a special way to Paulus, Augustinus, mysticism of the Middle Ages with its negative theology, to Kierkegaard and some postmodern authors.

[37](Nikolaus von Kues 1977), esp. I, 7–11 und 109–113. Nikolaus von Kues here takes a special position as he puts the "informed unknowing" as a basis to his theology exploring and fertilizes it for example epistemologically, for dealing with paradoxes, or for methods of negative theology.

[38]Acting for many N. Luhmann is here directed to, a significant theorist of contingency, who refers to Nikolaus von Kues again and again.

[39]To this from a primarily socio-psychological, techno-ethical and economical point of view: (Maring 2010).

Determination: Rediscovery of an Existential Dimension of Choice

The inadequacy of impact assessment, especially in complex contexts, leads to a rediscovery of an existential dimension of the phenomenon choice. If "choice" can no longer be handed over to the seemingly neutral, objective calculation of optimized results, it comes back in an ethically and personally qualified sense. It cannot be made from computers and mathematically optimizing models, but requires the courage of people who choose options and take responsibility. The subjective-decisionistic moment gains more meaning.

In the confusion of postmodern society, a person is driven by the randomness of offers. They become the observer and consumer of the world, other-directed especially in their supposed increase of choices in the autonomy of subjective experience maximization. With regard to that situation, the contribution of theology is not primarily knowledge for better choices, but the stabilization of determination[40] and the support of social, cultural, family and religious spaces for orientation that allow freedom in bonds. Determination does not direct to a maximization of possibilities, as Musil describes the slogan of the modern "multi-options-person", but to a contingency coping via rooting in personal relationships and cultural sense systems.

Phenomenological speaking choice is not primarily the choice between a certain number of alternatives, but the ability to decide on an option and provide capacities that enable a subject to stick to that choice for a certain amount of time against inner and external opposition.[41] Choice is the switching from observant watching to targeted expectation of consequences.[42] This requires an active structure and limitation in order to not get driven by the variety and complexity of the alternatives to a passive attitude of random and shortsightedly motivated "consumption of opportunities". Determination should not be confused with rigid adherence to choices made. From a Christian point of view, it has its origin in the relationship with God and not in the absolute entity of certain single goods, goals or choices. That is why it sometimes requires and enables revision of single choices for the sake of a more important goal.

Against this background, not only the question about such or similar choice seems ethically relevant for the questions about responsible acting under risky conditions, but also the competence for choosing and determination itself. The rapid rise of complex interactions and possible actions under the conditions of late modern society can undermine the possibility of a personally qualified decision in a

[40] Cf. Hafner (2009).

[41] Cf. Richard Schäffler's reflections about the term freedom Schäffler (2004, III, 329–388).

[42] Cf. Hafner (2009).

fundamental way by delegating this to a seemingly better and solely responsible specialist expertise[43] or to the randomness of opportunities.

Christian ethics can add something specific in order to raise rationality of acting in the circumstances of complexity, risk and uncertainty. What is crucial is the knowledge about the limits of one's own knowledge, what is not to be understood as a capitulation in the search for truth and goodness, but as an incentive to stay open for an everlasting process of permanent broadening of the horizon. To be a person is not completely rational, explainable and predictable. Without the system-bursting logic of paradoxes, mysteriousness and poetics, the tension between the unconditional character of human dignity and the varied conditionality of human existence is not possible.[44]

Not only technology but also the expectation that specific moral control systems are kept, and the decision for or against them seem increasingly risky in late modern pluralistic societies.[45] The experience that traditional interpretation and moral systems have lost persuasion, demands an ethic, a theology and a society which allows one to be irritated, yet not paralyzed, by the simultaneity of heterogeneous perspectives in a productive way. This demands learning ability not only with regard to single choices but as well with regard to the kind of choosing. In light of industrial risks that potentially affect everyone in an existential way, the model of pluralistic parallel existence of different options fails.[46] Responsibility in the highly complex, non-linear interdependent development processes of late modern society aims for a transformation of understanding of progress.[47] Resilience, robustness in change and the ability to react to unexpected disturbances become the new matrix of progress and risk management. The often underestimated risk of non-action sometimes requires courageous, wise and quite risky choices. Rationality of technological and social reason is more likely to be measured by the balance between intelligent self-limitation and innovative capability than by maximization of possibilities. The ability to deal with paradoxes and indissoluble tensions is increasingly shown to be the key to private living and the social art of living. A consciousness that directs to insight and learning ability instead of apologetic self-justification is the beginning of every responsible dealing with risks.

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[43]To this cf. the analysis about delegating political responsibility in the financial crisis to experts and constraints in Wilhelms and Wulsdorf (2012), esp. 3–5.

[44]Frühwald vehemently defends the access of poetry as a necessary perspective for the understanding of man. It runs danger of dying because of the dominance of perspectives that are fixated on facts. To see the humane in the human, whose complexity cannot be measured on a level of facts, requires poetry; Frühwandel 2009, 255–284. About the meaning of paradoxes for the understanding of man cf. Halík (2012, 44–58).

[45]Cf. Arntz (2009).

[46]Cf. the example of Green Genetic Engineering, (Köstner et al. 2007).

[47]Cf. Vogt (2014).

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Chapter 2
Distributed Responsibility in Risk Governance

Andreas Klinke and Ortwin Renn

Introduction

The principles of responsibility and accountability have increasingly become a significant concept for the political capability to act independently and make decisions without superior authorization. In the context of responsibility, the political system in modern democracies delegates political functions, duties and authorities and justifies the logic, meaning and reasoning behind this justification. The assignment and allocation of responsibility imply that the consequences of political action can be assigned to those subjects who are assigned to be responsible. Subjects of responsibility could be individuals, groups, organizations, states or other institutions. It is significant for the principle of responsibility that we can identify a causal relation between the subjects that are accountable for the decision making, the substance of the decision itself and the consequences of decision. Hence, a socio-political concept of responsibility conveys the freedom of decision and action as well as represents the social and legal rules and norms of a society by which we are able to judge the success or failure of political action.

The critical analysis and reflection in numerous studies on technological and environmental risks—such as chemical substances, biotechnology, energy, fracking, electromagnetic fields, biodiversity, climate change, water resources, food, etc. —that have been published in the last two decades point to some regularities and patterns of substantial problems and shortcomings in terms of the definition and localization of responsibility and accountability in the governance of such risks (cf., e.g., Hampel et al. 2001; IRGC 2013; Klinke et al. 2006; WBGU 1999, 2000a,

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2000b; Renn et al. 2011; Klinke and Renn 2014). In particular, the diffusion of responsibility and diminished responsibility in the context of handling uncertainty, the scientific production of reliable cognitive and evaluative knowledge, controversial expert opinions, expert-lay divides, ambiguous interpretation of consequences, questions of risk-benefit distribution, questions of fairness and justice, issues of acceptability and the legitimation of collectively binding action and arrangements, as well as the trade-offs between conflicting goals, reveal a conglomerate of conflicts, problems and challenges that have not been adequately addressed by present risk regulation systems. This situation co-accounts for the disenchantment with politics and the discontent of people affected, which becomes an increasing cause for the distrust of public risk regulation institutions.

One of the implications that can be drawn from a reconstructive and interpretive understanding and explanation of relationships and structure is that the causal connections are not clearly visible. This is true for the relationships between the source and agent of risks, the social perception and interpretation of risks, the conventional risk estimation, risk management solutions and traditional risk communication that are integrated in a political culture of risk regulation restrained and dominated by techno-scientific systems and complex political processes and structures. Thus, the principle of responsibility is incrementally losing its collective function to guide, steer and restrain the classical risk analysis process and produces a contradictory situation. On the one hand, the proportion of individual responsibility with regard to the risk consequences is growing to a greater extent. On the other hand, a decreasing number of actors are solely responsible for risk impacts. The rise of individual responsibility comes along with the diffusion of accountability and reasoning which has far-reaching implications. The accumulating interconnectedness of individual and collective actors enhances the willingness to be prospectively responsible for tasks and thus the possibility to fail. To the same degree, retrospectively, the acceptability of acknowledging the responsibility and accountability in a case of failure is declining.

Debates about responsibility and accountability in the handling of risk and uncertainty give rise to a set of pressing questions about the ethical-normative foundations of political responsibility and accountability, the relationship between individual and collective responsibility, the diffusion of responsibility, the justification and communication of responsibility, and procedures allocating and producing responsibility. These questions have implications for how a risk governance framework that augments the classical risk analysis approach could reorganize and facilitate the execution of responsibility and accountability, as it raises the question of how power, authority and legitimacy can be enacted, differentiated and distributed. Can responsibility and accountability of socio-political processes and institutions that guide and facilitate the assessment, evaluation, management and communication of risk and uncertainty be distributed, and how? Based on today's structures, we could envisage a distributed system of responsibility and accountability in risk governance in a more decentralized and non-hierarchical system. In this light, we argue for a functional differentiation and distributed responsibility and accountability in risk governance in order to be capable of grasping and addressing the relevant cognitive and evaluative knowledge, the explanation of risk phenomena and consequences, the implications for human existence and social life, and the social and political principles and goals of how to avoid, mitigate and control risk consequences and undesired uncertainties (cf. Klinke and Renn 2012, 2014).

This rationale sets the stage for the article. Our goal is to elaborate on a functional differentiation through distributed responsibility and accountability that can be produced through epistemic, associational and public deliberation in the governance of risk and uncertainty. This notion addresses the need for an approach to normative-theoretical advances and institutional feasibility that devolves authority and shares responsibility beyond the conventional political system and fosters a deliberative democratization in our society (cf. Klinke 2016).

The classical model of risk analysis, including risk assessment, risk management and risk communication, lacks an adequate ascription of responsibility and accountability to institutions and processes that have the ability to acquire the scientific and experiential substance relevant to how to handle issues of uncertainty and ambiguity in the course of public policy making and regulation. The challenges are associated with the role, significance and contestation in terms of systematic expert knowledge, anecdotal lay evidence, the ability to make sound judgments, and the societal involvement of norms and values in risk governance. These issues are manifoldly discussed and theoretically founded in scholarly literature under key words such as "speaking truth to power" (Wildavsky 1987), "regulatory science" (Jasanoff 1990), "democratization of science" (Funtowicz and Ravetz 1993), "civic science" (Bäckstrand 2003), "democratization of expertise" (Liberatore and Funtowicz 2003), "when does power listen to truth" (Haas 2004), or "a functional division of labor for post-normal risk governance" (Klinke and Renn 2014). They also have been theorized in risk society and reflexive modernization as discourse and practice of science (Beck 1992). However, the literature does not sufficiently reflect on who has the ability to act independently and make substantial estimations and judgments on the epistemological, ontological and teleological dimensions of risk and uncertainty, and how it could be organized.

Our approach to address this deficit favors a design method that is a focus on redefining specifications of a risk governance framework in order to gain key insights and essential understanding that lead to a more holistic perspective on risk governance that is capable of distributing responsibilities and accountabilities in terms of the acquisition of cognitive expertise and societal experience. However, our approach is not an abstract and ideal configuration of risk governance institutions and processes. Rather, our methodological approach is to normatively and theoretically reason a possible realization of responsible risk governance as an attempt "to make sense of practice, and guides to the actions by which we forge practices" (Bevir 2011, 7). The following proposal of distributed responsibility and accountability in risk governance accentuates the significance of the functional differentiation and incorporation of expertise and experience. It relies on three pillars of distributed responsibility through differentiated deliberation in risk governance: epistemological, associational and public deliberation. It is a new approach to resume political responsibility that can be seen as legal obligation of risk governance in a democratic political system that we denote as a substantial political responsibility and accountability.

Epistemological Deliberation

We argue that collective decision making in a risk governance process embedded in a democratic system depends on the authority and responsibility of experts that are appropriately selected and substantiated by the experts' acknowledged ability to provide effective and truthful expertise on the basis of scientific evidence on risks and related opportunities as well as the likely impacts of different policy options (cf. Mansbridge et al. 2012; Christiano 2012). The principle of distributing competences and responsibility is a fundamental pillar in modern democracies. Passing on the task and duty to produce substantial cognitive and evaluative knowledge to experts is therefore entrusting responsibility to a group in society that has a comprehensive and authoritative systematic knowledge and scientific skills in terms of the interdisciplinary risk estimation and characterization that other actors do not hold. The process of epistemological deliberation places the responsibility for assessing risks, analyze associated social concerns and characterize a risk profile to the careful consideration and discussion of scientific specialists in natural, technical and social science areas because they are the only actors that can generate reliable and profound scientific insights and the related substantiated body of knowledge that is policy-relevant. The designation as risk expert authority "is itself often conditionally earned through deliberative means and within specialized deliberative communities" (Christiano 2012, 15). These epistemic communities comprise loosely connected actors, each with issue-specific knowledge and competences, who seek to collectively facilitate convergence and agreement on cognitive and evaluative understandings and policy-relevant problem solving (Haas 1992).

The epistemological deliberation includes the scientific assessment of the risks to human health and the environment, an assessment of concerns, an estimation of social and economic implications and an ascertainment of irreducible scientific uncertainties. Experts of natural and technical sciences should produce the best estimate, including an assessment of exposure and vulnerability, and of the physical harm that a risk source poses. If possible, the estimate should be based on quantitative data. Experts of social sciences identify and analyze the issues that individuals or society as a whole associate with a certain risk. For this purpose, social science methods such as surveys, focus groups, deliberative opinion polls, structured hearings, econometric analysis or macro-economic modeling are valid inputs in the deliberative system because they can help to gather risk perceptions and experiences, and measure psychological stress and social vulnerabilities and conflicts (cf. Chambers (2012). Additionally, available information about irreducible and irresolvable epistemic and genuine scientific uncertainty need to be collected, and the potential for cognitive and evaluative conflicts are revealed. In conclusion, a deliberative assembly of natural, technical and social sciences is supposed to characterize the risks beyond the established assessment criteria and ascertain a risk profile (cf. Klinke and Renn 2002; WBGU 2000).

We believe that pre-estimation and interdisciplinary risk estimation require a deliberative process in which recognized scientists draw upon the classic ideal of deliberation in order to gain cognitive reference frames and meaning structures. Scientists aspire to identify and analyze relevant science-based data and knowledge, jointly learn about cognitive and evaluative understandings as well as define issue-specific challenges, especially irreducible uncertainty and issues of socio-political ambiguity. Scientific deliberation is based on coherent and conclusive reasoning and the persuasive power of arguments that emanate from probative facts, logics and systemic knowledge. This in turn sheds light on the risk sources and effects, the complexity of identifying and mapping cause-effect relationships, the remaining irreducible scientific uncertainties, and the consequences for current and possible future developments. The cognitive evidence and arguments exchanged by experts can be empirically verified on the basis of traceability and consistency. They resonate with their shared causal beliefs. The major task of expert deliberation is to ascertain the most cogent cognitive explanation of the risk phenomena in question as well as to clarify dissenting views (e.g., by addressing the socio-political, economic and/or environmental impacts which are to be expected given specific regulatory activities). The overall goal is to establish consensual knowledge about cause-and-effect relationships, uncertainties and ambiguity and policy-relevant criteria for judging acceptability and tolerability of a given risk. Since truth seeking motivates scientific experts, communication in the deliberation process aims at an agreement in the form of a cognitive convergence, i.e., the participating experts agree on a single outcome of pre-estimation and interdisciplinary risk estimation for the same reasons because no significant conflicts of opinions and interpretations emerge, and negotiation and bargained compromise are excluded (cf. Mansbridge et al. 2010, 70).

The epistemological deliberation will be socially and politically acknowledged and respected as institutional responsibility for the decisions on risk estimation and characterization when the deliberation is embedded in and takes place among legitimate risk-research institutions with relevant expertise, risk competences and consultative skills. State-run risk agencies, expert advisory bodies, institutes of higher education, independent and neutral research institutes and non-profit, impartial think tanks can, if they are able to facilitate the state of the art in the respected knowledge domain and if they are recognized to represent the respective epistemic community, provide professional expertise and resources that generate cognitive and evaluative knowledge relevant for reference frames and meaning structures (cf. Rich 2004). They can also validate ideas and concepts about and criteria for risk characterization and risk evaluation. These research entities possess substantial authority because they operate through a sense of credible obligation when it comes to the objective and unprejudiced production of expert knowledge and systematic information that is generally accepted by the public sphere. An example of an acknowledged state-run risk institution is the German Federal Institute for Risk Assessment—despite some critiques—that identifies and assesses risk with regard to consumer health through expert deliberation within a network of scientific institutes. Another example is the European Food Safety Authority that relies on the deliberation of expert committees and a Europe-wide network of risk research institutes to assess food and feed safety.

Though the structure of distributed responsibility through differentiated deliberations is not organized hierarchically and expertise is not superior, the subject of the epistemological deliberation is distinct from the central matters of associational and public deliberation, but relevant as it provides the substantial expertise that marks the beginning of the risk governance process. Hence, experts produce the cognitive and evaluative reference frames and meaning structures on which the other deliberative processes and institutions ought to rely. Associational and public deliberation "draw[s] from the rewards of expertise while reducing the potential deliberative costs of bias, disrespect and non-inclusion" (Mansbridge et al. 2012, 14). However, this expertise may not be self-explanatory for common-sense understanding and "competent experts are not adept at explaining the reasons for their decisions to non-experts, the system as whole requires some agents with the capacity to translate expert conclusions into recommendations" (Mansbridge et al. 2012, 15) that participants of associational and public deliberation can comprehend and continue processing.

Associational Deliberation

Meeting the disputed responsibility in terms of risk evaluation is the second pillar of a distributed responsibility in risk governance. We propose associational processes and institutions of deliberation that foster the interplay between scientific expertise and stakeholder experience. Associational deliberation refers to a group-based approach in risk governance that involves experts who represent the cognitive and evaluative reference frames and meaning structures of risk estimation and collective actor groups, who represent government, economic interests and public interest and bear the responsibility to deal with the ontological and ethical challenges and issues related to risk phenomena. Associational deliberation shapes an arena for a reflexive debate in which relevant collective actor groups of the state, society and economy exchange issues and lessons associated with the given risk that they learned from their lifeworld of experiences in a narrative way. Round table discussions, mediations and negotiated rulemaking are procedures that actively engage collective actor groups and have often proven to be valuable in real-world public policy making (Beierle and Cayford 2002; Renn et al. 1995).

The cognitive and evaluative reference frames and meaning structures produced through epistemological deliberation enter the associational deliberation as valid scientific substance forming the starting point of discussion. It begins with experts giving testimony. The responsibility of the agents representing scientific expertise in associational deliberation is to familiarize the other collective actor groups with the cognitive and evaluative reference frames and meaning structures that they, scientists, have attained through risk estimation and to reveal the challenges associated with the genuine and epistemic character of scientific uncertainty. However, the nature of risk means that actors need to acknowledge that science cannot adequately describe the virtual socio-political implications resulting from scientific uncertainty. The participants of the associational deliberation have the opportunity to question the cognitive and evaluative knowledge given. The collective actor stakeholder groups add their experiences and perspectives, gleaned from social life, and discuss commonalities and conflicts associated with a given risk. The stakeholders' perceptions of and reactions to uncertainty affect the situations and contexts as well as the behavior that is relevant when acceptability and tolerability are determined. The amalgamation of scientific and experiential substance creates an epistemic and moral surplus that enables the evaluation of risk on the large scale of society by judging the acceptability and tolerability of risks that are deemed to be socially and publicly reasonable in the light of the common good which is an essential process in risk governance.

The collective actor groups prejudge whether and to what extent society would accept the consequences of the risk being implemented and the remaining uncertainties and tolerate the tension between the responsive actions of appropriate safeguarding and acting under insecurity. In this regard, the participants encounter questions about the scope and profoundness of safety, protection and precaution. Here, perceptions of just or unjust distribution of risk and benefits are highly significant. Stakeholder deliberation seeks ways to ensure that good reasons are exchanged to elaborate to what extent uncertainty is reasonable for society, the necessary level of safeguarding, and the margin of safety that one is willing to invest in order to avoid undesired consequences. Through deliberation, stakeholders attempt to establish a balance between too little and too much precaution, agree to trade-offs between the competing extremes of over- and under-protection, and orient themselves to a pareto-optimal equilibrium in the degree of risk regulation. In so doing, the participants also try to pre-estimate the practical relevance and impact of preventive, adaptive and mitigative strategies and measures (e.g., containment of application, safety margins, extending retention etc.).

Drawing on Parkinson (2006, 148–150), we argue that the legitimate source for participation in associational deliberation is relevance and not a broad variety of groups or a fixed set of traditionally defined groups. Hence, the relevant kind of stakeholder is one who is affected by the risk decisions. It is important that agents responsible for the organization of risk governance take into account who is affected by the risk, actively seek to engage them, and justify their relevance. Furthermore, stakeholder groups ought to have the chance to nominate themselves and thus assume political responsibility. The selection of the relevant stakeholders does not reflect statistical representativeness, electoral or proportional representation or a selection based on partisanship, but should be a mirror of a variety of relevant perspectives. The participating representatives of collective actor groups personify an extraction of experiences and viewpoints of the society affected by the given risk. Hence, distributed responsibility in risk governance can claim a kind of descriptive representation of society because participants share experiences, social characteristics and underlying beliefs and values with outsiders (cf. Parkinson 2006, 154–155).

The Ethics Council on Energy Transition in Germany serves as an example of an intermediary and moral authority in a larger context of governance arrangements that accepted the responsibility to appraise the risk and benefits of phasing out of nuclear energy and render the decision of a transitioning to more renewable forms of energy (Renn 2015). The council acted as communicator and facilitator between the state and society in a pluralistic and corporate manner. The Council was established by the German federal government in 2012 in the aftermath of the Fukushima disaster and comprised representatives from the scientific community, government, the economic sector and civil society. The Council was associative and self-dependent in nature. The Council's recommendation and decision has been unanimously approved by the German parliament.

Another example is the UK Chemicals Stakeholder Forum that advises the UK government, specifically the Department for Environment, Food and Rural Affairs. The Forum evaluates risks of using chemical substances that are hazardous to the environment and to human health, and establishes priorities in terms of risk reduction. The Stakeholder Forum's risk evaluation is based on the scientific risk assessment of an expert deliberation within the Hazardous Substances Advisory Committee which is responsible for the compilation of the science-based background knowledge.

Public Deliberation

The third pillar of distributed responsibility in risk governance is that the public at large assumes the responsibility to share sovereignty over risk decisions and the framing of binding recommendations by means of deliberation that would be put to a vote.[1] Public deliberation constitutes a direct-democratic practice in risk governance where non-partisan, unorganized laypeople that are affected by a given risk are entitled to bring in their experiences and desires, have their voices heard and directly influence the risk decision making. Public deliberation is based on public reason giving that is intended to promote agreement. We canvass for public deliberation to be built into the heart of the formal democratic decision processes. Public deliberation would take place in the form of mini-publics, such as consensus conferences, citizen juries or panels, and deliberative opinion polls that are composed of ordinary citizens (cf. Fishkin 2009; Goodin 2008; Goodin and Dryzek 2006; MacKenzie et al. 2012; National Research Council 2008). Mini-publics do not meet claims of statistical representativeness or electoral representation, but the

[1]For different ways on how public deliberation could work at the core of formal democratic decision making, see Goodin (2008). Cf. also Warren and Pearse (2008) who analyze the case of a citizen assembly in British Columbia, Canada, that was empowered to make a decision on the electoral system which led to a referendum. Cf. also Chambers (2012).

"deliberation in these mini-publics is representative of—and hence can substitute for—deliberation among mass publics that simply cannot deliberate together in the same ways" (Goodin 2008, 11). Mini-publics meet some standards of representativeness of the public at large because the diversity of social characteristics and the plurality of perspectives in the larger society is substantially present, as Goodin (2008, 13) puts it.

We propose that citizens in mini-publics reason together about the risk decision by exchanging narratives about and making claims on the same topic (cf. Parkinson 2012, 154). Experiences with mini-publics reveal that citizens develop well-considered and reasoned valuations that can solidify the public opinion at large, complement expert judgments and formulate politically relevant policy options (MacKenzie et al. 2012, 95). Hence, public deliberation via mini-publics has two specific scopes of responsibility in risk governance: setting socio-political goals and establishing strategies for risk policy, and addressing socio-political ambiguity. To do so, mini-publics must receive the cognitive and evaluative reference frames and meaning structures as knowledge sources, hear the evidence and reasons behind it from the experts and then question them. They should also hear testimony—judgment of acceptability and tolerability—from agents of the stakeholder groups. After this, the citizens, who may have both common and conflicting interests, would deliberate on the specific risk at hand. They would determine the precepts and strategies for action that would instruct the specific public policy addressing the risk. "The best discussions clarify both conflict and commonality, and perhaps forge genuine commonality where it had not existed before" (Mansbridge 2006, 118). More practically, the mini-publics would reflect the reasons for specific risk management options, and participants would make a well-informed opinion based on a reasoned weighing of the options (cf. Klinke and Renn 2010). In so doing, mini-publics would strengthen the risk governance structures and processes by producing trust relationships with the public at large and executive agencies of the government (MacKenzie et al. 2012, 96–97). The public at large would trust the mini-publics because they would serve as faithful custodian of the information and experience that guides the people's political judgment. Government executives might trust public deliberation to help guide the risk decision making because they could anticipate public opinion on risk phenomena that has not yet been attached or cannot be grasped at all, especially with regard to contentious issues arising from socio-political ambiguity.

In the framework of the Great Lakes regime, mini-publics haven established as a part of the political process to discuss revision of the Great Lakes Water Quality Agreement (Klinke 2006, 2009). In these mini-publics, participants heard from experts and stakeholders and engaged in extensive discussions and then made recommendations that led to the enactment of the new 2012 Great Lakes Water Quality Agreement. Another example of effective mini-publics is the public deliberation about a waste disposal strategy for the Black Forest area in Germany. In the first phase, a roundtable of stakeholders determined policy goals and developed several options on how to meet these goals. In a second phase, randomly selected citizens of the area were asked to comment on these options and delineate lessons for their own municipality. Finally, the citizens were asked to locate waste facilities that would meet the goals of waste disposal and explicit fairness criteria.

When experts dissent, expert/lay divides or moral disagreements become apparent because of interpretive and/or normative ambiguity,[2] and citizens can attenuate the risk issue by addressing the underlying norms and values that manifest the inherent conflicts. To this end, citizens can cross-examine witnesses that represent conflicting perspectives and disputed claims. The citizens then determine which substance might be the basis for an agreement or account for dissent in the light of the cogency of the dissenting views, especially with regard to their factual and common good-related claims. What are the reasons for the dissent? How can differences be overcome? Is additional expertise necessary?

Cases of high levels of socio-political ambiguity may induce more conflict than commonalities in mini-publics, though, in such instances, the deliberation can at least clarify the obscured outlines of underlying friction. Such a discussion can lead to the revelation of antagonisms and repudiations, and thus to greater mutual understanding. According to scholars who advocate an expansion of the deliberative ideals for the practice in democracy, public deliberation may eventuate into a process of negotiation where the mini-publics cannot reconcile conflict and difference in opinions. "In negotiation, the members of the group try to craft a decision that all members can accept as better than their best alternative to a negotiated agreement" (Mansbridge 2006, 119).

Conclusion

This book chapter has argued for a shift from governmentally driven risk regulation with a classical approach to risk analysis to a risk governance framework that constitutes distributed responsibility by means of differentiated deliberation modes in order to be capable of tackling uncertain and ambiguous risk phenomena in way that is deemed to be socially and publicly acceptable. The notion of distributed responsibility in risk governance has an analytical-descriptive and normative dimension: as an analytical description of how responsibility and decision making in terms of risk estimation, evaluation, management and policy choices can be functionally shared and as a normative conception for improving the execution of this obligation through ways and means of deliberative democracy. The distribution of responsibility in risk governance directs our attention to the societal and political obligation to tackle issues of uncertainty and ambiguity that many risks are associated with and give rise to epistemological, ontological, ethical and teleological questions. We have outlined a risk governance frame with a functional differentiation that assigns particular responsibilities and tasks to experts, stakeholders and

[2]For the definition and explanation of complexity, uncertainty and ambiguity, see Klinke and Renn 2012, 2014).

the public because such a distributed responsibility through differentiated deliberation enables the integrative production of expertise and experience. In addressing the nature and scope of epistemological, associational and public deliberation, we have attempted to elucidate who is responsible for what, and how scientific and experiential substance via deliberative means can be acquired. This chapter contributes to the debate about the relationship and collaboration of the state, society and experts, as well as the tension between the scientification and democratization of risk decision making.

In advancing the democratic polity for risk governance, the institutionalization of distributed responsibility in risk governance structures and processes can contribute to increase legitimacy, accountability, political reasoning and effectiveness because it strengthens the role of society in risk policy making. It does this by rescaling political responsibility and authority through (1) reshaped existing risk governance institutions and (2) new and innovative risk governance institutions. First, existing risk governance institutions need to become institutionalized focal points and fill new, active roles that facilitate the distribution of responsibility. Second, new risk governance arrangements need to be institutionalized with an adequate political concept of distributed responsibilities by means of differentiated deliberation that constitute a democratic polity that complements our representative systems.

However, it is important to acknowledge that obstacles have to be faced in the institutionalization of the proposed distribution of responsibility in risk governance. We would like to draw the attention to two crucial issues that cannot be resolved conclusively from the perspective of our proposal. First, distributed responsibility in the form of epistemological, associational and public deliberation relies on the willingness and active participation of collective and individual actors. This claim has a procedural dimension to it that concerns inclusion/exclusion, the gate-keeping role, representativeness and adequate forms of direct involvement. Which members of epistemic communities will be recognized as experts with discernment? Which stakeholders and individuals are seen as trustful and having the ability to judge well? Which interest do collective actor groups represent? Who decides on the rules governing representation? Which deliberative forms and procedures are adequate? Answers to these questions are contested in policy and academic literature alike.

Second, deliberation presupposes procedural properties and conditions that facilitate reason giving and persuasion, even though restrained forms of bargaining and negotiation are acceptable when they led to a communicative agreement. Here, a substantial claim is crucial. Associational and public deliberation prompt the participants to assert publicly acceptable reasons and justifications. Such public reasoning presumes individual capability in terms of deliberative competences and skills. Hence, the outcome of a communicative agreement depends on participants being able to translate their interests into a commonly acceptable language and to differentiate conclusive from implausible narratives and good from bad reasoning (Bohman 1997, 337–338; Forst 2001, 362). The more the participants give reasons in favor of the common good, the more likely it is that they can resolve conflicts and achieve one outcome. Yet the reference frame and meaning structure of the common good also need to be defined by deliberation, taking into account the affected people of a given risk and the relevant substance.

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Chapter 3
Economic Growth: Opportunity or Risk

Michael von Hauff

Introduction

The assessment of economic growth is a subject of intensive controversy. This controversy is not a new one. In 1967, Mishan outlined the negative consequences of economic growth in his book entitled “The Costs of Economic Growth”. A characteristic feature of the current debate is that the controversy is becoming more diversified through the approaches of proponents and opponents. Advocates of growth view this as an opportunity for greater prosperity and stabilization of market-based systems, while opponents see in growth the risk of increased environmental pollution and an increasing disparity of distribution in terms of income and wealth. This controversy can be anticipated to intensify even more in the future.

Different approaches are of course also adopted amongst representatives of these two antitheses. Some advocates of economic growth scarcely acknowledge the risk. For example, in his widely used textbook “Introduction to Modern Economic Growth” (2009), Acemoglu ignores the problem of environmental risks, whereas some advocates of growth perceive the ecological risks and urge that these be reduced (Weder di Mauro Weder die Mauro 2008). Although taking these risks into consideration, such proponents nevertheless continue to see great opportunities in economic growth, amongst other things, by increasing people’s prosperity. The critics of economic growth also include representatives who fundamentally reject growth (Jackson 2013) or even call for a reduction in growth (representatives of degrowth economics such as Latouche 2009). On the other hand, other critics of growth favour ecologically and socially balanced growth in the context of sustainable development. Nevertheless, the risk of economic growth is essentially a predominant consideration for growth critics.

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Both growth advocates as well as their opponents take as a starting point macroeconomic growth, the indicator for which is the gross domestic product (GDP). However, this common starting point is problematic insofar as overall growth of a national economy only occurs in exceptional cases. In reality, there are sectors with varying degrees of growth, some which stagnate and others which are shrinking. A further consideration is that growth emerges through dynamic structural change in the various sectors. Economic sectors can be subject to stagnation and shrinkage, and new sectors—particularly service-oriented sectors such as the IT sector—can advance to become growth sectors.

On examining further the relationship between growth and the environment, additional factors are to be taken into account: some growth sectors are extremely harmful to the environment while others have only a slight environmental impact. The former, which cause climate change, for example, can certainly be classified under the "growth as risk" heading, whereas the latter type of growth sectors represent no risk from this perspective. Thus, there are growth sectors such as the spheres of health and nursing care, including care of the elderly, which are largely unproblematic in ecological terms, and from an economic and social perspective are fundamentally desirable. These sectors can unreservedly be categorized as "growth as opportunity", and in this context, they can also be seen as examples of balanced or sustainable growth.

On examination of the growth sectors which can be classified under the "growth as risk" heading, the question arises as to how these can be transformed into more environmentally friendly sectors. In Germany, this is illustrated by the energy sector, a growing and very environmentally polluting sector. By switching to renewable energy sources, this form of environmental pollution can be greatly diminished by reducing emissions, thereby enabling the growth risk to be adapted into growth offering opportunities. It should, however, be borne in mind that the creation of renewable energy sources requires specific rare earths and rare metals, which diminishes certain non-renewable resources. To an increasing extent, this is seen to involve the risk of scarcity (Reller et al. 2013).

The opportunities and risks relating to economic growth should of course also be viewed and evaluated from the perspective of demand, i.e. consumption. From the perspective of consumer sovereignty, growth of consumption is seen as an opportunity aimed at offering everyone the possibility of acquiring those consumer goods which conform to their preferences. The challenges presented by the three dimensions of ecology, economy and social issues should be examined from the perspective of sustainable development. This results in both ecological as well as social risks. Consumption can lead to environmental pollution and too much consumption can adversely affect well-being. Concepts such as consumerism and conspicuous consumerism were developed in this connection, phenomena which had been brought to light back in 1899 by the American sociologist Thorstein Veblen (1899). In this context, Jackson therefore proposes a redrafting of the paradigm that consumption must always grow (Jackson 2013).

The Different Approaches to the Growth Controversy

The comments in this chapter are confined to the predominant approaches to the growth controversy, and the illustration below shows that, in principle, five distinct approaches can be identified. In the neoclassical growth theory, and its subsequent development within the context of the endogenous growth theory, the main focal point is the justification of economic growth. The neoclassical growth theory views growth as an important contributor towards economic development and prosperity, and can therefore be classified under the heading of “growth as opportunity”. The relationship between growth and the environment is disregarded in most growth models. Some neoclassical growth models explicitly examine this relationship, which is frequently ignored by the opponents or critics of growth (Fig. 1.1).

The other four approaches are unambiguously critical of growth and call for an economy without growth or with decreasing growth. The common basis is that growth leads to an increasing destruction of the environment and thus jeopardizes the existential basis for human life (life-support system). As briefly mentioned in the Introduction, some approaches taken by opponents of growth also claim that a risk of growth is that it leads to a continuous growth in consumption and that although this does not in principle lead to an increase in prosperity, it can lead to an impairment of well-being. The following comments will now focus on the relationship of growth and the environment in the different approaches, and present an evaluation in the context of the “opportunity versus risk” antithesis.

Environment and Growth within the Context of Neoclassical Growth Theory

The proponents of the neoclassical growth theory assume that growth is necessary for resolving environmental problems. According to this theory, environmental problems can only be solved on a certain economic level, which is to be achieved through growth. Therefore, industrialized countries are afforded quite different possibilities for solving their environmental problems than in the case of developing

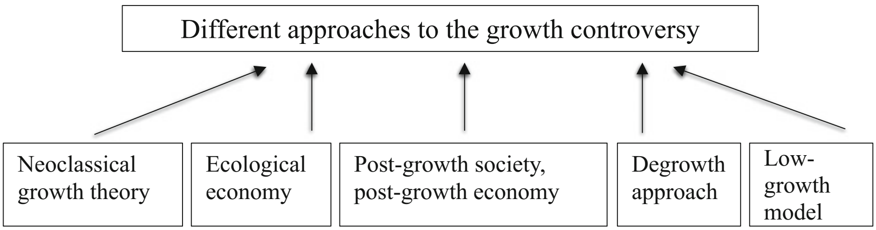

Fig. 1 Different approaches to the growth controversy. *Source* Author’s own illustration

countries. Furthermore, they fundamentally justify growth as necessary and desirable, as clarified by the following quotation: growth "is in Germany and Europe the only means of permanently guaranteeing quality of life and social stability. To this extent, as a political objective it has not only economic but also moral significance" (Paqué 2005, p. 1).

Robert Solow is regarded as the founder of modern growth theory. He presented his seminal growth model back in the 1950s with his article "A Contribution to the Theory of Economic Growth" (1956). Against the background of the first oil crisis and the heightened level of awareness created following the report by Meadows et al. "The Limits to Growth", the neoclassical approach was broadened in the 1970s to include the problems surrounding resources. The question of how to optimally establish the conditions to enable long-term growth if non-renewable resources are necessary for achieving growth was the main focal point of approaches to resource economics.

Furthermore, in some neoclassical growth models, environmental damage leads to limited production possibilities (den Butter and Hofges 1995). Therefore, a stabilization or even an improvement of the environmental situation involves loss-prevention expenditures, leading either to a reduction in consumption or a reduction of investments in production facilities. As a consequence, in the growth equilibrium based on a consideration of the environmental situation, the GDP is lower than in a comparable case taking no account of the environment. In summary, however, it is evident that the uncertainties and risks associated with scarcity of resources, and also with environmental pollution (e.g. caused by emissions) due to growth, are not sufficiently taken into consideration in neoclassical growth theory. Growth consequently implies a risk.

Environment and Growth within the Context of Ecological Economics

Ecological economics originated in the 1980s in the USA and was developed and established itself as a counter-position to neoclassical economics. Amongst the proponents of ecological economics, there is a broad consensus according to which constantly rising consumption of natural resources together with increasing environmental pollution, resulting from emissions for example, is not sustainable. They therefore view the economy as a subsystem of the ecosystem and reject further economic growth. This produces a call for a restoration of the economy within ecological limits, a position which they justify by the assertion that the quality of life in highly developed countries can scarcely be improved through quantitative economic growth. Furthermore, they also point to the limits of the viability of individual ecosystems and, in this connection, assert that some ecosystems have reached their stress limits or have exceeded them.

Daly (1999) in particular, and also other proponents of ecological economics, have called for a steady-state economy over the past few decades. This aspiration for a stationary state, however, has been developed in previous studies by other economists. Adam Smith, for example, investigated the stationary state of an economy (Smith 1776, p. 99). However, in contrast to the proponents of ecological economics, he arrived at the realization that this state led to poverty. He therefore came to the conclusion that only growth can guarantee prosperity. Meanwhile, other economists have taken as a basis the possibility of a steady state and, unlike Smith, have considered this to be desirable (Kerschner 2008, p. 125).

In the development of steady-state economics, Daly was particularly inspired by John Stuart Mill, in that he assumed that "an economy that does not grow nor shrink physically in the long run" (Daly 2005, p. 125). He bases the quantitative limits of growth upon the two laws of thermodynamics. These necessitate an intensified incorporation of scientific laws into economics. In contrast to the neoclassical growth theory, Daly became convinced that from a certain point onwards quantitative growth not only reaches its limits but is also uneconomic. In this connection, he gives the following example: a company, or a household, strives towards an optimal level of activities. If they exceed this level through additional activities, this may result in the additional costs (marginal costs) exceeding the additional benefits (marginal benefits). Daly describes this state as uneconomic. He aggregates these factors on a macroeconomic level. Increasingly more natural resources (green flow) are used to produce tangible goods (brown flow). "As we expand brown flow, we reduce green flow" (Daly 1999, p. 5). This results in "uneconomic growth".

The steady-state approach is widely criticized for failing to adequately demonstrate how it should be shaped and implemented. A further criticism, which is particularly expressed by neoclassical economists, focuses on the macroeconomic effects which are not analysed to a sufficient extent. Within the context of a market economy without growth, the following non-exhaustive list of factors should be mentioned: negative effects on the labour market, distribution, poverty, the financial sector, trade and the tax system (the counter-arguments are to be found in Daly 2008).

In conclusion, it is evident that the proponents of ecological economics call for an economy without growth due to the serious risks of economic growth. However, the macroeconomic consequences of this have not yet become fully apparent and it is not sufficiently clear how these consequences are to be overcome. In his article, Tichy demonstrates that for an economy without growth, safeguarding measures by the state with regard to the labour market and distribution policies will be indispensable. But he also comes to the conclusion that this has not yet been adequately thought through and elaborated in detail (Tichy 2009, p. 9).

Environment and Growth within the Context of the Post-growth Society or the Post-growth Economy

Following studies of the steady-state economy, a more recent discussion has arisen in connection with the approaches to the post-growth society or the post-growth economy, which likewise call for an economy without growth. The discussion on these two approaches reveals varying themes and emphases with regard to the relationship between the environment and growth. By way of example, the following comments are confined to a small sample of the findings (Hauff 2015, pp. 92 ff.). The connecting element in the two approaches to the ecological economy is the conservation and stabilization of nature and the ecological systems. Some publications concerning these approaches also discuss a stabilization of the social systems. The following quotation illustrates this: “The belief in the boundlessness of human expansion and needs, and trust in technological viability, inhibits the recognition that natural resources are finite, that the ecosystems are vulnerable and that increasingly more consumption scarcely creates greater happiness” (Seidl and Zahrnt 2011, p. 9).

This establishes the basis of a call for a change in lifestyles, and, particularly in this context, changes in consumer behaviour as well, and points to a departure from the “growth compulsion” currently predominating in mainstream economics and politics. In this connection, reference is often made to the need for a transformation process which goes far beyond merely partial reforms. In the view of proponents of the post-growth society, in the industrialised countries economic growth has not proven to be a far-reaching solution to social problems since the 1970s. For example, economic growth is no longer a contributory factor for a high level of employment. Moreover, economic growth has not promoted a reduction, but by contrast has produced an increase in social inequalities and, despite positive growth rates, national debt has constantly risen. And economic growth is increasingly faced with saturated markets.

As a proponent of the post-growth economy, Jackson is one of the most well-known critics of exponential growth. In his book “Prosperity without Growth”, which has attracted a great deal of interest, he expresses the view that for highly developed national economies of the western world, prosperity without growth is no utopian dream, but a necessity in terms of financial and ecological policy. After coming to the realization that in rich nations basic needs are satisfied in abundance and an increase in consumer goods can scarcely further improve material comfort, he raises the question: “In a world of finite resources, constrained by strict environmental limits, still characterised by ‘islands of prosperity’ within ‘oceans of poverty’, are ever-increasing incomes for the already-rich really a legitimate focus for our continued hopes and expectations? Is there some other path towards a more sustainable, a more equitable form of prosperity?” (2013, p. 4)

In addition to green economic policy programmes, as, in some cases, were implemented after the financial crisis, by South Korea for example, he also calls for an ecologically oriented macroeconomy which is designed to lead to a “Green New

Deal". In this connection he highlights the growth dilemma: on the one hand economic stability is to be maintained, while on the other hand the economy must be managed within the ecological boundaries. Ayres therefore calls for "a new growth engine, based on non-polluting energy sources and selling non-material services, not material products" (Ayres 2008, p. 292).

In this connection, models have been developed which, inter alia, target the need to reduce personal ownership as well as improving the use of capital resources increasing the material intensity of the economy. The basic concept here is to create and sell, instead of material products, dematerialized services such as the sale of energy services, for example heating, lighting and communication instead of energy from fossil fuels. This also includes the sale of mobility to replace the ownership of cars and the further development of recycling.

Environment and Growth within the Context of the Degrowth Approach and the Low-Growth Model

As a consequence of the concept of ecological economics, there was a development of additional approaches to the relationship between environment and growth, which will now be briefly introduced. In this connection the following comments will firstly focus on the degrowth approach and finally on the low-growth model. Whereas the proponents of the degrowth approach, at least in industrialized countries, call not only for an economy without growth but a reduction of growth, the proponents of the low-growth model base their concept on an economy without growth. They investigate the probable consequences of an economy without growth in the context of alternative macroeconomic scenarios.

A pioneer of the more recently established degrowth approach is the Parisian philosopher and economist Serge Latouche (2009). Proponents of the degrowth approach aspire towards a "fundamental transformation" as an alternative to economic growth. Consequently, this necessitates a reshaping of the sectors and institutions within society and the economy which are dependent upon growth and which stimulate growth, i.e. are "freed" from economic growth. This approach is therefore designed to overcome the existential dependence of many economic, as well as social, spheres from economic growth.

Analogously to the proponents of post-growth economics, degrowth proponents are particularly critical of the lack of awareness that natural resources are finite and that ecosystems are vulnerable and increasing consumption is scarcely conducive to greater happiness. They advocate a new paradigm for industrialized countries, in which connection it is evident that this relates not only to the relationship between growth and the environment, but that the social dimension of sustainable development, and thus society's relationship with growth, also has to be incorporated. Some of the fundamental principles are as follows:

- Placing the emphasis upon the quality of life instead of the volume of consumption.
- Achieving fulfilment of the basic human needs of everyone.
- Striving towards social changes, based upon a range of individual and communal activities.
- A substantial reduction of the dependence upon economic activities, thereby creating more leisure time.
- Observance of the principles of equality, participatory democracy, safeguarding human rights and respect for cultural diversity.

The objective is therefore to eliminate the risks of growth. However, the proponents of this approach have as yet not analysed in sufficient detail the specific consequences of a reduction in growth. In this respect, their approach differs from the low-growth model.

The economists Victor and Rosenbluth (2007) state three reasons why governments of states with highly developed economies should consider alternatives to the existing economic model:

- There is a prevailing scarcity of resources.
- In highly developed states, growth detracts from social prosperity.
- In western industrialized countries, political objectives such as full employment and reduction of poverty can also be achieved without growth.

In this context, Victor reproaches many proponents of an economy without growth, or shrinking growth, for reaching their conclusions without applying relevant models or taking into consideration the empirical methods of the modern economy. By contrast, they restrict themselves much more to qualitative information in order to illustrate or prove their arguments. Victor's approach is therefore based upon a computer-aided model for the Canadian economy, with which he seeks to investigate the effects of different growth scenarios on macroeconomic indicators. His simulation model contains, amongst other things, the variables of consumption, public expenditure, investments, employment, trade and the volume of production. He presented three scenarios on the basis of statistical data for the Canadian national economy, thereby arriving at projections of how indicators such as the unemployment and poverty levels, the per capita GDP, the debt ratio and greenhouse gas emissions will develop during the period 2005–2035, depending on the rate of economic growth. He develops three scenarios (Victor 2008):

- **Scenario 1 (business as usual)**: In this scenario, he assumes that the GDP trend will continue in a similar way to the last 25 years and that economic policy will not significantly change. With annual growth of 2.5%, social problems such as the unemployment rate would remain at roughly the same level, whereas poverty and public debt would increase and greenhouse gas emissions would rise by 80%.
- **Scenario 2 (no growth and low growth)**: A characteristic feature of this scenario is that growth will slow down severely or come to a complete standstill. In

the absence of any compensatory political measures, the macroeconomic trend would be devastating. The per capita GDP would stagnate, and poverty, unemployment and debt would increase sharply, which would likely produce social unrest. He calls this situation a “no grow disaster”.

- **Scenario 3 (low growth)**: This scenario shows that social prosperity can also be achieved without growth. He proceeds on the assumption that the per capita GDP will initially grow much more slowly and then completely stagnate from 2028 onwards. Measures will be taken by the state, such as income redistribution and other government programmes as well as a reduction of weekly working hours. As a consequence, unemployment and poverty levels will further increase in the first phase and then fall significantly below the base level up until 2035. Compared to 2005, debt and greenhouse gas emissions will in each case decrease by 30% and stagnate to a low level from 2018 onwards.

Victor presents the case for scenario 3, whereby this could be achieved through targeted political measures. In addition to a number of other measures, the reduction of total and average working hours plays a crucial role here. Alongside this latter measure, such action ought to also create a broader distribution of work to a larger number of people, which would positively influence the level of employment. However, he points out that in reality, these measures cannot be implemented to the full extent. These deliberations have recently been further developed by Victor and Jackson, in which connection they have examined the risks of growth and at the same time the minimization of the consequential risks of an economy without growth.

The Controversy from the Empirical Perspective

The relationship between growth and environmental pollution will now be examined on the basis of our own empirical research, which focuses primarily on the expanding sectors (von Hauff and Parlow 2014). This produces a differentiated analysis of which expanding sectors lead to environmental pollution. Furthermore, it enables an examination of whether environmental pollution in the expanding sectors is increasing or decreasing. These findings are of great relevance to a target-oriented environmental policy.

As part of this empirical research, the relationship between economic growth and economic pollution in 47 economic sectors in Germany for the period 1992–2010 was investigated. This focused on the CO_2/GDP relationship, in which connection some of the findings will now be presented. It is not surprising that the energy sector shows the highest CO_2/GDP ratio (see Fig. 2). This is explained by the fact that also in Germany, gas, oil and coal (including lignite) are at present still important raw materials for the production of energy. It is also evident that the processing industry in particular, which produces energy intensively, likewise creates a relatively high emission level. A consideration of the transport sector

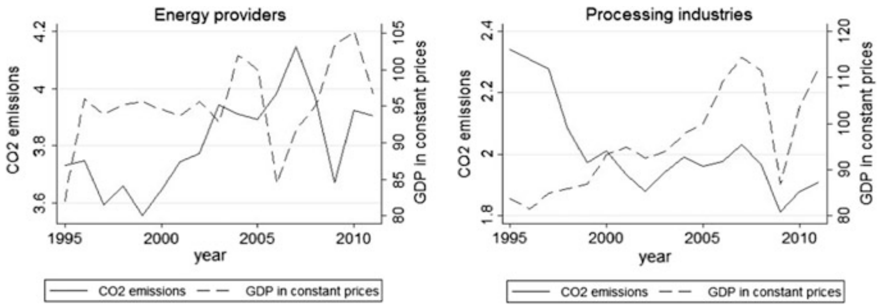

Fig. 2 Trends in CO_2 emissions and GDP—Energy providers and processing industries. *Source* Federal Statistical Office 2014

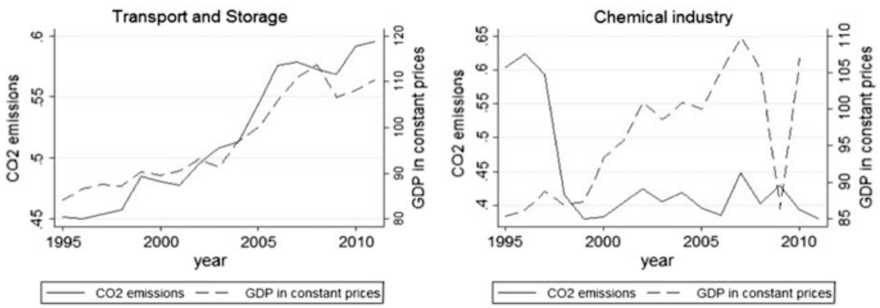

Fig. 3 Trends in CO_2 emissions and GDP—Transport and storage, and the chemical industry. *Source* Federal Statistical Office 2014

similarly shows a high CO_2/GDP ratio (Fig. 3). By contrast, the chemical industry demonstrates positive growth, while CO_2 emissions clearly decreased during this period. In conclusion: if the service sectors mentioned in the Introduction are also incorporated into the analysis of growing sectors, it is evident that only some growth sectors present relatively high environmental risks in terms of CO_2 emissions. Consequently, growth does not per se lead to environmental risks.

Conclusions

It has been possible to show that there is no simple answer to the question of whether economic growth leads to opportunities or risks. As has been demonstrated within the overall context of the controversy, if the macroeconomic indicator—GDP—is taken as a basis, a relatively clear focus can be placed upon the opportunities and risks of economic growth. In this connection, initial attempts to assess the economic consequences of an economy without growth within the context of complex macroeconomic models or empirical methods, and to demonstrate how these consequences can be reduced or avoided through economic policy measures, seem particularly interesting.

If, on the other hand, the focus is placed upon the relationship between growth and the environment from the perspective of individual branches of the economy, a different approach emerges which has as yet been disregarded within the context of the controversy. There are a number of economic branches which lead to considerable environmental pollution and are seriously detrimental to the quality of life. This can produce risks, which from a political perspective should be recognized and reduced. There are, however, also growth sectors which are scarcely detrimental and are socially desirable. In this case, growth offers real opportunities for improving the quality of life. To this extent, the view that growth fundamentally represents a risk and is therefore to be rejected, is not expedient.

If growth is considered from the perspective of consumption, it has been possible to show that constantly rising consumption can contribute towards both a reduction in scarce resources and an impairment to well-being. This trend, which is increasingly apparent in economically prosperous and aspiring national economies, introduced the discussion of sustainable consumption. Growing consumption can thus become a social as well as an ecological risk.

From the perspective of sustainable development, this is ultimately still a question of the relationship of growth and justice, which to a large extent has not been addressed in this article. In this connection, there have recently been a large number of publications demonstrating that, despite growth, inequality has increased worldwide—particularly in terms of income. In addition to the most recent publications, for example, by Piketty (2014) and Fratzscher (2016), the Organisation for Economic Co-operation and Development (OECD) has paid close attention to this subject. The titles of two studies should be mentioned by way of example: “Mehr Ungleichheit trotz Wachstum?” [“More Inequality Despite Growth?”] (2008) and “Why Inequality Keeps Rising” (2011). Growth therefore clearly offers no opportunities for more distributive justice.

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Chapter 4
Approaching Risk Management: General Perspectives on Handling Systemic Risk

Teresa Wildemann and Adrian Straub

Key Messages

A more interdependent and integrated world brings up systemic risks and a need for a global risk governance, which should not be driven by trial-and-error approaches but rather learn from existing risk-handling concepts.

The Role of Risk Management

The opposite of risk is security. "Regarding political and social awareness, the world appears more and more insecure and unstable" (Füller and Glasze 2014). As a consequence, it seems that security has become more important as well. A future scientist went so far as to proclaim that security would be "the new freedom" (Opaschowski 2010). Is this a reaction to the increasing complexity and connectedness we face in these times? Will this changing attitude towards security rob society of its capacity to handle risk, if only for preserving innovation and productivity?

Environmental hazards, climate change, immigration and integration, financial crises and terrorism: recent years have brought many diverse challenges. And not only have they grown in number, but they are also of an increasingly systemic and complex nature. The difficulties in dealing with the complexity, uncertainty and ambiguity surrounding such phenomena are evidence that there is no simple

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solution (Renn et al. 2011). Moreover, systemic risks threaten the collective, not merely the individual. A common trial-and-error approach would not be expedient—and could even be dangerous—and the damage caused might not be reversible.

Nevertheless, risk is (still) inevitable (Klinke and Renn 2002). Individuals, politicians, management boards or any other type or group of individuals endowed with decision-making authority have to face risk. Risk is part of the uncertainty of a decision's outcome and the difficulty in predicting future events (Knight 1921). Even if we know everything about a risk we face, there will still be an element of uncertainty, that which cannot be predicted or quantified. However, members of the workshop "Sustainable Risk Management" of the International Experts Group on Earth System Preservation (IESP) came to the conclusion that risk should not be interpreted as anathema to a successful decision. Furthermore, a risk, if addressed in the right manner, may even present itself as a chance worth embracing.

Risk Analysis and Evaluation as Part of Risk Management

Scholars have outlined various parameters of risk management and risk governance. However, in light of the many failures in governing these risks, these measures cannot guarantee success and may need to be reevaluated. During the 2016 IESP workshop, academics with expertise in various fields of knowledge pooled their experience to answer the question of how to deal with risk in a reasonable, responsible and sustainable way.

According to the findings of the workshop, knowledge and non-knowledge shape general risk handling by individuals or institutions. Therefore, responsibility and trust are essential. In every decision-making process, especially concerning systemic and complex issues, there will be knowledge, and there will be elements of the uncertain and the unknown. The individual or institution facing a decision that involves risk must accept responsibility for its own decision. The decision-making authority must be trusted by the stakeholders to take responsibility. Wachinger et al. (2013) suggest that a decision-making authority such as a government or an institution requires the trust of the stakeholders in order to successfully manage risk. If the actors do not trust the authorities, it is likely that they will not follow guidelines and will therefore jeopardize the governing authority.

In order to manage or govern risks, a decision-making authority should continually assess the ongoing situation. Risk governance may initially involve the critical evaluation of the environment in which the decision will be made, as well as a set of normative principles with which all relevant actors in a society should comply (van Asselt and Renn 2011). The experience of a natural hazard is an additional factor of risk perception. In fact, Wachinger et al. (2013) claim that it is the most important next to trust or lack of trust in authority. This is consistent with the findings of the IESP workshop: interaction between trust and responsibility is influenced by knowledge, which may originate from experience, or from lack of knowledge.

Renn et al. (2011) present several approaches for estimating risk: for example, by the extent of damage, probability of occurrence, reversibility, ubiquity and persistence of risk, delay effects, inequity and injustice, as well as spillover effects. Additionally, they note that risk analysis includes the best assessment of the physical harm a possible risk source represents. Scientific and statistical analyses may enable estimation of parts of these effects. The uncertainty, ambiguity and complexity of systemic risks arising from rapid technological change and an interconnected and integrated world make it impossible to be aware of all effects (Goldin and Vogel 2010; Renn et al. 2011). An awareness of the complexity and ambiguity of risks should not lead to their underestimation. Risks are often treated as if they were simple. Hence, the management of underrated risks lacks a sustainable purpose (van Asselt and Renn 2011).

After defining and analyzing a risk, the stakeholder or the trusted decision-making authority needs to evaluate the consequences and whether the risk should be avoided, reduced or accepted (OECD 2003). With respect to a reasonable evaluation of the effects of a systemic risk, as mentioned above, the responsible actors need to find a common normative framework upon which decisions can be made. This is important, since stakeholders are able to find a suitable solution only if their main goals coincide. Risk governance is about trade-offs, which adds to the concept of involving all stakeholders, or at least their representatives, in the governance and decision-making process. A democratic, participatory and deliberative decision-making process not only supports a mutual decision which incorporates several stakeholders; it also encourages institutional diversity which facilitates the governance of uncertain, ambiguous and complex risk. An integrated and diverse decision-making authority is capable of addressing problems with different scopes on different levels, appears to be more resilient in the decision-making process and facilitates the learning process within the responsible institution (Renn et al. 2011).

Klinke and Renn (2002) also describe risk evaluation as the determination of the acceptability of a given risk by societal institutions—social groups within society, agencies or individuals—in order to reduce or even eliminate risk.

Risk Governance Put into Practice: The Biopharmaceutical Industry

Collaborations in the biopharmaceutical industry along with their contracts present a possible example of risk governance. The discovery and development of new drugs is a very lengthy, costly and risky process (DiMasi et al. 2003). In order to facilitate and innovate drug development, pharmaceutical companies and biotech firms tend to cooperate (Lerner and Malmendier 2010). Collaborations in a risky environment such as the biopharmaceutical industry are therefore steeped in uncertainty and risk, not only with regard to the success of drug development, but also regarding the potential moral hazards and agency conflicts the collaborators face (Reuer and Devarakonda 2016). These contingencies drive both partners to the drawing of a contract which may include safeguards, provisions, governance and dispute-resolution mechanisms. Empirical research has proven that, among other factors, the content of contracts drawn up to mitigate risk is influenced by uncertainty, knowledge and trust (Gulati and Nickerson 2008; Lerner and Merges 1998). Collaborations in the biopharmaceutical industry try to mitigate specific risks which may interfere with the main goal: the development of a new drug. Approaches to (risk) governance in the biopharmaceutical industry are similar to scholars' opinions on managing systemic risk and the result of the 2016 IESP workshop.

A different approach to treating prospective contingencies is the establishment of an "administrative apparatus" (Williamson 1991) in the context of a governance mechanism, the aim of which is to manage risk in contracts. One example is a joint steering committee with certain ex ante-defined rights and authority, including reviewing, monitoring and approving, and to which both parties assign members. This committee facilitates joint decision-making, enhances communication within the partnership and fills the gaps of incomplete contracts. The presence of technological uncertainty during contract signing leads to the formation of joint steering committees (Reuer and Devarakonda 2016). Following Knight´s notion of risk, uncertainty can be treated as a measure of risk (Knight 1921). The committees are established to facilitate or even demand communication between the collaborators in order to prevent contingencies and mitigate the risk of failure. This is interesting, since Renn et al. (2011) propose that communication, positively framed, is "central to the whole endeavor" of risk management. In addition, the findings of the workshop suggest that the control of power, a form of checks and balances, is needed for sustainable risk management. Therefore, the constellation of such joint steering committees would be a key factor.

However, the uncertainties and contingencies that collaborators in an industry such as the biopharmaceutical industry face differ from systemic risks. The companies represent shareholders' interests and want to maximize their capital investment. Companies do not account for all stakeholders, and act mostly in their own interest. Their failure would cause damage for some, but usually not for the collective, and might also be reversible. Therefore, following the findings of the IESP workshop, careful consideration of systemic risks must take into account not only the benefits but also the disadvantages, and should compare several risks in order to find the best alternative for the collective.

Examples such as collaborations in the biopharmaceutical industry demonstrate an effective use of risk governance tools that have also been discussed and analyzed by scholars. A recent example is the merger agreement between Bayer and Monsanto signed in the fall of 2016. In the 2016 Harris Poll measuring of the reputation of companies in the U.S., Monsanto ranked fifth-lowest-among, for example, Goldman Sachs, BP and Volkswagen (The Harris Poll Reputation Quotient® study 2016). Bayer is taking on an uncertainty since the bad reputation of Monsanto might also reflect on Bayer´s reputation, although Bayer will grow to a global leader in the production of seeds, herbicides and pesticides after the merger of Monsanto (Statista 2014). In order to overcome the contingencies and deficiencies this deal holds, Bayer will need successful risk management and a responsible and trustworthy decision-making authority. Apart from that, the merger of Bayer and Monsanto might also be risky for society itself, as the two together would represent the agrochemical global market leader. It remains to be seen whether the market and society will be able to handle such a large institution.

Risk Governance and Globalization

There are several drivers that affect the emergence, the existence and the extent of systemic risks, with the effects of demographics, environment, technology and socioeconomic structure the most important (OECD 2003). Natural hazards affecting a single country or region, such as local flooding, are more or less easily dealt with if, as mentioned above, the affected actors trust and follow the instructions of the decision-making authority. The government or the institution in charge leads the way during the risk-management process and dictates how the issue needs to be governed. In the 2013 flooding in Europe, for example, a hybrid governance structure was employed to coordinate help. Hybrid governance models can be described as a combination of hierarchical and network governance approaches (Wittmann et al. 2015).

But clearly, if regional natural hazards are the outcome of a systemic risk, regional solutions will not be effective in the long term. With global systemic risks, risk management is elevated to a different level. Globalization can be seen as an additional step in global risk governance (Lidskog et al. 2011). For instance, environmental problems such as oil or air pollution, climate change, financial risk or cyber-terrorism illustrate global systemic risks or their outcomes. Globalization, economic growth and technological progress lead to greater interdependence and complexity. This interdependence and multidimensional integration could, for example, also lead to a global pandemic, since regional diseases might spread to the whole world (Ingram 2005).

Goldin and Vogel (2010) describe, as a consequence of this progression, the development of a global risk society, with the financial crisis of 2008–2009 the first systemic crisis to reveal itself. They also argue that the new interconnectedness of the planet in the twenty-first century gives rise to a different approach to global governance and risk management realized by national governments as well as by inter- and supranational institutions. As mentioned above, risk governance is also described by a set of normative principles with which all actors should comply. This creates additional difficulty for dealing with systemic risks on a global scale, since the different governments, institutions and stakeholders involved in the governance process must first agree on a normative basis. If stakeholders cannot agree on a goal, achieving successful risk management will be difficult.

Changing Leadership Qualities

Risk management requires trust and responsibility, and therefore good leadership qualities. No trial-and-error approach will be effective in facing systemic risk, as it will likely result in non-reversible damage—in other words, a complete "error".

Systemic risks and effective, sustainable and responsible risk management call for certain qualities, such as the ability to cooperate with different players or to act responsibly within a world that is more interdependent and integrated, as Goldin and Vogel (2010) noted. Furthermore, decisions concerning risks—and especially systemic risks—should be made fairly and must maintain a just balance of power. Ongoing assessments will be crucial, as the unknown and the unpredictable may increase. Joint steering groups can be part of effective risk management if their constellations are just and fair. A common normative understanding acts as a nutrient medium or even a condition for it. A fruitful attitude towards risks will be crucial for successful risk management, because there is a creative element in chaos, as experts of the 2016 IESP workshops affirmed.

A set of normative principles acknowledged by everyone involved in the decision-making process is imperative for the successful management and governance of systemic global risks. The immigration crisis in Europe, where members of the European Union cannot agree on conditions for sustainably managing this risk, presents one example where stakeholders have failed to do so. Agreements have been made but do not practically solve existing challenges, not least the long-term mission of integration. The governance of global climate change measures presents a different example, where leading industrial countries have not been successful in reaching consensus on a set of normative principles. The Paris Agreement of 2015, the global action plan for reducing climate change, brings hope, but its predicted goals will have to be proven. The Sustainable Development Goals adopted in a United Nations resolution in 2015 could also be seen as a set of such normative principles, as they are publicly shared guidelines and define thematic priorities for the next 15 years.

One potential difficulty in carrying out these proposals is that, despite the goals set forth regarding climate change mitigation and a specific global average temperature goal, there is no established reference system of normative measures to govern systemic risk management. These challenges, and the agreements mentioned above, are evidence of existing approaches to risk governance, and also clearly display the complexity and difficulties inherent in dealing with systemic risk.

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Part II
The Environmental and Ecological Dimensions

Chapter 5
Environmental and Ecological Aspects of Sustainable Risk Management

Martin Grambow and Jane Korck

Context Statement

Opportunities and risks are interconnected like effect and side effect. In the Anthropocene era, while we draw huge advantages from extensive technical changes, we need reformed risk understanding and risk management. Risks to or from the environmental changes can become a significant reality for mankind and its offspring. Risks take effect and interact in a complex manner; those that benefit from taking the risk and those exposed to it are very often not the same. This is reflected in paragraph "h" of the general recommendations issued by the participants of the workshop on "Sustainable Risk Management" (see Chap. 24): "*Risk management requires willingness to take responsibility. Decision makers have to take the likely consequences of their decisions into account. Only by responsible risk management and governance can trust in risk management institutions be created*" (slightly abridged).

Central facts to be considered are:

- Environmental risks take effect in combination.
- Environmental risks can only be recognized and interpreted when they are considered in their entirety and overall context.
- To this end, a risk matrix is proposed (recommendation No. 4, (see Chap. 25) that comprehensively represents the risks incurred in order to achieve an intended effect (and the risk of inaction respectively) as well as the risks evoked as a result (side effects) in all areas that significantly affect humans or the environment. In the same matrix, those that profit from incurring the risk and those exposed to the risk can also be listed as can those responsible for risk management.

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Introduction

The following article is influenced by the focus group “environment and ecology” of the workshop mentioned in the preface of this book. The group examined the question both from a technical/scientific and from a humanities-oriented and medical angle.

In the following, the term risk is discussed regarding both the intrinsic value of the environment and impacts on mankind and civilization. Constraints on and limits to dealing with risks (at the political level, in society, in the scientific community) are analyzed using a wide range of examples in order to reach a common understanding of the most important factors and processes that have positive or negative effects on risk management. The strong parallels between environmental and health-related risks suggest, in many cases, that conclusions and lessons learnt in environmental risk management can be applied to risk management in medicine or vice versa (see Chaps. 11–17 of this book). Finally, this leads to key recommendations and corresponding explanations compiled in Chap. 25.

Terminology/Definitions of Environment, Biodiversity

The term environment is defined as the combination of the components water, soil, air and light—understood as “received” energy, mainly from the sun (see schematic representation in Table 5.1)—based on Aristotle’s conception of the elements. In the “natural world”, the world prior to human impact, interaction between these elements created the climate, natural landscapes and, ultimately, life in all its variations.

Table 5.1 Schematic representation of the components of the environment before and during the “Anthropocene” era

Water	Life	A N T H R O P O C E N E	Degraded ecosystems
	Biodiversity		
Soil			Cultivated Landscapes
	Natural		
Air	Landscapes		
Light (Warmth)	Climate		Global Warming

Biodiversity (or biological diversity) is a widely used term with multiple definitions (Kaennel 1998). According to the definition used in Article 2 of the UN Convention on Biological Diversity it is "*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*" (UNEP 1992). Biological diversity is dependent on rates of genetic evolution which in turn depend on ambient temperature (warmth) (Gillman 2014). Even without human influence, natural systems have an intrinsic proclivity towards change, which amounts to "life" including all its opportunities and risks (H-P Dürr 2001). In the new "Anthropocene" era (Crutzen and Stoermer 2000), natural landscapes become cultivated landscapes and additional risks deriving from human activity emerge. As a side effect, diversity is rapidly decreasing (degraded ecosystems) (UNEP 2012) in an environment under permanent stress (e.g. the emission of greenhouse gases into the atmosphere is causing global warming). "Environmental risk" is the total sum of natural and anthropogenic risks.

Terminology/Definitions of Risk

The term "risk", as used in everyday speech, covers a wide range of different concepts often including a phenomenon better described as "uncertainty" (Knight 1924). In short, according to Knight, risk is measurable uncertainty and uncertainty is non-quantitative risk. Another widely used and similarly ambiguous term is that of "systemic risks" (e.g. EEA 2016). The definition proposed by the UK-based Systemic Risk Centre is "the risk of a breakdown of an entire system rather than simply the failure of individual parts" (SRC…c2013).

Risk, initially, sounds off-putting. But, as stated in the "Guidelines for the Readers", risks are a part of human life. We are incurring risks simply as a result of powerful technologies available to us today, whose imperative significance becomes apparent in the term geoengineering, i.e. targeted intervention into our global living environment. Sustainable risk management is consequently, in many ways, a prerequisite for preserving resilience, i.e. the capacity for proactive reorientation and the ability to make a fresh start when faced with unavoidable changes in climatic, economic or societal boundary conditions. Even with clearly identified risks, doubts remain as to the success of altruistic self-limitation on the part of those who benefit from the risk. The acceptance by individuals is not sufficient. What is needed is solidarity of actions in the interest of the greater good, even if the individual cannot profit directly. In conclusion, it is necessary to give the question of governance a more central role, because change can only succeed in the long term if the overall objectives are collectively anchored. Risk management becomes a civilizational task. Pope Francis takes this thought beyond the national level in Laudato Si (Pope Francis 2015) when he calls for stronger and more efficiently organized international institutions. Referring to the individual motivation of us humans, Sloterdijk calls for the upscaling of personal egoisms to more rational common decisions in the public interest as a "must" for survival (Sloterdijk 2009).

To motivate such processes, society must provide recognizable benefit-risk ratios that are open for discussion and use this as a foundation for risk management that is transparent and organized in and by society.

This requires a reliable definition and procedure for risk management. The International Risk Governance Council (IRGC) describes targeted and structured sustainable risk management (see Chap. 24). In each of the four steps of the IRGC risk model, the process of objectivizing the risk is accompanied by a subjective, emotional component.

This opens up a crucial connection with the psychology of risk coupled with the surprising human reactions to factual knowledge: the irrational way people deal with undeniable personal risks (e.g. smoking) is just one example. How much more difficult this makes good management in the light of multiple abstract, large-scale, complex or largely unknown risks!

Consequently, the technical definition of risk is, at best, half the truth. When it comes to common goods, risk management has much more to do with:

- the scientific recognition and description of the risk itself coupled with
- the psychologically directed societal willingness to even consider the risk and consequently to
- develop suitable universally binding response strategies along with
- the psychologically directed willingness of individuals and society to make a contribution (investing taxes or changing the behavior of others or even—if the worst comes to the worst—one's own behavior).

The following classification according to Wolfgang Bonss (see Chap. 1) has proved suitable for the description of different risk types also under the behavioral perspective (Table 5.2).

Table 5.2 Four-field risk matrix as proposed by Wolfgang Bonss

	Known (understanding)	Unknown (lack of understanding)
Known (awareness)	Normative risks	Technical risks
Unknown (lack of awareness)	Suppressed risks	Hypothetical risks

Challenges Arising from the Contemporary Environmental Risks

Basic Description of Environmental Risks

Environmental risks, according to the definition proposed earlier (Table 5.1), have to be understood in a new, comprehensive context:

In the Anthropocene, the known primary risks (natural hazards, wild animals, sickness, death, internal and external enemies and economic dangers) are seriously exacerbated by man-made systemic threats like climate change, environmental pollution and the destruction of nature. A key characteristic of the "new" environmental risks is that they are composed of innumerable individual components, making them complexly interactive, typically very difficult to identify and at the same time highly effective in that, together, they can have a critical impact on the earth system. This gives them particular ethical significance in the sense put forward by Hans Jonas, who warns mankind against taking risks which could threaten our survival (Jonas 1979). Peter Sloterdijk further specifies this approach by stating that the risk does not concern the survival of the human species but that of our values, our dignity and our civilization (Sloterdijk 2009).

In order to validate the statements above and gain a general understanding of the constraints and available options in environmental risk management, we take the examples of climate change, the loss of natural landscapes and agricultural practice:

Climate Change

The publication of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2014) documents the unprecedentedly high level of agreement in the scientific world about the anthropogenic causes of global warming. The well-informed proportions of the population understand that the world economy must undergo "decarbonization" and "depollution". In the political sphere, some excellent and courageous decisions were made, particularly the "Energiewende" (energy transition) in Germany. But worldwide, many political approaches don't take these findings into consideration. And yet, as described in the unpublished 2016 IESP workshop impulse statements by Wilderer and Toepsch (unreferenced), the sales of wasteful cars have never been higher and still continue to rise. In this sense, the risks posed by anthropogenic global warming seem to be suppressed risks, especially where mitigation is concerned. Risks relating to adaptation frequently fall into the category of the suppressed or even hypothetical risks, e.g. droughts and floods or the phenomena of large-scale flash floods (challenge of planning suitable and sufficient measures in the light of multiple and significant uncertainties). Another explanation is that those who enjoy driving a big and comfortable car are not the ones exposed to the risks the next generation is exposed to.

Regarding available options for transporting suppressed or unknown risks into conscious awareness, the challenges of an unimaginable future can be explored using models and scenarios. Such tools can also be used to assess the possible cost of inaction or the additional cost of delayed action, which can in turn provide motivation for the immediate implementation of measures. The Paris Agreement to keep global warming below 2 °C is a prime example of this effect, as it was ultimately the economic arguments that made the breakthrough in negotiations possible. At the same time, agreeing on limiting global warming to 2 °C is, in a way, not a rational decision as its systematic and binding implementation is, strictly speaking, impossible. Neither the achievement of the targets, nor the failure to do so, can be proven beyond doubt, and contributions towards failure or success can't be measured objectively. Nevertheless, in a different sense, the Paris Agreement is already a success today, because it forged a bond within a global community of nations whose representatives have acknowledged their joint responsibility to act.

The Loss of Natural Landscapes

A further example of suppressed or hypothetical risk results from the growing demand for land and a considerable lack of awareness regarding the dangers of uncontrolled growth. In combination with other land uses, peri-urbanization, with its insatiable hunger for land, is leading to an increasing loss of primary ecosystems, to extensive transformation of even the secondary cultivated ecosystems, to the marginalization of forests and other natural landscapes and to the loss of wetlands. This causes a significant decline in biodiversity and species abundance as well as the destruction of soils, whilst also disrupting the seasonal and long-term water balance. In addition, there is the currently not quantifiable impact on how humans perceive nature. The cumulative effect of these phenomena on the resilience of the essential function of the earth systems can hardly be gauged at this time. In conjunction with other risk factors, like chemical and waste emissions or the over-exploitation of deep groundwater resources, this creates risks in all of the four categories—from normative to hypothetical.

Agriculture

Agricultural land use is to be highlighted as a special example that reflects nothing less than an existential human dilemma: On one hand, due to the large-scale transformation of natural landscapes, the use of agrochemicals and massive water consumption, agriculture is one of the main causes of ecological risks for the planet (e.g. MISEREOR 2011; FAO 2013). On the other hand, feeding the population has the highest possible ethical legitimation. The projected increase of global agricultural production by 60% for 2050 compared with 2005 (Alexandratos 2012) is interpreted in the conventional terms of ecology and species protection as possibly jeopardizing all future considerations regarding conventionally understood sustainability.

In addition to these by virtue of their spatial magnitude and ubiquitously relevant risks, there is also a globally observable acceptance of breaches of norms in this domain. The unregulated or illegal exploitation of groundwater against all rational knowledge or the overuse of fertilizers and the improper use of pesticides can be observed all over the world—with dire consequences for humans and the environment (Rockström et al. 2009; European Commission 2013). This makes it one of the most distinctive manifestations of normative risk.

Only if the real risks for the earth system and our personal quality of life are widely recognized can there be a political opening towards alternatives in agriculture, like strict organic production, prevention of food waste and more effective protein production (e.g. less meat consumption).

The Ethics and Psychology of Environmental Risks

We, mankind, perceive these interrelations (see Chap. 6): It is remarkable how deeply, how inseparably the risks of the Anthropocene era are embedded in our psyche on the individual and societal level: Mankind is afraid of itself. We are caught in the ambivalence between naïve, life-threatening willingness to take risks and debilitating fear. Agriculture, as one example, is actor and sufferer under these developments, cause and effect are interwoven, the distribution of interests is too multi-layered to be transparent. Who can possibly be an objective and neutral party? A solution would have to be active, probably, in light of world trade and global environmental impacts, international risk ethics. These in turn can only be legitimized in a broad social debate.

Since the 1970s, technical progress has increasingly been discussed by scientists and philosophers under the fundamental global risk perspective. The Club of Rome already addressed the technical risks of resource consumption in 1972 (Meadows 1972). The hypothetical risk is, in part, considered very high. The philosopher Jonas and the biologist Wilson discussed the possible "suicide" of humanity (Jonas 1979; Wilson 1993), and both Sloterdijk and Welzer identify the fundamental endangerment of human civilization as the most probable scenario (Sloterdijk 2009; Welzer 2009). The global community is reacting to these warnings, especially within the framework of the UN, with its environmental resolutions on biodiversity, Agenda 21, the Millennium Development Goals (now Sustainable Development Goals (SDGs)) and the climate agreements. But economic interests, presented as the equally serious technical or hypothetical risk of shortages in the provision of goods and food, stand in the way of rapid implementation in national politics. So, whilst we are expected to accept that we are subjecting our earth system to irreversible changes of gigantic proportions, we are also led to believe that changes to our technological and economic system, optimized towards permanently increasing resource consumption, carry unacceptable risks (i.e. bank bailouts).

The global ethical questions resulting from this paradox are also being addressed by Churches and world religions. In his encyclical, published in 2015, Pope Francis discusses the resulting scientific and social cornerstones of the global system crisis. 2015 also saw the publication by Alt of the fundamental thoughts of his Holiness the Dalai Lama, who makes a passionate plea for new, ecological and peace-oriented global ethics. In his book "Ethics Are More Important Than Religion", he writes: "The difference between ethics and religion is like the difference between water and tea. Tea has other ingredients but its main ingredient is always water. We can live without tea but we cannot live without water" (Alt 2015).

Fundamentally, an ecologically based global ethic would be a desirable contribution to risk management. However, elaborating detailed specifications proves a difficult task. Again, with the Anthropocene, we have irreversibly transformed the ecological system; we have—so to speak—lost our ecological innocence (Haber 2010). We lack reliable criteria for reference conditions and even if we had them, there is no realistic prospect of reattaining them. So, a completely new question presents itself: What world do we want in the future or what are the criteria for sustainability? Do no-regret strategies exist?

Contemporary risk ethics must—in conflict situations—not only weigh up costs and benefits (all costs, not just monetary) in a public debate, but also include the risks resulting from the main and side effects of the activity from which the risk originates and communicate them accordingly.

Above all, this requires the incorporation of the fundamental principles of risk-ethics **precaution**, **concern** and **intergenerational equity** into the decision-making process.

Who Is Capable of Reasonable Risk Management? Political and Psychological Approaches: To Whom Can We Entrust This Kind of Risk Management?

Politics and the State

The method of collective learning through trial and error applied so far is becoming increasingly dangerous in the light of the dimension of global risks—the consequences of failure are growing more and more formidable.

Contributions to the debate seem to suggest that the entire responsibility for coping with these issues will continue to lie with politics (Jonas 1979), individuals willing to take responsibility and a collective and therefore politically relevant expression of opinion (see Chap. 3) in the future. But in this postmodern age, basal responsibility increasingly also extends to expertise and expert knowledge, which should also be included in decision making in a deliberative process. This results in a participative risk model according to the scheme

quantitative benefit/risk analysis (risk dialogue = (government + deliberative expert knowledge)) ↔ *parliament + society*

However, due to the complex global developments, the main subject of this political order—the State—is no longer a safe haven concerning social issues (e.g. influx of refugees) and economic issues (e.g. transboundary climate change). At the same time, a sustainable and globally effective legal order is missing that would create the necessary conditions for the protection of those vulnerable ecosystems and groups not yet affected by economically motivated lobbyism against the impacts of climate change. Some scholars recommend an expert system, but ask the question whether law can really regulate and assess something that it openly admits it does not know well enough?

Ecce Homo

Neurology and psychology provide us with highly valuable insights into the relationship between humans and rationality: The simple assumption that man acts as Homo Economicus does not always apply. The reasons are evolutionary: because we have always had to take practically all decisions based on incomplete conscious knowledge and information in a limited space of time, the quality of our decisions is higher when they are based primarily on subconscious experience-values and emotional association. One could even declare that: The assumption of the primacy of reason (Latin:ratio) is false! Every decision is based on intrinsic motivation (Chap. 9).[1]

[1]WIKIPEDIA: Intrinsic motivation is the self-desire to seek out new things and new challenges, to analyze one's capacity, to observe and to gain knowledge. It is driven by an interest or enjoyment in the task itself, and exists within the individual rather than relying on external pressures or a desire for consideration. Extrinsic motivation refers to the performance of an activity in order to attain a desired outcome and it is the opposite of intrinsic motivation. Extrinsic motivation comes from influences outside of the individual. Common extrinsic motivations are rewards (for example money or grades) for showing the desired behavior, and the threat of punishment following misbehavior.

At Harvard Medical School, the psychologist McCelland was able to demonstrate that when certain needs (according to his motivational model, the so-called Three Needs Theory) are satisfied, the body releases specific neurotransmitters:

- For power adrenalin (epinephrine) and noradrenalin (norepinephrine),
- For affiliation dopamine,
- For achievement arginine vasopressin.

Proposed Solutions: Merging Personal Benefit and Risk with the Global Risks

To maximize the chances of success, measures to achieve individual or collective behavioral change must actively use knowledge about intra-individual and inter-individual decision-making processes. This means that individuals and the collective must be addressed accordingly and synergistically motivated. At the same time, both the provision of the material conditions and the psychodynamic components of cooperation must be actively promoted.

This behavioral pattern provides a better understanding of how society can manage risks: In the examples above, as for the many others discussed but not recorded here, motivation was identified as the most crucial prerequisite for action. Particularly in the case of suppressed and hypothetical risks, but also for the other risk types, motivation to act must be created and sustained and destructive arguments must be countered (a point also recently made by Pope Francis (2015), e.g. Laudato Si, 14 and 56).

Sloterdijk makes a pessimistic prognosis regarding the likelihood of mankind on board Spaceship Earth behaving in a way that benefits the common good. He writes: "*We have become unable to imagine any form of freedom that doesn't include the freedom to accelerate, to travel to the most distant destinations, to exaggerate and be wasteful and ultimately the freedom to explode and self-destruct*" (Sloterdijk 2015). As a solution, he therefore recommends upscaling enlightened self-interest which would, of course, have to be communicated with the necessary emotional intensity (Sloterdijk 2009).

In actual fact, a link does exist between the highly individual matter of personal health and environmental protection—as regards intrinsic motivation, this is an important and transdisciplinary insight. Mortality—for example, from a heart attack—is greatly influenced by induvial life style and environmental factors. Causal analyses of this relationship appear to have been insufficient so far. However, in 1986, the Ottawa Charter of the World Health Organization (WHO) already stated that people should be motivated and empowered in an appealing way "to take their health into their own hands" in the places where they play, learn, work and love (Chap. 10).

Psycho-social and natural environment have a strong influence on motivation and other health-relevant parameters. Thus, there are regions in the world where people live much longer lives than elsewhere. The indicators analyzed in the "Blue Zone Project" don't specifically mention the environment, but it was included as an integral part of people's daily routine. Healthy exercise is probably easier in an "ideal landscape", or indeed any diverse and unpolluted landscape, than in a monotonous, intensively agricultural or smoggy industrial region (Chap. 10).

Activation Through Comprehensive Description and Explanation of the Risks

The fundamental recognition that the state of the environment is connected to one's own quality of life and life expectancy, possibly coupled with the sense of responsibility for one's own offspring, leads to an intrinsic motivation to act. Activation alone is, however, no use if there are no ideas as to what should be undertaken, avoided or how the general risk affects (personal) benefits and (personal) risk. Therefore, it is necessary to contrast the known benefits and advantages of undertakings with the real disadvantages and the manifold risk types.[2] It is also important to ensure transparency regarding the question of who benefits, who will ultimately be exposed to the risk and who is therefore either an advocate or an affected party. Also, the actors and responsible entities should be identified and made known. Alongside immediate emotional accessibility and transparency, the representation should also include alternative solutions, and opportunities, respectively.

Only transparency provides access to abstract issues which would otherwise be considered too complex and, on the emotional level, "unsolvable". Abstract, "unsolvable" presentations create cognitive dissonance and then reduction which may read: "before I let it upset me it is easier just not to care".

Demand No. 1: Risk—Combination—Transparency

Environmental risks take effect in combination. Most risk examples quickly displayed a high, potentially overwhelming level of complexity (for example, the frequently simultaneous occurrence of all four of the previously mentioned risk types) which can make environmental risk management off-putting, especially for politicians or local administration. A possible solution lies in a comprehensive but still comprehensible visualization of different environmental risks, in which possible measures, or "remedies", motivation and instruments are summarized in simple terms.

Demand No. 2: Benefit—Risk—Transparency

The interwoven interrelationships between risk components should be made accessible for reasonable assessment so they can be the basis for deriving ethically

[2]This approach is fundamentally reminiscent of the Environmental Impact Assessment and Strategic Environmental Assessment, though these don't include references to risks or the naming of different acting parties.

founded evidence or political recommendations for action. As stated above, one difficulty is the fact that those exposed to the risk are often not the beneficiaries of the opportunities associated with the risk.

> Therefore, the following applies: A solution-orientated approach to risks should not be determined by individual interests or the unilateral exertion of power. The key issue is ensuring transparency regarding benefits and risks.

Recommendation: A Conglomerate Risk Inventory

To this end, a risk model is proposed that visualizes the conglomerate of risks ("risk conglomerate") as a product of relevant human activities (e.g. economic sectors):

For this risk conglomerate, a structure according to the following criteria is proposed:

1. A dynamic risk inventory classified according driving forces (e.g. sectors).
2. Differentiation between normative, technical, suppressed and hypothetical risks, as well as between conventional (relating to individuals or organizations) and systemic (overarching, supra-personal) risks.
3. Along with the definition of the risk itself, the risk inventory should also incorporate the benefits/opportunities and the potential or likely costs. Both categories can lead to a risk being taken or avoided. They may also serve to explain taboos and justifications that might be the underlying causes of the negation of a risk. In addition, specific remedies and measures and the responsible institutions should be listed.

As stated above, the risk inventory is organized by sectors. In some cases, several matrices per sector will prove necessary in order to accommodate wide-ranging subject matter. Also, the scale of application should be kept in mind, as the joint representation of local, regional and global information may not always be possible (Chap. 3) on the process of "Framing" in Risk Governance). The suggestion of making the risk inventory a living document reflects the joint conclusion that we need a culture of re-evaluation of past decisions, as these were inevitably made in context and are therefore based on "provisional knowledge": "Developmental paths should be kept open provided they have no obviously foreseeable detrimental impact" (Chap. 6). Consequently, "*environmental risks and remedies have to be regularly questioned and re-evaluated in keeping with scientific and technological developments*" (recommendation No. 4, slightly adapted, see Chap. 25).

The following structure for a table (Table 5.3) is considered helpful for gaining an overview of selected sectors by providing a more comprehensive picture, thus

Table 5.3 Basic structure for a risk inventory matrix

0	1	2	3	4
Risk type	Examples of risks	Motivation for risk management (possible/ probable costs)	Arguments for negating a risk (use, benefit)	Institutions for remedies
Normative				
Technical				
Suppressed				
Hypothetical				

enabling a more profound understanding. For every sector, it comprises at least one matrix with four rows, one for each risk type (Table 5.2), and the following four columns:

Column 1 specific examples of risks in the relevant sector,
Column 2 factors with the potential to sufficiently motivate those responsible to minimize the risks,
Column 3 arguments that are used to negate the existence of a particular risk or the necessity to act (publishing destructive arguments is considered an effective first step towards overcoming the obstacle they represent),
Column 4 specific remedies and responsible institutions and sectors that can contribute to successful risk management.

Using the Risk Inventory

Table 5.4 documents the results of an exercise carried out during the IESP workshop in Feldafing mentioned in the "Preface", in which the focus group "environment and ecology" tested the process of building the proposed inventory by completing a matrix for the topic of "agricultural production of protein" (a brief explanation of the individual entries into the matrix is given in Annex 1):

Summary and Conclusions

The key recommendations derived from the discussion above are summarized as follows:

- "*For a systematic overview of environmental risks (e.g. climate change, water and soil degradation, loss of bio-diversity, engineering landscapes) a dynamic risk inventory is necessary according to causes and sectors*" (recommendation No. 4, Chap. 25).

Table 5.4 Draft sketch of a risk matrix as part of the proposed dynamic risk inventory—completed for the topic "agricultural production of protein"

Risk type	Examples of risks	Motivation for risk management	Arguments for negating a risk	Institutions for remedies
Normative	• Violation of good practice • Water Framework Directive • Current standards	• Transparency • Knowledge transfer • Changes in consumer behavior • Public disapproval	• Lack of acceptance • Short-term advantages • Lack of knowledge	• Strengthen implementation • Strengthen awareness of standards • Sanctions
Technical	• Drying of wetlands • Reduction of capacity to bind CO_2	• Technically evident events • Gaining insight	• additional costs for existing systems	• Setting standards • Benchmarking the State as guarantor
Suppressed	• Multi-resistant germs from animal husbandry • Health effects of unbalanced consumption • Consumption of terrain • Secondary effects in developing countries	• Create concern • Public discussion, among other things, as "scandal" • Visualization	• Resistance to change • Negation of opportunities	• Science • Civil society • Medicine • The media • Education system • Authorities
Hypothetical	• Effect of emerging chemical substances • Synthetic nanoparticles • Spreading of resistant germs • Scarcity of food	• Precautionary principle • Analysis of scenarios	• Ideologies • Resistance to insights • Violation of the "codes" of science • Bias of the large financial backers	• Fantasies, fears, hopes • Think tanks such as IESP • Governmental bodies • Environmental associations • Research

- "*Global goals, such as the Sustainable Development Goals of the United Nations or the Paris Agreement, have to be taken into consideration at all subsidiary levels of political decision making regarding the limitation of risks. Such considerations have to be part of any risk communication*" (recommendation No. 5, Chap. 25).

The focus group mentioned above validated recommendation No. 4 by filling in one matrix, as an element of the risk inventory, for the specific and complex example of "agricultural production of protein". This proved a valuable exercise, demonstrating that the process of analyzing a risk conglomerate could be quick, pragmatic and yet provide a useful point of reference for planning and prioritizing measures.

Recommendation No. 5 was developed in the course of the discussion of the environmental risk examples "climate change" and "loss of natural landscapes" which highlights that the universal acceptance of the proposed goals is crucial to the success of joint risk management objectives.

The broad identification with global ethical assumptions would make it easier for politicians to act responsibly in favor of the greater good (e.g. when it comes to investments in development aid and other expressions of solidarity). Moreover, such successful joint initiatives and agreements counteract the fatalistic collective paralysis resulting from the feeling of being powerless as an individual, despite recognizing the global risks.

This positive perception should also apply to our relationship to the EU. The role of the EU as a strong collective immunization system, especially against environmental risks, is much too rarely recognized and often purposefully defamed as being "dirigistic". As experience shows, internationally binding programs such as the Water Framework Directive and the Natura 2000 network represent highly effective strategies for minimizing risks.

Annex 1

Explanation of individual entries into the matrix in Table 5.4: Draft sketch of a risk matrix as part of the proposed dynamic risk inventory—completed for the topic "agricultural production of protein".

NORMATIVE RISKS (Table 5.4, row 1)
Violation of good practice (Table 5.4, row 1, column 1)
Normative risks can be summed up as the "known knowns". Examples of normative risks in the present system for the agricultural production of protein are therefore given as the risks deriving from the violation of existing norms such as the so-called "Good Agricultural Practices (GAP)". The GAP comprise a wide range of specific methods and measures that are only partially legally binding and whose implementation is often insufficiently monitored (UBA 2015a).
Violation of the Water Framework Directive, violation of current standards (Table 5.4, row 1, column 1)
The situation is comparable for some areas of the Water Framework Directive, notably regarding the closely related Nitrates and Groundwater Directives, where legally binding, nationally harmonized standards are repeatedly violated. For example, the binding 50-mg/l threshold for nitrates is exceeded at more than one in ten German groundwater monitoring stations (UBA 2015b), and despite the regulations, some farmers still spread manure on frozen fields or too close to river banks (personal communication 2016, undisclosed source).
Transparency, knowledge transfer (Table 5.4, row 1, column 2)

(continued)

Greater transparency in the form of publicly available and easily comprehensible data on the voluntary implementation of good practice measures can be motivation in itself. Raising awareness among professionals in the agricultural industry and providing practical guidance, not only about the risks of "bad" practice but also about the advantages of, for example, modern agricultural measures such as no-till farming (TOPPS Prowadis 2014), can also be highly effective.
Changes in consumer behavior (Table 5.4, row 1, column 2)
It is a well-known fact that the choices made by consumers can also contribute to encouraging good practice and improving environmental protection in the production chain. A case in point is an innovative project in northern Bavaria that encourages farmers to voluntarily refrain from reapplying nutrients at the end of the growing season to reduce nitrogen transfer into the groundwater system. Flour produced from these crops cannot reliably satisfy market requirements for high protein content, but the bread baked from this flour is successfully marketed locally as a contribution to groundwater protection (Regierung von Unterfranken 2015).
Public disapproval (Table 5.4, row 1, column 2)
Whilst sustainable consumer choices can drive the market, public disapproval, or even outrage, can be a valuable force for change at the political level by putting important but neglected issues onto the agenda.
Lack of acceptance (Table 5.4, row 1, column 3)
The ambiguous role of science and expert knowledge was demonstrated in the recent debate on the herbicide glyphosate. Two reports presented by different scientific advisory bodies came to different conclusions on the likelihood of a cancer risk to humans (Cressey 2015). Faced with contradictory information, the key actors appear to be reluctant to implement precautionary measures.
Short-term advantages (Table 5.4, row 1, column 3)
As Pope Francis explains in his encyclical Laudato Si, this kind of situation is exacerbated further if there are business interests at stake (Laudato Si, 181, Pope Francis 2015).
Lack of knowledge (Table 5.4, row 1, column 3)
Knowledge is the key to risk-appropriate behavior. The recent case of pollution of arable land with PFAS (perfluoroalkyl and polyfluoroalkyl substances) in southern Germany, caused by mixing de-inking paper sludge into compost (Regierungspräsidium Karlsruhe 2016), demonstrates how a lack of knowledge can lead to catastrophic results.
Strengthen implementation and awareness of standards and sanctions (Table 5.4, row 1, column 4)
Public authorities should maintain, or in some cases reinforce, the implementation of existing legislation and standards, including imposing sanctions for non-compliance, and provide practical guidance if there are no legal standards in place (e.g. Bayerisches Landesamt für Umwelt 2015).
TECHNICAL RISKS (Table 5.4, row 2)
Drying of wetlands (Table 5.4, row 2, column 1)
Technical risks, as illustrated in Fig. 2, are the "known unknowns". Within the agricultural sector, there are a great many risks relating to technology, health, the weather, market developments, etc. (OECD 2009) that could arguably be described as technical risks. To illustrate how risks with global impacts can result from developments at the local level, the example chosen in the matrix is the loss of wetlands. In Germany, a large proportion of floodplain meadows has been lost, in part due to agricultural land use practices (UBA 2009 as cited in UBA 2015a). Because of their capacity for water retention, wetlands such as floodplain meadows can

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TECHNICAL RISKS (Table 5.4, row 2)
have a significant positive hydrological impact by improving groundwater recharge and flood dynamics, and their loss, accordingly, poses a risk (though studies imply that major flood events are not significantly affected by this phenomenon (e.g. Asenkerschbaumer 2013).
Reduction of capacity to bind CO_2 (Table 5.4, row 2, column 1)
The analysis and quantification of functions and services provided by wetlands, including their capacity to bind CO_2, is the subject of a wide range of recent studies and publications (e.g. TEEB DE 2015, Bundesamt für Naturschutz 2015; Global Nature Fund 2013).
Technically evident events (Table 5.4, row 2, column 2)
Generally speaking, technical risks become evident when the system fails, often triggering a period of intensified risk awareness. For example, political debate about recurring biogas plant leaks into nearby rivers and streams succeeded in raising awareness among the agricultural community, providing strong incentives for risk prevention (personal communication 2016, undisclosed source).
Gaining insight (Table 5.4, row 2, column 2)
With the help of some background knowledge, the hydrological—and even the climatic —impact of drained farmland becomes evident. The group believes that for more abstract technical risks, the process of understanding is a vital step towards active risk management. Unfortunately, not all obstacles can be overcome by knowledge alone.
Additional costs for existing systems (Table 5.4, row 2, column 3)
As with normative risks, the willingness to act can, in the face of technical risks, be fundamentally undermined by financial concerns, often linked to an imbalance between long—and short-term considerations or disagreement about cost distribution. In his unpublished impulse statement for the IESP workshop (unreferenced), Renn explains that such problems can only be solved in a process of continuous risk dialogue.
Setting standards, benchmarking (Table 5.4, row 2, column 4)
Public institutions can make a valuable contribution by defining norms and setting standards—for example, the Bavarian handbook for biogas production (Bayerisches Landesamt für Umwelt 2016)—and monitoring their implementation in voluntary benchmarking projects (Bayerische Landesanstalt für Landwirtschaft 2013).
State as guarantor (Table 5.4, row 2, column 4)
The contributions of public institutions are not simply optional extras. The State as guarantor (the German term “Staatliche Garantenpflicht” describes the guarantor duty of the State usually regarding issues like public health and security) has an obligation to avert dangers to public security and to guarantee basic health and safety standards.
SUPPRESSED RISKS (Table 5.4, row 3)
Multi-resistant germs from animal husbandry, unbalanced consumption, consumption of terrain (Table 5.4, row 3, column 1)
Suppressed risks are those classed as “unknown knowns” (Fig. 2). The examples relating to agricultural practice given in the risk inventory matrix reflect this wide spectrum: multi-resistant germs encouraged by the frequent use of “broad spectrum” antibiotics in animal husbandry can affect both animal and human health and pose a long-term financial risk for the health system and public funds (Bundesregierung 2015). Similarly, unbalanced consumption (such as eating too much meat) can affect individuals but also society as a whole, whilst land use pressures lead to a loss of biodiversity and other environmental problems (FAO 2013).
Secondary effects in developing countries (Table 5.4, row 3, column 1)

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SUPPRESSED RISKS (Table 5.4, row 3)
At the global scale, ever increasing product volumes sold on the world markets at relatively low prices have secondary effects in developing countries, undermining local production and increasing the risk of poverty (MISEREOR 2011).
Create concern, public discussion, even "scandal" (Table 5.4, row 3, column 2)
It stands to reason that to overcome suppressed risks it is necessary to raise awareness and to make people care, even to the point of provoking public outrage, which can in turn create favorable conditions for action at the political level.
Visualization (Table 5.4, row 3, column 2)
One effective way this can be achieved is by visualizing the possible impact of the risk (e.g. UNEP 2013 analyses trends in agriculture now and in the future).
Resistance to change (Table 5.4, row 3, column 3)
Nevertheless, there is always the danger of sustained resistance to change. One example is the widespread use of antibiotics in animal agriculture despite the fact that the EU banned the use of antibiotics for 'growth promotion' over 10 years ago. The ban appears to be being undermined by non-therapeutic use being disguised as 'treatment' (FAO 2011).
Negation of opportunities (Table 5.4, row 3, column 3)
By tolerating the continued overuse, the responsible authorities are giving those still resisting the changes an unfair business advantage over those willing to accept the necessity for, and the advantages of, a wide-reaching ban.
Science, civil society, medicine, the media (Table 5.4, row 3, column 4)
Complex obstacles of this kind can only be overcome if science, civil society, medicine, the media, the education system and the public authorities cooperate successfully.
HYPOTHETICAL RISKS (Table 5.4, row 4)
Emerging chemical substances, synthetic nanoparticles (Fig. 4, row 4, column 1)
Hypothetical risks are, essentially, the "unknown unknowns". This means that neither definitive proof nor a general, intuitive public awareness of the risk exists. For example, in the long term, emerging chemical substances and synthetic nanoparticles may or may not prove to be detrimental to human health or the environment, but at the moment there is no way of confirming either hypothesis.
Spreading of resistant germs, food scarcity (Table 5.4, row 4, column 1)
Risks such as the spread of resistant germs or food scarcity also have elements that can be classed as "unknown unknowns", though they also share some of the characteristics of normative, technical and suppressed risks.
Precautionary principle, analysis of scenarios (Table 5.4, row 4, column 2)
Especially for hypothetical risks, adherence to the precautionary principle provides protection and builds trust (e.g. implementation of the first Watch List for emerging water pollutants in the EU (JRC 2015)). Also, the evaluation of scientifically based scenarios is highly recommended. It provides decision makers with information on which to base their actions in the face of uncertainty and allows for transparency and risk dialogue (e.g. climate scenarios in IPCC 2014).
Ideologies, resistance to insights (Table 5.4, row 4, column 3)
Of the four risk types, the hypothetical risk is, arguably, the one most in danger of being ignored or negated by actors in positions of responsibility. For ideological reasons, or simply to distract from incompetence, politicians and decision makers may be tempted to claim ignorance or defend their lack of action by citing the inconclusive evidence.

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HYPOTHETICAL RISKS (Table 5.4, row 4)
Violation of the "codes" of science, bias of the large financial backers (Table 5.4, row 4, column 3)
Sadly, science may also prefer to focus on more lucrative areas of research. In exceptional circumstances, researchers will even choose to violate the "codes" of science, for example, by analyzing the business opportunities in catastrophic scenarios rather than working on risk prevention (personal communication 2016, undisclosed source).
Fantasies, fears, hopes, think tanks such as IESP, etc. (Table 5.4, row 4, column 4)
Fantasies, fears and hopes relating these undefined risks need to be explored and discussed persistently and unrelentingly by think tanks such as IESP, but also by governmental bodies, environmental associations and in the wider scientific community.

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Chapter 6
Maxims of Risk Ethics for Sustainable Agriculture

Franz-Theo Gottwald

On Risks in Agriculture

All over the world, agriculture has impacted both the environment and ecology in very particular ways, as it interacts directly with both the environment and nature. It changes landscapes positively and negatively. Excessive amounts of nutrients introduced, of climate-relevant and soil- and water-polluting emissions and a worldwide reduction in biodiversity in industrially, respectively intensively farmed agricultural landscapes raise questions about ecological and social sustainability of agricultural production. Further there are discussions concerning the negative impacts of farming upon world climate, e.g. due to factory farming. All of these are critical factors concerning good agricultural practices in the twenty-first century (Gottwald and Fischler 2007).

Generally, it can be stated that intensive agriculture as practiced worldwide puts the foundation of its productivity rapidly and measurably (or scientifically controllable and verifiable) at risk (Agriculture at a Crossroads: IAASTD findings and recommendations for future farming 2016, and World Climate Report 2016); (see also Grambow/Korck in this book, especially Annex 1). It is neither ecologically acceptable nor socially sound, and therefore neither sustainable nor a viable path for securing global food systems in keeping with the 2015 goals of the Paris Agreement on Climate Change.

Therefore, the Sustainable Development Goals (SDGs) enacted on January 1, 2016, specifically address the need for transformation of agriculture. Goal no. 2 "aims to end hunger, achieve food security and improved nutrition and promote sustainable agriculture." Under the same heading, sub-goal 2.4 states: "By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems,

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that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality" (UN Sustainable Development Goals 2016).

These statements list the (negative) expectations with regard to consequences of present-day agriculture. They clearly point to all the perceived risks inherent in future agricultural operations: the preservation of ecosystems is at risk, and in many regions of the world, the adaptability of agricultural practices to counter the effects of climate change cannot be guaranteed. This poses great risks, even without including the risk of droughts, flooding or natural catastrophes facing agriculture. According to the insurance sector, these events can be measured and calculated in part, i.e. covered by insurance premiums. (Munich Re 2010). These comprise risks that fall within the narrow definition of the word: measurable, calculable uncertainties modeled in keeping with probability calculation and expected impact.

What Is Sustainable Agriculture?

Thus far, no generally accepted concept has been developed for sustainable science-based agriculture that could replace additional industrialization. However, there are a number of more or less successful approaches that wrestle with the goal of sustainability (Gottwald and Lutzenberger 2000). Judging from the vantage point of ethically normative assessments or material-value ethics, more sustainable or less sustainable agricultural practices in farming, animal husbandry, horticulture, viniculture, fisheries and silviculture can be identified. Applicable yardsticks such as the Ecological Footprint (Global Footprint Network http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_basics_overview/), the Carbon Footprint (Carbon Footprint Ltd. http://www.carbonfootprint.com) and material input per service unit (MIPS: Green EcoNet http://www.greeneconet.eu/material-input-service-unit-mips) or similar methods of calculating the socio-ecological consequences of agriculture are useful. They are all of a normative nature, adhering to the maxim: less is more sustainable and therefore morally more desirable. They could help farmers—if applied in on-farm decision-making—use more appropriate agricultural, i.e. sustainable practices. They establish what is morally tenable in order to meet the debt owed to an ethically responsible future life on planet earth.

In keeping with these tenets, the Deutsche Landwirtschaftliche Gesellschaft e.V. (German Agricultural Association), for instance, developed a certification system for sustainable agriculture which has been in use at German farms (DLG 2016). It promises to reduce the risks of unsustainable agriculture, while helping individual farmers work towards sustainable agricultural practices. It further promises to increase efficiency of resource management, improve environmental protection, ensure economic efficiency and guarantee social responsibility in farming, to list but four of the dimensions of this audit and certification system.

In this context, organic agriculture using legally standardized environmentally friendly farming and food-processing procedures plays a special role, given that these practices are more favorable for biodiversity and more socially sustainable than those of intensive agriculture (IFOAM EU Regulations 2007/2008).

In summary, the present focus on good technical practices clears the way for a more sustainable future for agriculture. Ethically speaking, this direction should be maintained with the emergent ethos of sustainability providing the necessary moral orientation (Gottwald 2011). This leads to the applicable maxim: take from available knowledge morally desirable values in order to use sustainable practices to farm the land responsibly. And the natural outcome is this ethical command: refrain from anything that might be seen as irresponsible by present-day society or future generations. There are a number of valid reasons giving rise to the assumption that certain aspects of agriculture, food and environmental ethics are instrumental in a transformation of agriculture towards sustainability, which in turn reduces the risks inherent in traditional, conventional intensive farming practices. One might even call it an ethics of survival.

Maxims of Risk Ethics for Sustainable Agriculture

A number of essential directional decisions in keeping with SDGs will have to be made in the transformation of farming into a more sustainable type of agriculture. Some of them are more business administration-oriented and concern managerial decisions by the individual farmer. They also present a macroeconomic aspect and concern innovative strategies of knowledge communities of the twenty-first century, for instance, smart farming technologies. In both cases, risks are taken, given that the final consequences due to the deployment of new technologies in rural areas frequently manifest themselves only in the long term. For example, a new epidemic of "superweeds" has been shining a spotlight on industrial farming practices. Therefore, it is correct to talk about long-term risks that will require funds, knowledge and new technologies to offset them in the end—always provided there is any real chance of ever "fixing" them (PhysOrg http://phys.org/news/2014-01-superweeds-epidemic-spotlight-gmos.html).

Another risk case could be made with reference to new synthetic biology technologies used in animal breeding. New ways of genetic manipulation using nucleases (DNA cleavers) are expected to allow for more specific genome manipulation. However, these procedures are neither free of side effects, nor as precise as claimed. Just like known genetic manipulations, they require several intermediary steps which result in more "wasted" animals.

In recent years, official numbers have proven the trend towards more experiments with genetically altered animals. 2015 was the first year when the number of genetically altered animals used in tests in Germany exceeded one million for the first time.

Genetically altering mammals is not ethically neutral, given that it clearly entails suffering and pain. Many animals are born genetically defective, stillbirths are common, or the animals have to be killed due to illness or failure to produce the desired genetic qualities. Therefore, the production of individual genetically altered mammals leads to the sacrifice of a large number of animals. Moreover, other animals are used as surrogate mothers and egg or embryo donors, exposing them to additional pain and suffering. Unfortunately, novel genetic engineering procedures demand all of these steps. They are not free of risks and side effects. In addition to the desired genetically altered traits, there may be unwanted changes in the genome. Releasing these animals into natural environments may seriously impair biodiversity. Contact with or consumption of the meat of these animals may ultimately endanger human health.

In addition to ethical problems, this poses questions of human and environmental security: before interfering with the genome of animals used in agriculture or released into the environment, it is important to realize how little is certain. The structure of the genome and its manipulation not only determine the frequency of illness, but complex manifestations of social and environmental interactions. There is no way of gauging long-term consequences for biodiversity once these new genetic recombination processes have been allowed to proliferate among natural populations (Then 2016).

This shows very clearly that decisions for the future always carry risk. But doing nothing is no option. This also proves that a special risk ethics need to be established to keep possible transformative paths for sustainable agriculture open. There are a number of required maxims that stipulate how areas of transformation like farming, risks, uncertainties and improbabilities have to be dealt with to achieve more sustainability (Beck 1999).

The present political debate about new breeding methods in farming highlights this requirement. The "Grünbuch Ernährung, Landwirtschaft, Ländliche Räume" (Green Book on Food, Agriculture and Rural Areas of the German Federal Ministry of Food and Agriculture) published at the end of 2016 states: "We want to strengthen the power of innovation of predominantly mid-size German breeding enterprises. We need productive food plants, resistant to disease, pests, heat and drought. This is an important building block of sustainably productive agriculture, ready to tackle environmental and climate changes." And it continues: "New breeding technologies in farming like CRISPR/Cas-Technologies need to be thoroughly vetted scientifically. This is the only way to create a sound basis for proper assessment. We must not cut ourselves off from all new developments. We plan to conduct an open and transparent discussion process with all stakeholders involved" (BMEL 2016, p. 29).

This draws on two maxims of contemporary risk ethics: First, developmental paths should be kept open, provided they have no obvious foreseeable detrimental impact. This is the message behind the statement: "We must not cut ourselves off from all new developments"—it is a statement of political ethics designed to allow for sufficient developmental space for science and research, but moreover to keep a door open for German agriculture to make use of innovations involving living organisms. A second maxim in the spirit of an ethos of risk management is added: "We plan to conduct an open and transparent discussion process with all stakeholders involved." It is designed to help shareholders assess risk-relevant decisions concerning introduction into the market and food cycle of genetically altered organisms. It also aids in preparing political standardization of actions as desired by society.

Beyond questions concerning sustainability of certain agrarian technologies there are other conflicts inherent in values and differing farming practices that need to be agreed upon by societies. They all comprise a number of risks for a more sustainable type of agriculture. These include:

- Conflicts in land use (for human use, animal feed production, raw fibers, fuel, etc.)
- Conflicts between local use of plants and animals and export of plant and animal-based products
- Conflicts between use and protection of landscapes (for instance, rain forests)
- Conflicts of use: What takes precedence? (e.g. food products or energy plants)
- Conflicts concerning patents on life
- Conflicts between technological innovations and social changes (structural changes in rural areas)

Depending on the political, economic and technical solutions of these conflicts, there will be winners and losers and thus clear ecological and social risks for the future of agriculture in certain regions of the world. In view of all these looming conflicts and in the hope of keeping paths open for the future, an additional maxim in keeping with the ethos of proper handling of conflict risk will have to be applied: the precautionary maxim. The ethically, easily justified "precautionary principle" is constitutional within the European legal framework with regard to novelties (always a wellspring of conflict) (Beyer 2004). But more threatening is the higher risk of time-ecology: the critical speed of innovation has to be kept in check, given that there are no useful lessons to be learned from the consequences when it is too late. It is this realization that forces compliance with an additional maxim of risk ethics: the speed of socially and politically controllable innovations is determined by the possibility of reversibility (reversibility maxim).

At this point, more additional risk ethics maxims for sustainable agriculture could be developed. Suffice it to refer to the "General Recommendation for Action to Decision-Makers in Politics, Economics and Society" published at the beginning of this book. Most of these recommendations are comparable to ethical maxims. They are the absolute and most general statements for the social establishment of sustainable risk management. Their aim is the creation and establishment of institutions for safeguarding risk. These institutions, set up "in the interest of reason" (Immanuel Kant), are designed to uniformly align human desires in economy, politics, science and (agri)culture. Risky ventures will have to be assessed and measured in keeping with basic principles applicable to all of humanity. In other words, institutions of this kind, e.g. round tables, real-life workshops, town hall meetings and other forms of stakeholder management, investigate the risks of collectively desired actions and make informational contributions for politically and economically acting risk regulators.

Ethically Informed Agricultural Policy

Sustainable risk management for sustainable agriculture requires an ethics of risk closely meshed with real agricultural policies. There are three ways of interlocking: The first instance is the creation of dependable principles for those working in agriculture. These have to be invested with legal powers and legitimacy and have to be legally and politically empowered. Furthermore, incentives for responsibly acting entrepreneurs have to be created, and sanctions in the case of irresponsible business actions have to be introduced and enforced. Additionally, consumer policies have to be put in place, enabling members of the public to make decisions based upon ethical aspects, e.g. to consider the quality of farm products rather than be swayed by quantity.

All efforts in the creation of reliable, resilient (guaranteed to be enforced) governmental frameworks for agricultural and on-farm economic activities have to present motivation for better ecological, social and agricultural performance that help meet as many SDGs as possible. No more furtherance of orientation towards the lowest possible expenses will be allowed, whereas competition for the best possible quality will be encouraged. Setting the lowest price will have to be tolerated, except if this action can be proven to increase social and ecological costs and will in turn have to be borne either by the general public or passed on the next generations.

Seen from the vantage point of governance, the creation of reliable frameworks is advanced if (minimum) standards in the production of farm and other food items, including all input and output created along the value chain of agriculture, are framed by policymakers following the tenets of climate protection, environmental protection, soil and water protection, and consumer protection, thus rewarding actors who display integrity when dealing with the common good and protecting them from market losses or restrictions. In other words, any monetary disadvantage due to better material ethical production procedures, processing or distribution of farm products or food items, has to be kept to a minimum. In addition, everything has to be done to reduce unfair cost benefits, or socially discredited activities in agriculture and food production.

To achieve this goal, "fair rules of game" have to be ethically based and legally established. Global competitive conditions force German agricultural policies to lobby worldwide for the establishment and protection of a "level playing field." Ethically based agricultural policies can produce standardized orientation, fair rules of game and reliable frameworks that are generally justifiable. The internal control frameworks are simple: they check for "good" or "bad," viability is measured and the impact on the future assessed. Clearly, lack of responsible behavior has to be sanctioned.

Ethically based agricultural policy taking recourse to generally understandable standards and value orientation that make sense is capable of creating enlightened order, even in cases of conflict. It gives direction for activities of all engaged in the economy and allows room for decision making, such as choice at the level of individual economic production or consumption.

Enterprises and organizations competing in the market share responsibility for upholding the standards of competition of their trade mentioned above. Government holds the regulatory claim to the rules of the game. These are the guidelines for law-abiding and legitimized entrepreneurial activities for businesses and organizations. Thus, the business world is legally bound to set up their processes and products in such a way that they correspond to the legally binding competitive framework.

This also means that each respective line of agricultural business has to be able to ethically justify any technologies applied in individual enterprises or organizations. Ethical justification applies to both the desired outcomes of technologies used and to the manner in which this chosen technology is used (the means used) and its possible consequences, even if unintentional. Extensive, comprehensive and verifiable documentation is required (e.g. sustainability report).

An ethically informed agricultural policy reflects criteria for good corporate governance, corporate social responsibility, good corporate citizenship, and corporate responsibility, and in cases of doubt, will reward responsible enterprises with all political means available (e.g. export business), rather than those showing less business integrity (for instance, those causing social or ecological problems).

Additionally, appropriate agricultural policies are constructive, solution-oriented tools that help enterprises find trade-offs stemming from conflicting stakeholder expectations and interests in economics, society and culture (e.g. in emission trading).

Ethically informed agricultural policy of the twenty-first century includes consumers and customers in the decision-making process. The highly diversified field of agricultural production more than ever before needs politically supported consumer information. In view of the vast number of technological innovations related to agricultural products and food items, the responsible public has to be kept abreast of origin, quality, content and socio-ecological consequences inherent in their purchasing decisions. Clever nudging may further socially preferable and desirable eating habits.

A responsible individual is accountable for all purchasing decisions and their consequences. However, clever information and education campaigns informing the public of their dual roles as consumers (in relation to the product, or means of production or distribution) and as members of the public (in relation to society and politics) have proven helpful.

The spectrum of informational, educational and nudging measures available to governments is extensive: from making consumers more aware of consumer policies—which can be seen as market policies strengthening emerging and expanding markets (see campaigns in Bavaria for the expansion of organic agriculture to a 20% share), to the creation of transparency via labels (government animal welfare label), and finally, to various consumer information campaigns addressing individual topics in the fields of health and nutrition.

Visionary agricultural policies are guided by the above maxims. Their measures help advance the desired transformation towards sustainable agriculture, without increasing the risks inherent in processes of change.

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Chapter 7
Risk and Water Management Under Climate Change: Towards the Nexus City

Daphne Gondhalekar, Jörg E. Drewes and Martin Grambow

Key messages

To address climate change-related risk more effectively, urgent action is needed by cities to curb their consumption of natural resources, particularly water. Operationalizing the Water–Energy–Food Nexus is a possible solution for both developed and developing economies, but requires a paradigm shift, with strong policy support by national and local governments, as well as in-depth study and testing through pilot projects.

Introduction

A growth-dependent free market economy assumes a limitless supply of natural resources. This has caused over-consumption of resources like water, energy and food. Scientists have been warning of the consequences for about half a century (Meadows 1972). Cities in particular consume far more than the carrying capacity of their hinterlands (Rees 1992). This pattern of over-consumption of natural resources has caused dangerous alterations in climate (IPCC 2014). Despite the apparent risks associated with climate change, demand for these resources continues to rise worldwide (OECD 2012): Global water demand is expected to exceed supply by 40% within 20 years (UNEP 2014). By 2030, global energy demand will

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have grown by 40% (IEA 2009), and by 2050, food demand is expected to have increased by 60% (WBCSD 2014); moreover, a high level of consumption of these resources continues to be equated with a good quality of life. This development is contrary to what the founding fathers of the free market economy had imagined: they assumed that when wealth had increased so that everyone could cover important needs, the economy would be sated and stop growing (Keynes 1930; Uchatius 2011). Instead, however, satisfaction with quality of life in countries like Germany has not risen since the 1970s (Uchatius 2011), and ongoing economic growth has served 0.7% of the world's population in amassing 45.2% of global wealth (Credit Suisse 2015), whilst billions of people continue to live in dire poverty and lack basic services.

Cities in developing economies in particular are already facing serious water-related environmental challenges (Marcotullio 2007), as the development of water infrastructure is often unable to keep pace with urban growth. The resulting inadequate access to safe drinking water and management of wastewater causes serious public health risk in cities worldwide (Galea and Vlahov 2005). This situation is being exacerbated by climate change-induced water scarcity and planning uncertainty (Vörösmarty et al. 2000). Cities in the West are also increasingly facing water challenges set to sharpen with climate change: the over-capacity and under-utilization of infrastructure networks resulting from shrinking inner city populations, for example, can cause major problems in technical functioning and economic feasibility (Moss 2008). Yet the paradigm of using water only once remains surprisingly persistent in the face of water-related development challenges (Wilderer 2004; Drewes 2014), in both developed and developing economies. The concept of a flush toilet coupled to a centralized sewage system remains the preferred option and is seen as a symbol of "modernity" and as the "solution that works", despite being very water- and energy-intensive, which is why it has been termed by some as "ecologically mindless" (Narain 2002).

This situation introduces various risks: the greater the consumption of resources including water, energy from fossil fuels, and food, the more CO_2 is released into the atmosphere. Hence, with the lack of adequate climate change mitigation, the predicted impacts of climate change will occur faster and will be more extreme (IPCC 2014). At the same time, the over-dependence on natural resources such as water, energy and food reduces the capacity to adapt to climatic changes such as heat and drought, rendering societies more vulnerable. For example, large-scale centralized sewage systems cannot function with reduced water and energy, leading to blockage of solids and subsequent corrosion of the system, causing public health risk and the need for major investments. The management of water resources is especially critical in adapting to climate change, as this resource impacts almost all aspects of society and the economy (UN Water 2010). With climate change, the equitable distribution of natural resources—and water in particular—will be increasingly important for a peaceful future (Roberts and Finnegan 2003). Water is a finite resource and is essential to human survival. Despite the urgency of this issue, the majority of approaches in both research and practice are aimed at supplying the ever-increasing demand for resources such as water, energy and food, rather than devising the means to reduce it.

In order to enable cities to curb their consumption of natural resources, and hence to avert disastrous climatic change, an integrated urban planning approach is urgently needed. Given the limited capacity of most cities, an approach that leverages potential synergies of climate change mitigation and adaptation strategies is necessary. Further, in order to meet the climate target of less than 2 °C, such an approach needs to be implemented and mainstreamed at a worldwide scale by 2030 (IPCC 2014).

The Water–Energy–Food (WEF) Nexus approach, which has rapidly gained momentum in recent years, is one possible way to effect such integrated urban planning. This approach highlights interlinkages between the water, energy and food sectors, in that it takes much energy to supply freshwater and remove and treat wastewater, and that much water is needed to produce energy and food (ADB 2013). It aims to optimize the water and energy systems in a synergistic manner whilst also optimizing food production. The concept emphasizes responsible governance (GWSP 2014) and that a new perception of water is needed, with the water–food link being of the highest social and political significance (ADB 2013).

However, although many suitable technologies exist, to date there are few operationalized examples worldwide of the WEF Nexus approach at the neighbourhood or city scale. To enable its operationalization, more pilot projects are needed at the neighbourhood scale to serve as a beacon to demonstrate the viability and monitor the efficiency of this approach.

The WEF Nexus approach combines three systems that are each complex enough: water, energy and food. If we consider that the original impetus for public water supply and sanitation was to establish proper hygiene standards to protect public health in the wake of various devastating epidemics in Europe, the WEF Nexus even covers three separate systems whilst still maintaining overall public health protection. The development and current state of each of these systems are path-dependent, and every approach for optimizing one of these systems generates new path dependencies. As the WEF Nexus approach aims to optimize these individual path-dependent systems in combination, it is evident that a particularly high level of complexity with special challenges and risks exists. Furthermore, the WEF Nexus is also connected to other related path-dependent systems, such as solid waste or transportation, which also need to be considered to achieve a holistic approach to the development of a given city.

In this paper, two case studies in very different climatic, geographic, cultural, and economic development zones are juxtaposed and the WEF Nexus approach hypothetically applied to each of them: Leh is a small city with about 60,000 inhabitants in the semi-arid high-altitude Ladakh region of the Indian Himalayas, and Maxvorstadt is a neighbourhood of Munich with a population of about 50,000. Munich is located in the water-rich alpine foothills region of Southern Germany. The two cases are chosen to illustrate key potentialities of operationalizing the WEF Nexus approach, particularly in terms of potential synergies of climate change mitigation and adaptation strategies, and measures of as well as barriers to implementation. The case study in Leh, where there is currently no centralized or large-scale wastewater management infrastructure, aims to show how water consumption patterns in the West can impact and play out at the local level in the context of a developing economy where such centralized water infrastructure is currently being developed. The case study of Munich aims to illustrate the situation where a centralized water infrastructure was implemented around 140 years ago. In both cases, the paper aims to illustrate what an alternative future development could look like and what challenges exist for a more sustainable development approach. The paper summarizes the results of two research projects conducted in 2011–2015, one on Leh funded by the European Commission and the German Research Foundation and the other on Munich funded by the Bavarian State Ministry of the Environment and Consumer Protection.

Methods

For the analysis in Leh, field surveys were conducted in 2012–2015 in collaboration with the Ladakh Ecological Development Group (LEDeG), a local non-governmental organization (NGO). Changes in land use and urban development were mapped using geographic positioning (GPS) and geographic information systems (GIS), a WorldView-2 very high-resolution satellite image (ground resolution 50 cm, DigitalGlobe©, supplied by European Space Imaging) as of November 2011 as a base map, and Google Earth imagery from 2003 as a reference. In addition, a socioeconomic questionnaire survey of 200 households, representing 5% of all households in Leh, a questionnaire survey of approximately 320 guesthouses and hotels, and semi-structured interviews with various local stakeholders were conducted.

For the analysis in Munich, spatial datasets on urban morphology and surface characteristics were provided as 2D polygons (Environmental Systems Research Institute [ESRI] shapefiles) and as a 3D city model (City Geography Markup Language, level of detail 2 [CityGML LOD-2]) by the Department of Environment and Health of the City of Munich and the Bavarian Land Surveying Office. Tabular statistics on population at the block level were provided by the Bavarian State Statistics Department. Spatial statistics were calculated using ESRI ArcGIS and QGIS (www.qgis.org). To retrieve the slope angles of all roofs in Maxvorstadt, the CityGML file was processed in FME (Feature Manipulation Engine, www.safe.com). To calculate facade area, facade length was multiplied by number of storeys, assumed to be 3.5 m each. Facades were simplified by omitting *avant-corps* of <1 m and "filling" gaps of <0.5 m. These values were chosen empirically after iteratively testing values on distortion of the resulting streamlined facades. Orientation of facades was retrieved by calculating the "directional mean" for every facade subsection. Building fronts were grouped by cardinal and intercardinal direction, and surface area was calculated for every class.

Leh, Ladakh, India: A Case Study in a Semi-arid High-Altitude Himalayan Region

Leh is an oasis of green agricultural fields in a quasi-desert in the Ladakh region, a part of the Indian state of Jammu and Kashmir in the Indus Valley. Water is scarce: annual precipitation is only about 10 cm, and snow and glacial melt water is the only available surface water. The apparent lushness of Leh is thus not a natural occurrence, but the result of hundreds of years of extremely careful water management. Until as recently as a few decades ago, Ladakh was still a largely self-sufficient traditional irrigation agriculture society, but since the early 1980s, the number of tourists has increased exponentially, particularly in the last decade: today, around 180,000 tourists visit Leh each year, mostly in the summer months between April and October. In winter there are very few tourists due to extremely cold temperatures. With climate change, increasing uncertainty in the amount of surface run-off from glaciers is expected in Ladakh. Surface water resources are already decreasing, impacting the availability of irrigation water and groundwater recharge.

Over the last few decades, almost 400 hotels and guesthouses have opened in Leh, which are increasingly establishing conventional Western-style water infrastructure concepts including showers and flush toilets to attract tourists. This has driven a rapid rise in freshwater demand and wastewater production. Freshwater is supplied mainly from groundwater aquifers, including the Indus River aquifer, which is very energy-intensive due to pumping and conveyance needs. Leh already faces regular power cuts, with available hydropower being insufficient. With socioeconomic change and less water available for irrigation due to climate change, 30% of agricultural fields have fallen barren, rendering Leh more or less completely dependent on food imports. Leh currently has no systematic wastewater management, with wastewater collected in soak pits and septic tanks that are not properly managed. Because groundwater is a source of drinking water, groundwater pollution through seepage represents a health risk. To address this issue, the local government is currently building a centralized sewage system comprising around 80 km of piping. A central wastewater treatment plant is planned at the foot of Leh, where wastewater is to be treated and discharged to the Indus. Currently, the government aims to provide 75 L of potable water per capita per day (Lpcd). However, in the future, 135 Lpcd will be extracted from groundwater aquifers, and a significant portion will be used simply for flushing the system.

Integrated urban planning using the WEF Nexus concept, with decentralized urban water reclamation and reuse to conserve water and energy for small clusters of hotels, guesthouses and households, could be an alternative development option for Leh. With multiple reclamation facilities, the associated decentralized sewage systems require less water to flush. The reclaimed water could be used locally to regenerate barren land for vegetable production, increasing food security. In off-seasons, it can also be used to replenish the local groundwater aquifer. In order to cover the power demand of smaller decentralized water reclamation facilities, solar energy can be utilized, augmented by the production of biogas, whilst providing water quality tailored to local needs in close proximity to irrigation water demand. Larger facilities could also produce biogas and reclaimed water, but in Leh this would have to be supplied/pumped back to where the demand is, which would require an additional distribution system and a significant amount of energy for pumping. Biosolids containing residual nutrients and organic substances can be used as fertilizer in agriculture. This alternative development option can also generate green jobs locally for operation of the treatment facilities and growing and marketing valuable crops. Given the smaller size, these systems are more flexible and hence resilient to effects of climate change such as reduced water availability.

The project was conducted in close collaboration with the key environmental NGO LEDeG in Leh that advises the local government. Several stakeholder meetings were held where representatives of the local government the Ladakh Autonomous Hill Development Council (LAHDC), including the Chief Executive Councillor and senior advisors, were present. However, plans to implement the centralized sewage system could not be modified because construction had already begun at the time, although many senior advisors favoured a decentralized water reclamation and reuse concept.

The plan for a centralized sewage system in Leh had been under consideration since 2009, when a consultant in Delhi was engaged to design it. The Indian national government granted the funding for the project in 2013. The plan was based on assumptions that may provide challenges in the future: the system was designed for 30 years and a projected population of 80,000. It assumed that all households would be connected to the system and would consume about 135 Lpcd, which is required to flush the system. Customers are expected to pay the service charge to cover operation and maintenance costs. However, only 30% of households currently own a flush toilet, only about half have private water connections, and about only half of these pay their water bills. The cost of connecting to the centralized sewage system and the necessary sanitary infrastructure to consume 135 Lpcd of water is to be borne by the households. Thus, there is a fair degree of uncertainty as to the number of households that will ultimately connect. Energy is seen as the only current bottleneck to the project. Ladakh has leased huge areas of land to the Indian national government for solar energy development, which will also provide a more reliable supply of energy to Leh. Water resources available through the Indus River and its connected aquifer are considered ample as well.

According to government guidelines, in urban areas of India with a centralized sewage system, the government must provide 135 Lpcd of water, of which 35 Lpcd is needed just to flush the system. However, in urban areas without a centralized sewage system, 75 Lpcd is sufficient. In Leh, the LAHDC aims to provide 75 Lpcd but actually provides less due to local power constraints: according to our survey, the local population may be consuming as little as 21 Lpcd. Thus, with the implementation of the centralized sewage system, the LAHDC is essentially encouraging the local population to consume six times as much water as before. This, to many Ladakhis who have been using water extremely sparingly for centuries and are very much aware that they live in a desert, seems preposterous and even immoral.

Ladakh, as a semi-autonomous region, can adapt national policies to its own context. However, water-saving technology alternatives are not readily available. There are almost no case studies of urban water reclamation and reuse at the neighbourhood scale in semi-arid regions. Large-scale infrastructure investment in a centralized sewage system in Leh translates into economic growth, and hence there are many barriers to the operationalization of the WEF Nexus approach, even though it may be a more sustainable development option in theory. However, a central question that many inhabitants are also asking in view of the present development remains unanswered: What will happen in Leh if less water becomes available? Considering this uncertainty, is the implementation of a centralized sewage system sustainable?

Munich, Germany: A Case Study in the Water-Rich Alpine Foothills Region

The city of Munich, the largest city in southern Germany and the capital of the state of Bavaria, has a population of 1.4 million (City of Munich Statistical Department 2014). The Maxvorstadt neighbourhood in Munich, with an area of 430 ha, has a total population of 51,642 and population density of 12,000 persons per km^2, making it among the most densely populated of Munich's 25 neighbourhoods (City of Munich Statistical Department 2014).

Impacts of climate change in Germany are expected mainly in terms of extended periods of drought and heat, as well as changes in precipitation patterns. In Bavaria, it is expected that average temperatures will increase by 0.5–2.5 °C by 2050 and 1.5–4 °C by 2100 (City of Munich, 2014). The number of summer days (max. temp. >25 °C) is expected to increase by up to 19 days by 2050 and up to 43 days by 2100; the number of heat days (max. temp. >30 °C) will increase by up to 9 days by 2050 and up to 25 days by 2100; "tropical nights" will increase by up to 5 days by 2050 and up to 16 days by 2100, and cold days will decrease significantly (StMUV, 2016). Average precipitation is currently 400 mm in the hydrological winter half-year (November to April) and 533 mm in the summer half-year (May to October) (LfU, 2012). In southern Bavaria, where Munich is located, precipitation in winter is expected to increase by up to 11% by 2050 and up to 21% by 2100, and in summer is expected to decrease by up to 7% by 2050 and as much as 17% by 2100 (StMUV 2016). With its high density of five-storey urban blocks as the dominant urban fabric type and a large amount of impervious surfaces, Maxvorstadt is particularly prone to heat island effects and flooding due to excessive rain events. Heat island effects are already affecting Maxvorstadt in terms of public health risk, particularly for elderly people and small children, who are especially vulnerable to heat.

In Munich, current water demand and supply is as follows: the city provides its 1.4 million inhabitants with around 300 million litres of freshwater daily, abstracted from groundwater in the foothills of the Alps and delivered by gravity to the city (SWM 2015). Average freshwater consumption in Munich is 128 Lpcd, of which an average of 35 Lpcd is used for toilet flushing (SWM 2015). If a population of 46,960 (living only in the blocks, and without children under the age of 3 years, who use significantly less water and energy) is assumed, current total freshwater demand in Maxvorstadt blocks is 6010 m^3/day. Of this, roughly 1640 m^3/day or 600,000 m^3/year is used for flushing toilets.

A significant source of water currently not being utilized in Munich is rainwater. If all roof surface steeper than 15° were used for rainwater harvesting, a total of 87 ha of roof area would be available in Maxvorstadt. If an accumulated rainfall of 0.4 m between November and April and of 0.5 m between May and October is assumed, this could result in a total harvested rainwater volume of 783,000 m^3/year. Thus, the total available rainwater volume in Maxvorstadt is sufficient to cover current freshwater demands for toilet flushing, which in theory could enable a reduction in current freshwater supply by 26%. For the hypothetically required storage of this rainwater, it is assumed that most buildings in Maxvorstadt of three storeys or more have a cellar, and that these, along with existing underground parking, could be turned into watertight cisterns relatively easily, but with significant cost and space constraints for other uses. The footprint of these three-storey-plus buildings comes to 913,724 m^2. If the current 50,139 m^2 of underground parking is added, and an average ceiling height of 2.5 m is assumed, this gives a potential water storage capacity of 2,410,000 m^3. That is, to store a whole year's worth of rainwater, 30% of existing underground structures in Maxvorstadt would be needed. There is a well-functioning economic incentive in place in Munich for rainwater harvesting. Property owners are encouraged to unseal impervious surfaces, allowing rainwater to infiltrate the groundwater aquifer, whereby they can save up to 70% of the wastewater discharge tariff, which currently is a combined fee of 1.56 €/m^3 for wastewater and 1.30 €/m^2 for rainwater for sealed surfaces connected to the sewer system (Münchner Stadtentwässerung 2005). Also, Munich has a groundwater aquifer below the city where water can be stored more effectively than in cisterns. However, the incentive to implement rainwater delivery facilities to substitute drinking water for non-drinking water purposes is currently rather low: considering the current tariff for drinking water, the savings by not paying for drinking water would account for less than €4 million/year. Not considered in this scenario are costs for rainwater treatment to meet specific use requirements, the conveyance systems to customers, or pumping energy. In addition, rainwater for percolation into the aquifer must comply with quality standards and is likely to need pretreatment in urban areas. Further, the existing stormwater drainage system must still be maintained and paid for as long as some of the rainwater collected continues to be discharged into the sewer system, such as rainwater from traffic areas. This example illustrates that in cities with an existing fully built-out sewage infrastructure, which is also designed to capture wet weather events, the economic and energy-saving incentives are not highly conducive to implementing a major change in urban water infrastructure. Incentives that merely cover costs would also not be sufficient: additional (economic) incentives would be needed.

In terms of energy, the primary energy consumed in households in Munich is for heating, at 78% (SWM 2014). Current total consumption per person of electricity in households in Maxvorstadt is estimated to be 1800 kWh per year (SWM 2015-2). Of this, about 715 kWh per person per year is needed to provide hot water, 585 kWh for food refrigeration, 195 kWh for electric cooking, 195 kWh for lighting, and the remainder for other electrical household appliances (SWM 2014).

At Jenfelder Au, a newly built neighbourhood in Hamburg, Germany, and home to 2000 people, a different water management concept was established, wherein the collection of blackwater (from toilets) and greywater (from kitchens and bathrooms) from households is separated. Blackwater is mixed with organic waste to generate biogas, which is re-supplied to households for heating and other energy demands. The residues from the greywater treatment are also fed into this process, and the clean water channelled to water bodies in the landscape. The process generates 340,000 m^3/year of biogas, which after transformation yields 370 kWh/person*year of electricity and 778 kWh/person*year of thermal energy (Schönfelder et al. 2013). If one were to apply the same process to Maxvorstadt, in theory, the same energy savings per person are possible, and biogas production could reach 7,983,200 m^3/year. Thus, a significant amount of local household heating and electrical energy demand could hypothetically be met through decentralized energy production using domestic sewage mixed with biomass such as organic kitchen waste. Saving the water used for flushing toilets, as described above, by using rainwater can also enable energy savings of 5.5 kWh of electricity per person per year for the Jenfelder Au development (Schönfelder et al. 2013). However, in Munich, where the favourable topography obviates the need for pump energy to supply drinking water, the energy needed to pump rainwater from underground cisterns or the groundwater aquifer to the top of buildings for toilet flushing could well exceed any energy saving. An energy-saving incentive may be more attractive to households than costs saved due to conservation of drinking water. Considering the current energy rates in Munich, however, it may be difficult to convince households and homeowners to invest, as such a use would require a dedicated dual distribution system, which would be very expensive to implement in existing buildings. What is more, parallel distribution systems come with some risk of faulty cross-connections. However, retrofits might become more economically viable in combination with energy conservation measures or restorations.

In terms of food, the current practise of urban agriculture is negligible in Maxvorstadt. For this case study it was hypothesized that to most effectively cool the microclimate and avoid an urban heat island effect, both today and in the future under climate change, as much green infrastructure as possible would need to be integrated into the urban fabric. In this study, based on the WEF Nexus approach, this is surmised to be intensive urban agriculture. However, other types of green infrastructure could be used to cool the microclimate effectively. There is a significant amount of haphazard building development inside the Maxvorstadt block courtyards, owing amongst other factors to acute housing shortage in the wake of

World War II. Buildings of less than three storeys inside blocks were assumed to be non-residential (e.g. garages) and were hence hypothetically eliminated without decreasing population density. It was further assumed that impervious surfaces inside blocks could be unsealed if a trend towards decreasing car ownership were assumed, as these are mainly car parks. These freed-up areas could be used for urban agriculture. Also, it was assumed that flat roofs and those with less than a 15° angle, as well as southwest-facing facades (except of landmarked buildings), were suitable for horizontal and vertical urban agriculture. Obviously, these net areas identified cannot all be used for urban agriculture, as shading and space needed for other activities have to be considered. But for the sake of simplicity, here, the net horizontal and vertical areas are assumed to be available for urban agriculture. This represents a total area of 168 ha, with an irrigation demand of 1840 m^3/day in the growing season between May and October.

In Bavaria, due to the abundance of water resources, there is no systematic data collection on crop irrigation: when crops need irrigating, water is simply applied. Much of the irrigation demand is currently met by rainfall, unless the summer is dry and hot, as was seen in 2003 and 2015, in which case vegetables must be watered regularly (LWG 2015). Hence it is necessary to plan for urban agriculture irrigation in view of the expected increase in warm days and the significantly reduced summer precipitation during the planting season, as described earlier. Stored rainwater or reclaimed water could hypothetically be used in Maxvorstadt for this application, but only after very cost-intensive treatment, including disinfection, to make it safe for reuse.

Although exact figures are missing, recovery of energy from wastewater is practised in approximately 30% of all wastewater treatment plants in Germany. These facilities convert the biogas generated to energy and heat, providing on average 80% of their energy demand and approximately 10% of their heating demand (Statistisches Bundesamt 2015). Biomass is generally considered CO_2-neutral and can be stored, as opposed to other regenerative sources such as wind or solar energy. Munich currently has two wastewater treatment plants that use co-digestion to generate biogas, which is converted to supply 78% of their energy demand (with projected upgrades to cover up to 90%) and more than 100% of their heating demand. In comparison, the efficiency of a multitude of decentralized smaller-scale wastewater treatment plants in various parts of the city may be much lower. Biogas generation has been supported by the political agenda in Bavaria in the past, but only from crops and animal manure (StMWIVT 2011). Recently, biogas from energy crops has become less politically popular: it is the most expensive renewable energy and comes with significant environmental degradation (e.g. erosion, pesticide use). Incentives for the use of biomass as renewable energy are currently restricted to the agricultural sector in Germany, which is a barrier to promoting increased generation of biogas in municipal wastewater treatment plants. In fact, there is even a disincentive in place for wastewater treatment plants to feed electrical energy from biomass into the grid (German Renewable Energy Law 2016). Nonetheless, in Bavaria, research into biogas generation from wastewater has been conducted for decades. Further, municipal wastewater continues to be a very stable resource in cities. Renewable energy is the primary job creator in Germany (The °Climate Group 2007), and decentralized energy generation using wastewater and biomass can create further jobs. Biomass from urban agriculture such as cuttings and stems and from household organic waste can be added to municipal sewage to enhance local biogas production. Currently, roughly 28 kg per person of organic waste is collected each year in Munich in so-called bio bins, but the full potential is assumed to be 93 kg per person if all organic waste were to find its way into these bins (AWM 2015). Hence, organic waste, if systematically harvested, is also a valuable potential resource that is currently being under-utilized in Munich.

At Jenfelder Au, the investment needed to generate energy from the blackwater of 2000 persons using a fermenter, heat exchanger, sludge thickening process and cogeneration plant was €935,000 (Schönfelder et al. 2013). If the same plant size to generate energy decentralized for 46,960 persons over the age of 3 years living in Maxvorstadt blocks is assumed, 23 plants will be needed. These resource recovery facilities are hypothetically installed underground to enable collection of wastewater by gravity in the block courtyards: rainwater is channelled to flush toilets by adding a pipe in existing shafts, and blackwater is collected by disconnecting the toilet pipe from greywater pipes. Using plants of the Jenfelder Au type, total investment in the plants would only be around €20 million. With 136 blocks, one plant per block may be more sensible in order to avoid pipes below roads. In that case, the total investment would be around €130 million. However, at Jenfelder Au, this cost was for development on a greenfield site. Thus, the cost to install the same infrastructure for source separation in Maxvorstadt, an existing urban setting, would be much higher. In addition, costs for installing pipes and pumps, and operational and maintenance costs, would also need to be considered.

The central sewage system of Munich is 2500 km long, and the cost of the redevelopment of a 1.6-km section was recently estimated at €26.5 million (SZ, 2014), or €16 million/km. The cost is high because this segment of the sewage system is particularly old and of a particular type of construction. Nonetheless, using this cost as the basis for a rough estimation, renovation of the system for the area of the Maxvorstadt blocks, which comprises about 25 km, could cost around €400 million.

However, implementing the WEF Nexus-based scenario as described above in Maxvorstadt would entail huge investment at the household and municipal levels: provisions would also have to be made to store rainwater and reclaimed water during the non-growing season. Further expense would be involved in ensuring appropriate quality in terms of health and safety of reclaimed water for reuse, installing the new systems required to harvest bio-energy, adapting existing systems, and distributing the reclaimed water and harvested bio-energy to the designated demand locations, including pumping energy. The cost of implementing and operating urban agriculture at a large scale would be significant as well. A large set of individual plants and separate systems would also entail huge additional operational and maintenance costs. Finally, complicated socioeconomic, land ownership and administrative issues would need to be tackled, incurring further costs.

Hence, transitioning to an alternative system in Munich is not economically attractive. Further, the conversion or redesign of such large-scale existing infrastructure and planning conventions would require a considerable amount of time. It would also have to be proven that energy savings, in particular, would be more than marginal. If we compare this scenario to what Munich is already doing, the water- and energy-saving incentive for the municipal government to adapt the existing system in a neighbourhood like Maxvorstadt is very limited. In a new development such as Jenfelder Au on a green- or brownfield site, the cost calculation is completely different, making water reclamation and reuse potentially much more viable. However, in an existing neighbourhood of the urban fabric type of Maxvorstadt, the costs far outweigh the benefits.

Nonetheless, the fact that the centralized sewage system is in need of expensive large-scale renovation, along with its strong path dependence, is a “window of opportunity” to think about other technological solutions in view of future climate change-related water challenges, and to use these thoughts to support a paradigm shift. At the moment, decentralized water recycling is much less economical than the centralized sewage system if a time frame of 20 years is considered (Sedlak 2015). Yet, what if we look at the next 100 years and factor in the cost of providing sufficient freshwater for current demand over great distances to cities in water-scarce regions? Munich is a special case, where freshwater provision requires relatively little energy. In contrast, cities like Sao Paolo in Brazil are already experiencing the burden of such costs. In the United States, the cost of restoring existing water systems that are falling into decay is estimated to be at least $1 trillion over the next 25 years (AWWA 2012). If more pilot projects are built now, the long-term benefits of more flexible decentralized water reclamation and reuse schemes tailored to local needs could be determined. In Munich, just as in Leh, there are many potential barriers to the operationalization of the WEF Nexus approach. Key questions to consider for future development of Munich are: Is maintenance of the existing infrastructure sustainable? Which type of infrastructure may be suitable for new parts of Munich that are now being planned?

Synthesis of the Two Cases

This paper has aimed to illustrate that under climate change-related water uncertainty, implementation of natural resource-intensive technologies such as traditional water supply and sanitation systems may carry risk of failure, considering current and future boundary conditions. Implementation of all technologies is path- and resource-dependent, and hence implies risk. However, some technologies can be more flexible and thus more resilient to changing conditions than others. These uncertainties are currently also reinforced by the lack of clear policy intent to curb consumption of natural resources such as water, energy and food. Hence, the question of how to reduce consumption to mitigate and adapt to climate change, and particularly to conserve water resources, is just as urgent in the West as elsewhere.

There are many viable water reclamation and reuse technology options available. Implementing these in some urban fabric or city types may inherently support the conservation of water and energy resources and increase the system's overall resiliency. However, thus far, these technology options have rarely been implemented at scales larger than individual buildings or single service providers. Additional pilot projects are needed to test the efficacy of these options, for example, at the neighbourhood scale. There is a large volume of data regarding conventional large-scale systems and energy efficiency, but virtually no such data to enable a comparison of smaller-scale options. Research is needed to address questions such as the amount of energy that could be recovered through a WEF Nexus-based approach as described here, in Leh as in Maxvorstadt, and whether this could be as efficient, in order to support implementation efforts.

In order to assess whether a WEF Nexus-based alternative development option is suitable for a given location in terms of the so-called triple bottom line, i.e. social, environmental/ecological and economical aspects, a thorough study of a given city's boundary conditions is needed. Decentralized options may not be best for some types of cities (Wilderer et al. 2016). In the case of Munich, the city is already engaged in the conservation of water and energy resources. A radical change to the existing system, for example, as described above, could harbour unintended consequences that are difficult to foresee. However, there may be other types of neighbourhoods in existing cities where this would not be the case. For example, in Germany these might be cities where populations are shrinking or ageing and water consumption patterns are changing, or urban fabrics that are in need of large-scale renovation due to low building quality, such as neighbourhoods constructed in the post-World War II era. In developing economies, these could be cities where water infrastructure development is unable to keep pace with urban growth. An alternative development option may also be suitable as an add-on in certain contexts in a semi-central or hybrid approach, for example, where a centralized sewage system already exists but there are areas of the city that are not being serviced by it. A catalogue of key indicators coupled with reliable numerical values might help to determine the suitability of these boundary conditions. Such a catalogue might be structured to address various key questions, examples of which are described in Table 7.1.

This study has many limitations, as it is very hypothetical and makes many assumptions. However, the main aim of the study was to indicate potentialities for operationalizing the WEF Nexus approach. As such, it advocates that a thorough investigation into such potentialities is warranted.

Conclusion and Recommendations

The WEF Nexus approach cannot be dismissed as a "development topic". A paradigm shift is urgently needed to enable the broader implementation of water reclamation and reuse, resource recovery, and sustainable food production—

Table 7.1 Aspects that influence the choice between centralized or decentralized (sub)systems or acceptance (of change to existing systems)

Key question	Key indicators
1. Which resources predominantly trigger supply needs/abilities?	Climate; geographical and regional differences; water, energy and food demand; supply and availability; history and trends; ethics/religion
2. What are the components of the existing water management system?	Relative location of water supply sources, topography, distribution and storage system, sewage system, existing legislation and by-laws, existing infrastructures and construction features
3. How acceptable is a different system to the local community?	Awareness; socioeconomic indicators on income, education, health
4. How can a modified or new system be administered?	Existing institutions, legal and regulatory framework, policies, budget
5. What would be the necessary material and financial investment?	Financing, cost-benefit analysis, existing resources e.g. for construction

centralized or decentralized—in existing cities. Here, actions by local city and national governments are crucial. When water, energy and food were scarce in the past, national and local governments were very stringent in curbing consumption of these resources by local populations, for example during the first oil crisis. Today, such action is urgently needed to help propel the plethora of existing bottom-up initiatives. To meet the climate target of less than 2 °C, government action on climate change needs to become a key aspect of welfare capitalism within the next few years.

In the future and under climate change, the question of water availability will be critical in identifying the appropriate type of water management infrastructure for urban development at a given location. Water availability, however, cannot be precisely predicted, and forecasting is even more uncertain under the impacts of climate change. Hence, it is imperative that when windows of opportunity open for the construction of new infrastructures or for renovating and modifying existing ones, these infrastructures must be planned to conserve water resources to the fullest extent possible in order to support the resilience of cities against climate stresses. If we had known then what we know today, we might have designed the mainstream water management systems constructed over a century ago to better conserve water and energy resources. As it is, the focus of urban water infrastructure provision has changed over the last decade, from one focused solely on hygiene, towards a Nexus-based approach, including recovery of energy and nutrients such as phosphorus. Today, existing systems are diluting a very valuable resource, namely municipal sewage, to such an extent that it is difficult to recover its intrinsic energy content. Modifying existing systems requires a long-term planning horizon to adapt city design (taking future developments in terms of climate change into account). Both case studies hint towards the need for supporting tools such as economic incentives, refinancing regulation, cross-sector balance and expert appraisal in order to assist various aspects of change.

Path dependency, meaning loss of flexibility when choosing a system for a water infrastructure, becomes a risk when boundary conditions change, such as changes in population or climate. This risk is expected to decrease when interdependencies of water infrastructure with other sectors such as energy or food are more closely taken into account when a window of opportunity opens for implementing new or modifying existing water infrastructure.

A catalogue of key indicators coupled with reliable numerical values to describe boundary conditions can support taking rational decisions. These decisions should not be hamstrung by path-dependent developments in the water, energy and food sectors, as they have been in the past, but instead must acknowledge and utilize the synergies for an integrated development of all three sectors. To a certain extent, decision-makers will always have to rely on their instincts and common sense. Incentives for taking sustainable decisions must also extend beyond economic considerations, to visions of a desirable future for generations to come.

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Chapter 8
Risking Weather Engineering: Fiction or Contribution to Conflict Prevention?

Peter A. Wilderer, Helmut Fluhrer and Elena Davydova

Context Statement

Water scarcity causes a lack of tradable agricultural products, resulting in insufficient income for farmers and hunger among consumers. Evidently, insufficient income and lack of food triggers either emigration or engagement in terrorism. Preventing this chain of causes and effects—particularly in semi-arid and arid countries—requires effective water supply for irrigation. To make irrigation water available, innovative methods of delivering water are required, even from unconventional sources such as atmospheric humidity. Ionization technology belongs to this category of innovative methods. The willingness to accept risks associated with such an unconventional method is indispensable, not only to effectively counteract scarcity of water, food and income, but also to safeguard national security. It is necessary to further develop ionization technology, to learn about potential risks and to identify methods to deal with such risks wisely. As stated in the Memorandum (see Chap. 24)—General Recommendations, point "g": *Politics must strive on the one hand for an evidence-based approach when it comes to weighing opportunities and risks, yet on the other hand, promote a safety culture favoring error-friendliness and resilience due to the remaining uncertainties.*

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Introduction

This article is in a way a homage to Aristotle, whose 2400th birthday was celebrated in 2016. His observations and commentaries have not lost their importance over the past 24 centuries. Aristotle, in his first book, discusses the principles of meteorology. In this context he wrote:

> The same parts of the earth are not always moist or dry, but they change according as rivers come into existence and dry up. And so the relation of land to sea changes too and a place does not always remain land or sea throughout all time, but where there was dry land there comes to be sea, and where there is now sea, there one day comes to be dry land. But we must suppose these changes to follow some order and cycle […]. But the whole vital process of the earth takes place so gradually and in periods of time which are so immense compared with the length of our life that these changes are not observed, and before their course can be recorded from beginning to end whole nations perish and are destroyed.

Nothing has changed since then. Prosperity and peace depend mainly on the availability of water and food. Water as the basis of food. Food as the basis of the opportunity for income creation comparable to that in developed countries.

The basic need, therefore, is water, fresh drinking water as well as irrigation water for agriculture. Naturally, irrigation of agricultural fields is taken care of by rainfall (rain-fed agriculture). In semi-arid and arid countries, however, rainfall is scarce. In this case, weather engineering based on scientifically sound knowledge should be considered not as a fiction but as a valuable contribution to the preservation of peace and prosperity.

Analysis of the Problem

The observed increase of the Earth´s surface temperature is undoubtedly caused, at least in large part, by human-induced emission of so-called greenhouse gases, including carbon dioxide. Climate change is the immediate consequence. Atmospheric physicists and meteorologists forecast severe increase of natural hazards in various regions of the world. Excessive rainfall events are expected to occur more and more frequently, as well as extended drought situations. To avoid large-scale damage of assets, cutback of bio-diversity and loss of human lives, action is to be taken in the form of reorientation towards enduring resilience of natural systems (Fig. 8.1). Taking this into account, the members of the past United Nations conference on climate change held in Paris in 2015, COP21, agreed to take measures that limit the global temperature increase to less than 2 °C (United Nations, 2015).

The result of COP21 is certainly remarkable. However, can we expect that meeting the two-degree limit will be sufficient to provide prosperity and peace to people on Earth? Unfortunately, global warming and climate change are not the only elementary problems life on Earth is currently facing. Victor Gorshkov et al.

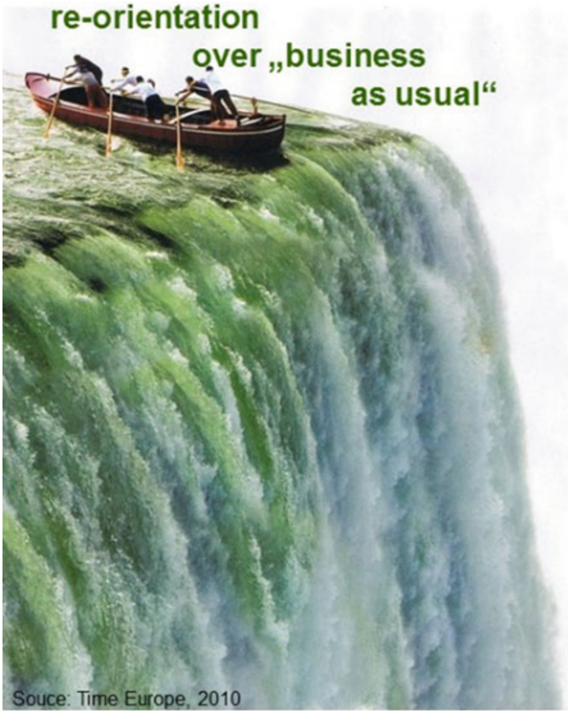


Fig. 8.1 Escaping from the global warming trap through action taking (adopted from Times Europe, 2010)

(2000), James Lovelock (2009) and many others already warned decades ago that disrespect of the principles of biotic regulation is inacceptable, and might eventually lead to a global disaster. The Zugspitze Declaration, issued by the participants of the 2008 Institute for Earth System Preservation (IESP) Workshop, pointed to three other global crises to be solved in parallel to global warming/climate change (Fig. 8.2). In this context, a crisis should not be confused with destiny. In contrast to destiny, a crisis can be overcome by proper action.

A concerted action is required (Wilderer and Grambow 2016).

In many parts of the world, a significant increase in existential threats such as thirst, hunger and unemployment are spreading. Deficiencies in water and food are partly caused by climate change, which triggers extended drought situations. As explained below, there are other causes amplifying such deficiencies. Experience teaches that the continuing lack of water, food, energy and jobs destabilizes economies as well as societal coherence. Similarly, the sacrifice of natural landscapes for infrastructure build-up and economic profits leads to a severe loss of bio-diversity and the abundance of bio-capacities, and subsequently to destabilization of large-scale ecosystems. This has negative impacts on agricultural food production, thus leading to further economic destabilization, including loss of jobs,

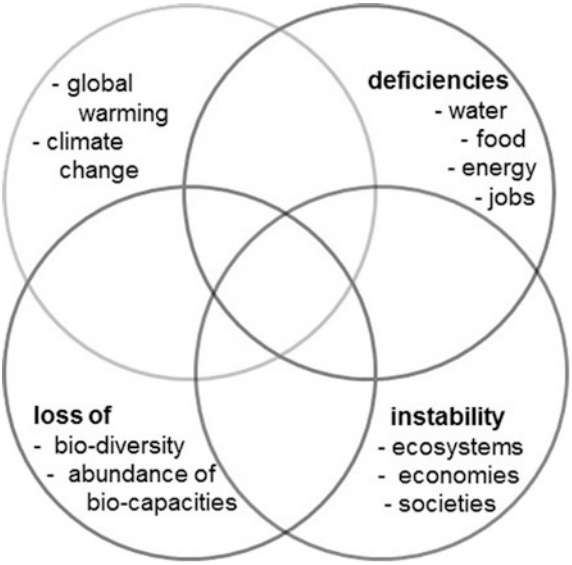


Fig. 8.2 The four global crises threatening life on Earth, as well as prosperity and peace

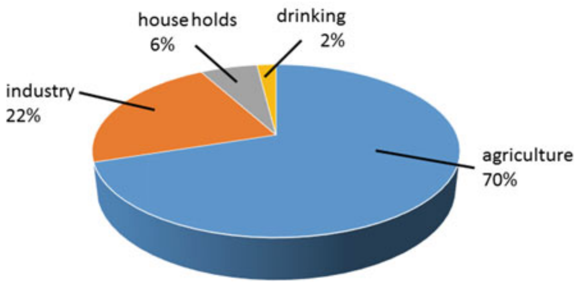


Fig. 8.3 Distribution of water consumption in the world (Source of data: UN Food and Agriculture Organization, 2016)

higher unemployment, increased crime, civil uprising, and eventually migration. Water scarcity plays a substantial role in all such impacts.

It is broadly understood that the reasons underlying the deterioration in conditions essential for societal stability are

1. Population growth
2. Accumulation of people in urban settings
3. Lifestyle changes.

Currently, more than seven billion people live on Earth. Most of them prefer living in urban settings, often causing the local demand for water, food and jobs to exceed the capacity of the local economy and the locally available water resources. Of particular concern is the lack of water for the production of agricultural products, typically accounting for 70% of the overall water demand (Fig. 8.3).

Lifestyle changes not only exacerbate the need for food, but even more for animal fodder (e.g., maize, alfalfa and sorghum), biofuels (e.g., soy, rapeseed, sunflower) and textiles (e.g., cotton). Selling such products on the international market provides particularly high profits. Thus, a considerable fraction of agricultural land is used for the production of tradable agricultural products, including wood. Simultaneously, enormous quantities of water are taken for growing plants of commercial interest. As a consequence, in many parts of the world, particularly in arid countries, water scarcity is continuously increasing. Indigenous farmers not only lose land for growing domestic food, but they also lose access to water for irrigation. Simultaneously, the demand for water in urban areas is growing but often cannot be satisfied. Thus, hunger and thirst is spreading. Local economies and societies destabilize, leading to radicalization of hungry and thirsty people and eventually to emigration (Mauser 2007). In essence, decreasing water availability due to such developments can be considered an even greater existential threat than global warming and climate change.

Global environmental changes predicted by the Intergovernmental Panel on Climate Change (IPCC) and then observed over the past decade that can be attributed to anthropogenic impacts are also related to water. Examples are sea level rise due to melting of snow and ice-covers, and changes in the frequency and/or intensity of extreme rainfall events and extended drought situations. The problem affects an estimated 2.7 billion people for at least one month of every year, across every continent—and is particularly pressing in cities as the global urban population grows. At present, almost four billion people live in cities, with a further 2.5 billion expected to join them by 2050.

Traditional Methods for Mitigating Water Scarcity

The evolution of civilization and rise of the first high cultures in Egypt, Mesopotamia, India and China has been closely related to advances of organized water distribution to farmlands (Wittfogel 1967). Obtaining water on demand allowed farmers to grow agricultural product beyond the existential needs of their own families. Food could be delivered to citizens working outside of the farming community, namely in towns and cities. Municipalities developed, providing the basis for city life, commerce, manufacturing, mathematics, physics, astronomy, meteorology, writing, philosophy, and above all, a knowledgeable administration organizing capture, transport and fair distribution of water to farmers and to city dwellers. Wittfogel called this “the cradle of civilization” and “the cradle of the hydraulic society”.

To be able to provide water to farmlands and municipalities, it was necessary to identify proper sources of water, those which fetch water even during dry seasons. Digging wells for exploiting stored water of aquifers was and still is the first choice. Secondly, efforts were and continue to be made to store water aboveground in reservoirs. Consequently, dams have been built, followed by canals and aqueducts to transport the water from the source to the users of water (e.g., dwellers, farmers, manufacturers, industry). It is amazing how quickly and effectively dams, canals and distribution systems were built and operated in ancient times.

It is even more amazing that, even today, the building of dams and canals for mitigating water scarcity is still the state of the art. In Germany, the Stuttgart region receives most of its water through long-distance pipelines from Lake Constance. Water from the Danube River is pumped to the Nuremberg regions using a navigable canal. The California State Water Project stretches from north to south over several hundred kilometers (Fig. 8.4). In China, water is transferred from south to north through several routes (Fig. 8.5).

Application of the ancient concept of water scarcity mitigation causes a number of consequences and systemic risks, for instance:

- Decay of soil fertility through precipitation and accumulation of salts, leading eventually to complete loss of fertility in the irrigated agricultural land. (Doneen 1954; Schoups 2005).
- Contamination of land caused by drying out of receiving water bodies (Fig. 8.6). (Jarvis 2016; Lindsey 2000)

Fig. 8.4 Aerial view of the California Aqueduct

Fig. 8.5 China South–North water transfer project

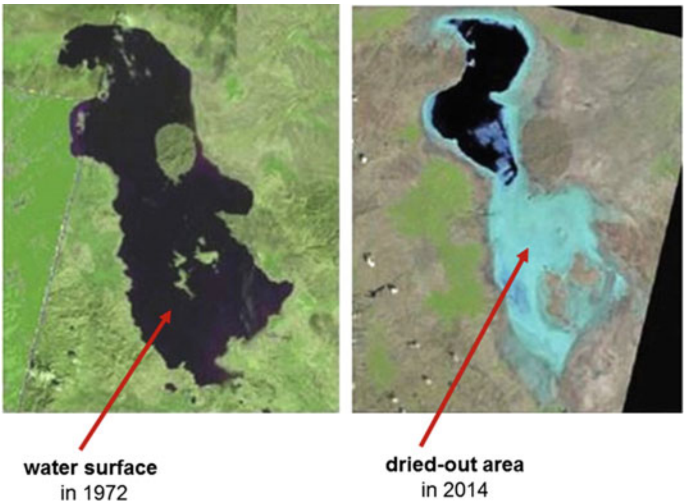


Fig. 8.6 Shrinking of Lake Urmia, Iran, over the past 42 years (adopted from Madani, 2014)

- Dangerous loss of groundwater resources (Fig. 8.7) caused by over-extraction of water in northern India (Rodell et al. 2015). Similar depletion of the groundwater table has been observed in many other areas of the globe, for instance in Syria and Iraq (Voss et al. 2013).
- Loss of homeland and ecosystem function in the context of building dams in the Yangtze River catchment area. The 2013 issue of *The Guardian* listed problems which include:
  - *The dam reservoir has been polluted by algae and chemical runoff that would normally have floated away had the dam not been built. Algae and pollution are building up.*
  - *The weight of the extra water is being blamed for earthquake tremors, landslides and erosion of hills and slopes.*
  - *Due to ongoing problems, tens of thousands more people have already had to be moved from areas in and around the project.*
  - *Because of the instability and unpredictability of the project, scientists are calling on the government to do the following: establish water treatment plants, warning systems, shore up and reinforce riverbanks, boost funding for environmental protection and increase benefits to the displaced.*
  - *Some scientists are advocating the reestablishment of ecosystems that were destroyed by the project and are suggesting the additional movement of hundreds of thousands of residents to safer ground.*
  - *Before the project, there were 1392 fresh reservoirs of water, which have become "dead water", destroying drinking water for over 300,000 people.*
  - *Boat traffic on the Yangtze River has been negatively affected, as the depths and shallows of the river have been completely transformed, and thousands of boats regularly run aground.*

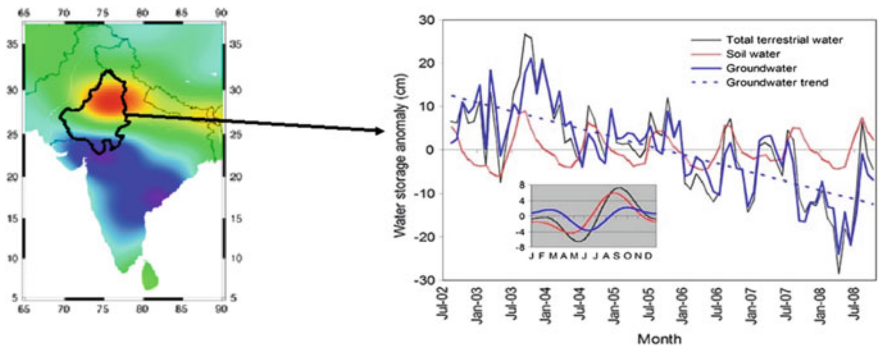


Fig. 8.7 Groundwater depletion in Northern India (adopted from Rodell et al., 2015)

- *The design of the project has resulted in damage to the Yangtze River such that water no longer pushes mud and silt downstream, but stagnates it above the dam.*
- *While the current problem is a drought over the past decade, floods and droughts have come and gone, and the flow control mechanism of the dam project does not seem to be operational, having no effect on water levels.*

The Biotic Pump—Natural Means for Delivering Rainfall

Global change exacerbates the process of desertification. According to intensive studies by Makarieva and Gorshkov, two scientists of the Russian Academy of Science at St. Petersburg, there is another factor causing desertification to spread, namely clear-cutting of coastal forests (Makarieva and Gorshkov 2006; Makarieva et al. 2013; Ellison et al. 2017). Apparently, natural forests provide a strong impetus to the transport of humidity from the oceans to the inland. Data regarding horizontal precipitation patterns published for various river catchment areas (Fig. 8.8) led to this very perception.

Further studies led to development of the theory of ecosystem-mediated humidity transport depicted in Figs. 8.9 and 8.10. In short, the authors assume that evapotranspiration in the canopy area of forests leads to the ascent of humidity into the atmosphere. There, condensation processes and subsequent rainfall cause a decrease of the local water gas partial pressure, triggering horizontal transport of humid air from areas where the water gas partial pressure is comparably higher, for instance from the area above the sea. Thus, water is delivered to the forest where an iteration of the chain of processes (evapotranspiration, condensation, rain-drop

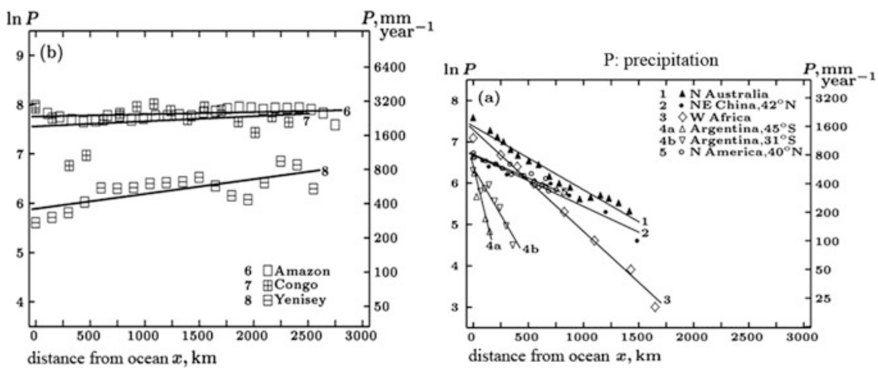


Fig. 8.8 Evolution of precipitation with distance from the ocean: watershed where coastal forests are present (left) in contrast to catchment areas where coastal forests were removed (right) adopted from Gorshkov et al. 2000)

formation and rainfall) leads to delivery of humidity over large distance (Fig. 8.8, left side). This chain of processes is called the "biotic pump".

As depicted in Fig. 8.9, the "biotic pump" enables transportation of humidity towards the inland, assisted by coastal forests. Regions with water-storing vegetation ensure regular rainfall even 2500 km from the coast (Fig. 8.8, left side). Without coastal vegetation, rainfall decreases drastically with increasing distance from the coast (Fig. 8.8, right side, and Fig. 8.10).

With the extensive deforestation of coastal areas over the last century as a result of the development of urban areas and tourist resorts, the "biotic pump service" has been strongly hampered. Although restoration is possible through afforestation, the maturation of newly planted forests requires decades. To improve the situation, particularly for the benefit of local farmers, we need alternatives to the "ancient" method of surface transport of water though biotic pumps, canals or conduits from dams or from seawater desalination plants; alternatives may include rapid development and implementation of innovative methods of rainfall enhancement. As Friedensreich Hundertwasser (1981) put it in one of his famous Danish posters: "slutt fred med naturen—Save Rain", in English: Make peace with Nature—Save Rain (Fig. 8.11).

Innovative Methods of Rainfall Enhancement: "Cloud Seeding" as an Example

Enhanced growth of cloud droplets can be achieved if the air temperature within the clouds can be artificially lowered. In the case of clouds containing supercooled droplets, rapid cooling—for instance, by injecting dry ice (frozen CO_2)—is a potential trigger for turning droplets into ice particles. The ice particles can be expected to grow, since condensation with respect to ice is particularly high.

Vincent Schaefer was the first to suggest this idea and to investigate its applicability. In a laboratory operated by General Electric Company, he was able to

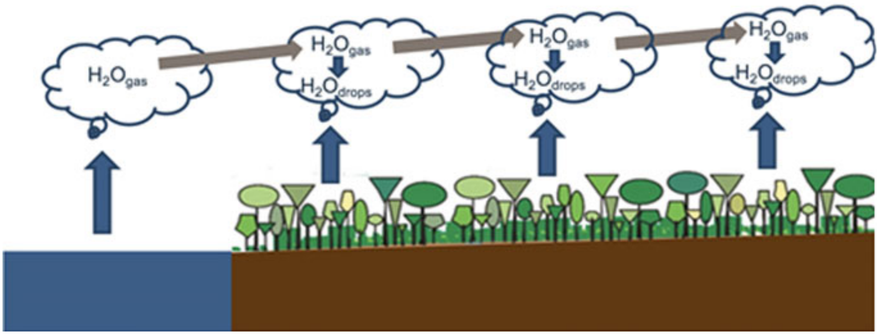


Fig. 8.9 Horizontal humidity transport mediated by forest ecosystems (adopted from Makarieva and Gorshkov, 2006)

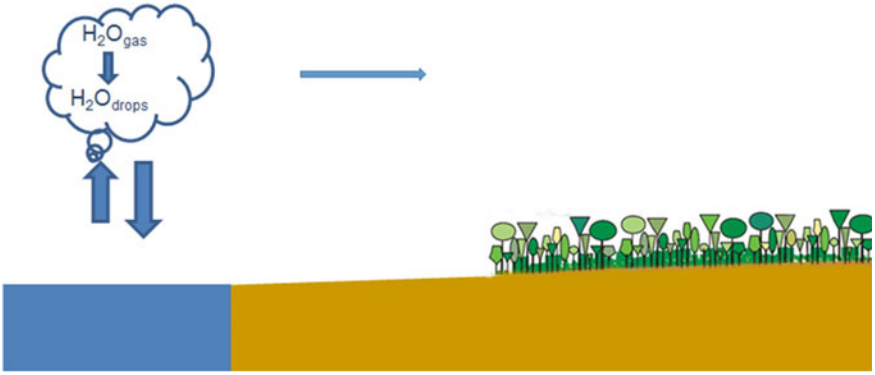


Fig. 8.10 Minimized or even interrupted humidity transport where coastal forests are absent (adopted from Makarieva and Gorshkov, 2006)

Fig. 8.11 Eternal wisdom

achieve positive results, and on November 13, 1946, he conducted a field test in the vicinity of Mt. Greylock (MA, USA). In this test, an airplane was flown across a supercooled stratus cloud and dry ice particles were dropped along its flight track. Within minutes, the texture of the cloud changed dramatically, and below the cloud, snowflakes were detected.

Under the leadership of Irving Langmuir (winner of the Nobel Prize for Chemistry in 1932), and in cooperation with Vincent Schaefer and Bernard Vonnegut, experiments continued. The group tried to find a substance which would be as effective as dry ice, but would work at temperatures closer to the freezing point of water. It was Vonnegut who identified silver iodide (AgI) as a potential seeding material.

Today, cloud seeding technology is used the world over. According to a report by the World Meteorological Organization (WMO), in 2015 there were 56 countries applying cloud seeding programs (Fig. 8.12). With 45 programs, 10 US states were the most active in cloud seeding worldwide. In China, approximately 60,000 staff members serve in the "Rain Army", which controls 20 planes, 4000 artillery and 2000 rocket launchers.

During cloud seeding operations, only a fraction of the available cloud cover can be influenced. Cloud seeding with chemical substances such as silver iodide remains most questionable since there are concerns about the impacts to health. Cloud seeding with ice nuclei creates clear water, but the ecological footprint of the flight operations is substantial.

One of the first cases was the Kingdom of Saudi Arabia, which had an intensive cloud seeding project from 2005 to 2011; the project was stopped because of insufficient results and increasing heath concerns of the population.

Fig. 8.12 Global cloud seeding operations (prepared by the authors)

Ionization Technology: The Alternative to Cloud Seeding

The first field tests using corona discharge (i.e., atmospheric ionization) for fog dissipation and rainfall enhancement were carried out in the Soviet Union during World War II (personal communication with Valerie Uybo), but only now has a detailed description of the trials been found in the literature. The use of electrically charged particles of fine sand for cloud and fog modification was also considered at that time (Smirnov 1992).

Phelps et al. (1962) and Vonnegut (1970) were presumably the first to consider the role of electricity in processes to enhance precipitation. They realized that the deliberate introduction of electrical charge into existing clouds could trigger precipitation (summarized by Wilderer et al. 2011).

A relatively simple method for charging aerosols in whole clouds is deployment of a direct current (DC) corona discharge device emitting positive and negative ions. In general, this device comprises two electrodes connected to a high-voltage DC (HVDC) source, the cathode having one or more surface parts with a high curvature, called the emitter electrode.

Today, thin wires enwrapped in a pyramid structure are used to release negatively charged ions (Fig. 8.13). The mostly negatively charged earth surface serves as the anode.

In this configuration, negative ions released from the wire surface drift towards the positively charged collector, thus forming an electric current passing through the air. This current is often referred to as an ionic current. Aerosol particles, carried

Fig. 8.13 Ion emitter used during earlier projects of WeatherTec-Services GmbH in 2007 in Queensland, Australia; the very thin wires can hardly be seen (Photo: Wilderer)

by an air stream through the ion drift zone between the emitter and collector, become negatively charged in this zone by direct ion attachment. Those electrically charged particles serve eventually as condensation nuclei for raindrop generation. Charged droplets (as liquid water or ice) are forced to aggregate, forming larger drops which become subject to gravitation. Thus, rainfall occurs unless evaporation and/or sublimation transform the water into its gaseous state. To be able to handle this kind of systemic risk, it is necessary to make use of specific scientific knowledge. Furthermore, extensive measurements of external factors such as vertical temperature and humidity profiles, direction and extent of wind, and weather conditions are to be continuously carries out and evaluated. Figure 8.14 depicts the setting and the evolution of a sequence of processes expected to eventually lead to rainfall enhancement.

The emitting devices in their current form were developed by the Munich-based company WeatherTec-Services GmbH, chaired by Dr. Helmut Fluhrer (co-author of this chapter).

The review of various scientific institutions in Australia and Germany concerning scientific fundamentals of the ionization-based method reveals that this technology is scientifically plausible. In their reports and publications, the reviewers conclude that, applied in a scientifically sound manner, the technology exhibits significant potential. In particular, the results of an extensive statistical analysis were summarized by Beare et al. (2010).

Clouds, covering a significantly larger area, can be modified by remote cloud charging at low cost, especially if a grid of multiple ground-based installations is deployed. Moreover, the technology is highly scalable and suitable for applications which cannot be implemented or are difficult to implement by cloud seeding.

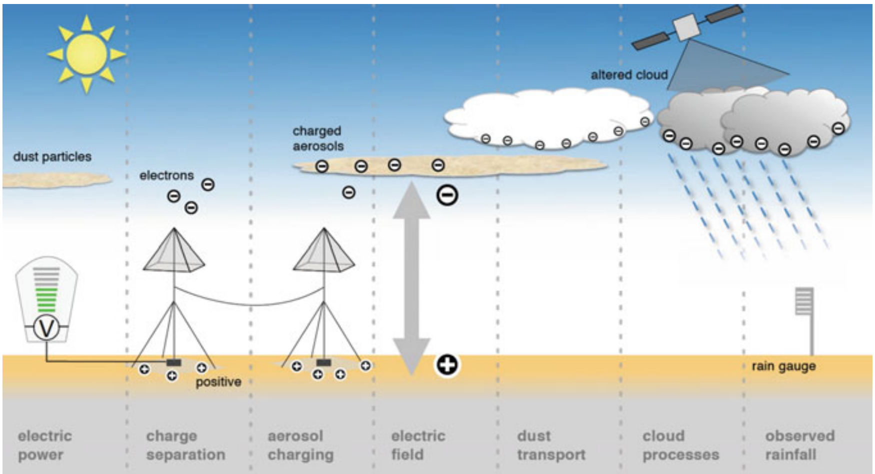


Fig. 8.14 Schematic representation of the processes succeeding electrical charging of emitters (here shown as the modern version of WeatherTec pyramid structures enwrapped with wires)

In summary, the ionization-based technology, if accepted by the scientific community and supported in more detail with scientifically sound knowledge, has enormous potential to become a viable and widely used weather-modification technology. It should be considered, however, that full-scale application of such a weather modification technology carries a high risk of interest-driven international conflicts. Therefore, commissioning of the operation of ion-emitting setups can only be issued by state authorities backed-up by robust agreements with neighboring states.

Field Trials, Observations, Assessments

Presented in the following are results obtained during field trials in Australia, the United Arabic Emirates (UAE) and Jordan (HKJ).

Example 1: United Arab Emirates (UAE), 2006

Summary of observations

- Unusual rainfall during the otherwise dry season in a desert region; significant increase in rainfall amount during the operation period (Fig. 8.15).
- Drop in surface temperature caused by cloud formation.

Example 2: Queensland, Australia, 2007

on May 26, between 1:00 and 8:40 pm.

Summary of observations:

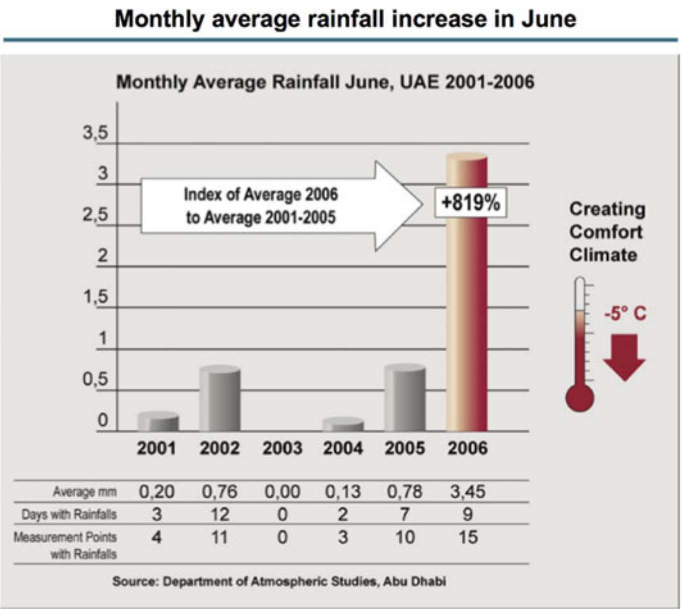


Fig. 8.15 Rainfall enhancement in June 2006

- Breaking three-year drought period.
- 7400-km^2 area equipped with most modern measurement instruments by the State of Queensland and other state universities.
- Large cloud systems moving inland from the Pacific providing rainfall after passing emitter location (Fig. 8.16).
- Record volume for man-made rainfall enhancement: total precipitation of 930 gigalitres within 6 weeks (measured by the Advanced Water Management Centre of the University of Queensland).
- Replenishment of Wivenhoe Water Reservoir.

Example 3: Hashemite Kingdom of Jordan, from May 1 to December 31, 2016

Ionization technology was selected to enhance rainfall in the second driest country on earth, a semi-arid region, covering more than 1000 km^2. The major goals were to:

1. Increase the country's self-reliance in food production.
2. Provide income to the farmers in an attempt to counteract emigration towards cities and foreign countries.
3. Safeguard the hydrological treasure box of the country, namely the groundwater reservoirs.
4. Allow afforestation with the aim of introducing natural rainfall enhancement in the future (biotic pump concept explained above).

Four emitter stations were installed in the northwestern part of the Kingdom, along the northeastern part of the Jordan Valley. The area is regularly reached by humid air masses from the Mediterranean.

The operation covered an area of approximately 13,000 km^2. The stations were positioned between Irbid in the North and the Dead Sea in the South with an extension of 100 km. The effect of the emitters could reach a distance of 100 + km.

Figure 8.17 shows the location of the emitters, and Fig. 8.18 provides a photographic view of the emitting devices.

Ionization technology is quite complex and needs a professional team of meteorologists, atmospheric physicists and chemists as well as highly specialized information technology (IT) experts for handling the enormous amount of data continuously flowing in. The monitoring and command center installed at Amman (Fig. 8.19) may provide an impression of the command center built at Amman, Jordan

Fig. 8.16 Radar images taken by the Queensland Bureau of Meteorology (BoM)

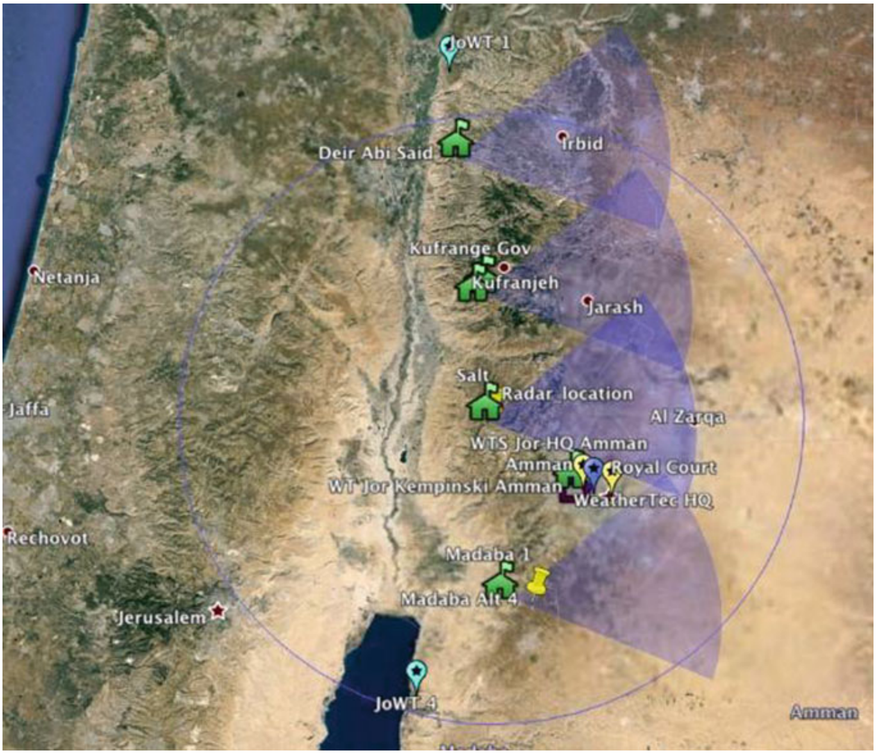


Fig. 8.17 Location of emitter stations in the Madaba region, west of the Jordan valley

Fig. 8.18 Photographic view of four emitters placed in a row

A selection of rain radar images shown in Fig. 8.20 demonstrates the development of precipitation cells influenced by the ionization emitters and by the prevailing wind conditions.

Fig. 8.19 Command, monitoring and control center headquarters, Amman

Summary of observations and data assessment:

Despite the fact that it was an average natural rainfall year within the region, the WeatherTec operation triggered additional precipitation well beyond what has occurred in the previous 10 years (Fig. 8.21).

The impact of the ionization technology can be assessed as follows. The figures show the economic benefit actually achieved:

- Compared with the previous years and compared to the adjacent areas, the amount of rainfall increased significantly (Fig. 8.22).
- The installation created 384 Mm^3 of additional precipitation, of which 28.4 Mm^3 could be used directly, partly for agricultural purposes, partly for infiltration into the aquifer.
- The 44% increase in rainfall in the operation area was 39% higher than that in neighboring regions.
- The usable water generated has a value of €36.9 million at a global market value of €1.3/m^3.

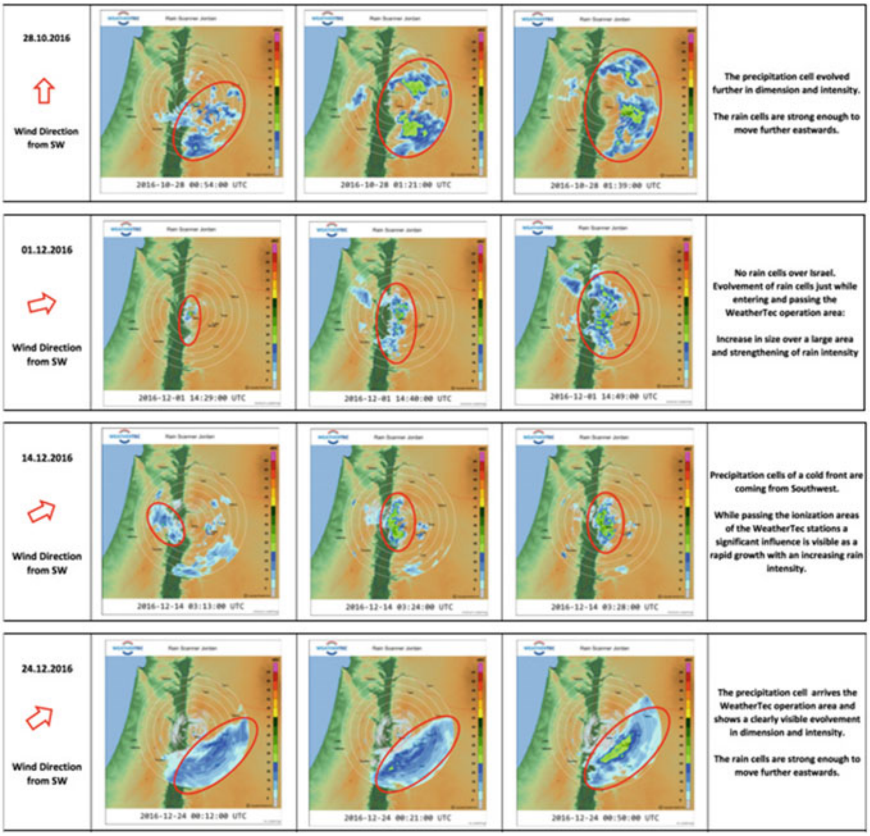
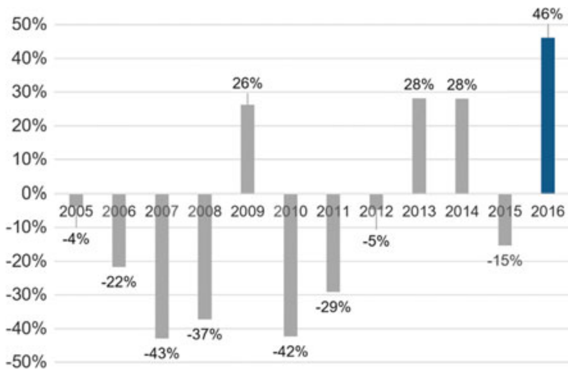


Fig. 8.20 Example of rainfall enhancement achieved in 2016

Fig. 8.21 Average annual rainfall during the past 11 years in comparison with the results obtained in the year 2016 (Source: Data from Jordan Meteorological Department)



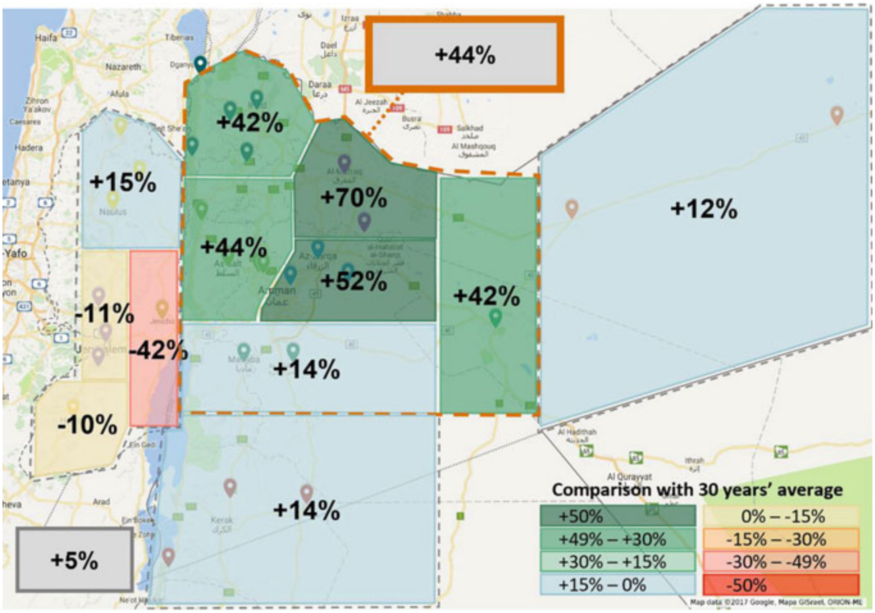


Fig. 8.22 Increase in rainfall of 44% in the operation area, 39% higher than neighboring regions (*Source*: Data from Jordan Meteorology Department and Palestinian Meteorological Department)

Rainfall Enhancement—a Sustainable Alternative?

Enhancing rainfall intensity by means of technical intervention is occasionally confused with climate engineering. In paragraph 6 of the Zugspitze Declaration (Wilderer and Grambow 2016), it is stated: "*Climate engineering should only be permitted after rigorous assessment and authorization by a process of international consensus to which all nations are supposed to contribute*". In the explanatory section of the Declaration the authors defined: "*Climate engineering is the deliberate, planned, large-scale intervention in the climate system*". Further on: "*Climate engineering must never be seen as an alternative to the necessity to solve the global crisis at its roots*".

Rainfall enhancement does not affect global weather conditions, but only the very local weather conditions. In the sense of the Zugspitze Declaration it is, therefore, fair to consider this type of intervention as "permissible".

The technology can be explained as a sustainable method of providing rainwater to agricultural fields. Sustainability is defined as the likelihood of natural and man-made systems not to exceed tipping points that negatively impact ecosystems and their functions, as well as human societies, such that associated economies do not slip over any tipping point, ultimately leading to collapse (Makarieva et al. 2015). To prevent this kind of collapse, a balance must be found that guarantees the identity and integrity of society, economy and environment alike. These three

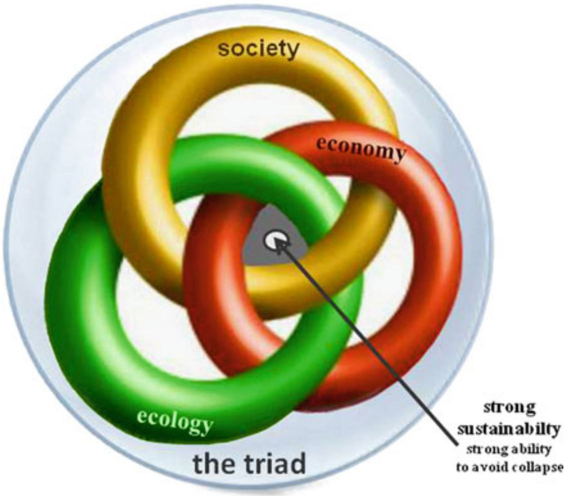


Fig. 8.23 3D-modified 2D Venn diagram (Venn, 1881) representing the eco-social triad and its subsystems. The gray area represents strong sustainability, as all three entities are covered and considered

systems are interwoven in multifaceted manners, forming a complex super-system that has been coined the "eco-social triad" (Fig. 8.23). Sustainable development of the triad requires simultaneous sustainable development of each of the three subsystems, regardless of the conflicting interests of the various actors in each. Acquisition of advanced knowledge (science), transfer of knowledge (publication) and skills (education and training), encouragement of creativity and preservation of ethical values must be the guiding principles for setting and implementing sustainable development goals and strategies.

Enhancement of rainfall using ionization satisfies all the conditions mentioned above—for instance, avoiding the collapse of farming. Rain-fed agriculture is supported without deterioration of ecological and societal functions in upstream and downstream areas. The delivered irrigation water is low in salt concentration and organic pollutants. A minimum of energy and construction material is required. Receiving sufficient rain encourages farmers to refrain from migration into urban areas. Thus, decay of societal function is minimized. Economically, the methods provide the preconditions of a viable economy. However, preservation of the local ecology depends not only on the delivery of rainwater but also on a sustainable agricultural practice. Here, education and information transfer appear to be as important as they are in all other agricultural areas.

Envisioned Risks

In Chap. 24 of this book (Memorandum—Explanation of the general recommendations, point "a"), the term "risk" is defined as the possibility of the occurrence of negative or inadvertent consequences of an action or an event. Following this interpretation, the lack of irrigation water falls in the category of a "suppressed risk". Managing such a suppressed risk requires an awareness of the adverse consequences. In the case of the inability to generate food for people and husbandry, the spread of hunger is the consequence. This leads, at least potentially, to societal instability and loss of economic prosperity. To avoid such a downward spiral, political decision makers are obligated to take action that mitigates water deficiencies.

As discussed above, the traditional concept of excess use of the available water, in particular groundwater, for irrigation is not necessarily sustainable but rather the opposite. In many parts of the world, ground-based water resources in sufficient quantities are simply nonexistent. What does exist, albeit in limited quantities, is atmospheric water. It is delivered by wind over large distances, meaning that this water resource is continuously replenished. The harvesting of atmospheric humidity appears to be a solution that should be seriously considered.

Ionization technology is a prominent method, which can be used for enhancing rainfall, thus mitigating water scarcity, hunger and thirst, and subsequently enhancing the monetary income of farmers and merchants. Is it a risky adventure to apply this technology? Experience shows that this technology is treated with suspicion, often considered as fearfully magic. Fears borne of emotions are not a good guide for action (Chap. 24 Memorandum—Explanation of the general recommendations, point "c").

Numerous cases—over 120 on three continents over 12 years, all ordered by governments such as that of Switzerland, Australia, UAE and Jordan—of successful rainfall enhancement have been documented, measured and observed by independent parties.

This leads to a point of critical self-reflection:

- Risk is a relative value, with societal, political, economic and ecological dimensions.
- Risk has a different meaning for each individual person and in each unique instance.

To judge what a risk is in a specific case and what impact it may have cannot be left in the hands of only a few people. It must be judged by the community of stakeholders.

The task of determining whether the operation of ionization technology is a risky endeavor is a difficult one, particularly for the sub-Saharan region. The authors of this article can only offer some thoughts and opinions. Among these are the following:

- People in sub-Saharan Africa need swift solutions for obtaining fresh water. Regardless of whether the solution has been proven, all that matters is avoiding the risk of death.
- People in the Northern Hemisphere who decide what technology should be used and financed to help the people in sub-Saharan Africa should understand that drilling water supply wells in water-scarce areas might have been a successful

undertaking in the past, but not in light of circumstances we are confronted with today.

- Weather engineering may remain a fiction, but it has to be considered as a readily available and sustainable solution.

This chapter was written with the clear intention of providing the knowledge necessary for a rational, science-based approach to decision making. We understand that the proposed solutions must be actively communicated in an easily understandable manner and continuously reviewed against current scientific knowledge.

We clearly understand that ionization technology bears the probability of failure. The decision as to whether the likelihood of failure in any particular case is tolerable requires a participatory discourse. As stated by the participants of the IESP Workshop on Sustainable Risk Management (Chap. 24 Memorandum—Explanation of the general recommendations, point “e”), living a culture of failure must be established to achieve societal acceptance that technical systems may fail. Thus, information and justification for both the probability and the extent of harm is a must.

With reference to the explanation of the Memorandum (Chap. 24 General recommendations, point “g”), this article should be understood as contributing to the following:

- Setting up a knowledge base while observing scientific standards, data protection regulations, and quality standards
- Promoting and emphasizing goal-oriented and result-oriented research
- Maintaining fact-based knowledge transfer, improving educational efforts with respect to probability and risk knowledge, and creating awareness so that critical decision-making processes will not be distorted by subjective perceptions
- Accepting the fact that most of the innovations today are produced by entrepreneurs and companies. The Internet and the digital and environmental revolution are facts. In all these areas, the world of innovation has been shaped not only by large companies, but by small and midsized ones as well. They shoulder the responsibility for seeking better solutions.

In this context, weather engineering must be considered as a solution for regions in need of water.

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Chapter 9
The Contribution of Neurobiology to Human Decision-Making Processes and Motivation

Stefan Braune

Risk and Uncertainty as a Part of Human Existence

Practically all human decisions and reactions have to be made on the basis of incomplete and usually non-verifiable knowledge and information in a limited time frame. On one hand, this is due to the prospective character of the decisions, and on the other, to the very high number of unknown or variably evolving covariates. Also, decisions are rarely taken by one individual in isolation without a social context. Relevant bidirectional influences on decision making exist between the individual and the reference collective. Findings from neurobiological research over the last 20 years on individu al and collective decision-making processes can provide the foundation for the modulation of the behavioral changes necessary for a sensible and appropriate reaction to changes in the environment and in society.

In short, the following statements are possible on neurobiological grounds.

Individual Decision-Making Processes

1. The assumption of the primacy of ratio/reason is false. In actual fact, decisions are made on the basis of subconscious tacit values and emotional associations that draw on past experience. Only when a clear-cut decision does not succeed on these grounds is it in fact taken by the so-called ratio. Otherwise, reason only supplies the rational explanation for a decision that has already been taken.
2. Every decision relies on intrinsic motivation, which results essentially from inter-individual interaction through social resonance with recognition, atten-

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tiveness and trust. The morphological prerequisite for mutual awareness and its influence on individual behavior are the cerebral mirror neurons.

Collective Decision-Making Processes

Human behavior is geared toward cooperation and social resonance due to the evolutionary advantages of aligned collective behavior. Here, the strength of collectively held convictions is more essential than the supposedly rational benefit-risk structure of the behavior.

The willingness to cooperate in a group occurs in the interplay of, essentially, the following factors:

- The individual assessment that a situation is advantageous in itself or in conjunction with the collective
- The importance accorded to instant or delayed gratification, respectively
- The number of persons involved: the collective effect increases only in proportion to the size of the group if the individual advantage is preserved, irrespective of group size

It has been successfully demonstrated that groups able to depart from the majority principle for decision-making processes achieve greater decision effectiveness and accuracy. For an individual's positioning in a collective decision process, it is decisive in how, by whom and at which point in time information is conveyed. Hence, there is dynamic adaptation in the course of a collective decision algorithm.

Impacts, for Example, on the Option of Consciously Managing Large-Scale Risks Using Behavioral Change

As comprehension of the factors mentioned above and their effectiveness grows, substantial efforts are being made to translate these findings into statistical models (evolutionary computation employing multistate regression modelling) for the predictive assessment of probable individual and collective behavior as a reaction to measures targeting behavioral change. These developments are being pursued to serve scientific, economic and political interests. The statistical model calculations represent the chance to determine probability ranges for behavioral patterns. They will replace the currently valid concepts that are frequently based on socio-ideological convictions, theoretical assumptions or models that are simply associated with a renowned name. This development is advancing very swiftly thanks to the growing availability of large amounts of data (big data) about individual assessments and collective decisions, making the statistical models increasingly robust regarding their predictive reliability.

When planning measures for inducing individual and collective behavioral change, an understanding of the processes mentioned above increases the chances of successful implementation. Only if the individuals and the collective are addressed in a concerted manner and synergistically motivated, and if both the provision of the material conditions and the psychodynamic components of cooperation are actively promoted, can the measure achieve an optimal result.

The outline for planning a future measure, i.e. for changing individual and collective attitudes towards common resources could assume the following form:

1. Analysis of subconscious and emotional factors when the resource is accessed
2. Analysis of subconscious and emotional factors when the resource is created
3. Understanding the intra- and inter-individual hierarchy and interconnections between these factors
4. Identification of factors of social resonance, reinforcing and steering collective development
5. Development of specific measures for the targeted addressing of intra- and inter-individual mechanisms that act in favor of the project, by stimulating the intrinsic motivation to implement it
6. Verification of the concept, using statistical methods including the development of a predictive model with which variations in the influence and potency of different factors can be modelled and the corresponding impact simulated
7. Development of psychosocial parameters that can be collected in the field, that serve to monitor project progress and that can be compared with expected values from model simulations.

For actual implementation, efficient means are either available or can be created on the basis of widespread, globally accessible web-based and mobile network communication technologies that make the inclusion of all involved parties possible. On one hand, these technologies allow substantial amounts of information about behavior and opinions to be generated, while on the other, they facilitate the targeted influencing of individual and collective behavior by using adapted information strategies to create material and intrinsic incentives, possibly even independently of dominating local socio-collective structures.

Irrespective of cultural socialization, opinion leadership will continue to be founded on the evolutionarily established pillars “presence, charisma, credibility and trust”. In the past, this was inextricably linked to the physical experience ability of opinion leaders, whilst nowadays substantial intrinsic motivation to join aligned collective behavior can be generated by replacing the physical with the multimedia experience. As a result, collectives anywhere on earth are within reach that were previously not accessible in this way. The competence and willingness to use these new possibilities will, in the future, essentially dictate the success of economic and political measures.

Chapter 10
More Sustainability in Cardiovascular Disease Prevention—Holistic, Practice-Oriented Approaches Taking into Account Environmental Topics

Ulrich Hildebrandt

Various interdependencies exist between personal health and the general condition of nature. There are indications that the condition of ecosystems, including the landscapes characterised by them, has a direct and an indirect influence on health. General precautionary environmental protection would provide an immediate contribution to individual health. Thus personal health risks have a more comprehensive correlation with environmental risks than previously communicated.

Can the Risk of Coronary Heart Disease Be Predicted? Can It Be Influenced?

Coronary heart disease, usually in the form of an acute heart attack, is the most frequent cause of death in men in the prime of life from 40 to 70 years of age. Women, inter alia through their hormonal protection, on average are affected 10 years later, but then to the same extent.

A heart attack is not a matter of luck; rather, it is 90% predictable based on nine classical risk factors. People who have all nine risk factors have an approximately 334-fold (!) higher risk of suffering a heart attack than those without these risk factors (Interheart Study). This applies in a similar fashion for bypass operations or stent implants. The causative risk factors are, without exception, controllable. There is a prevalent opinion that people with genetic risks can barely avoid their fate. The opposite is the case; precisely, if a genetic risk exists, the individual specific risk can be extensively neutralised through a holistic preventive approach. Thus, heart attacks and, in a similar fashion, bypass operations or stent implants are 70–80% preventable.

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Through improvements in acute care, particularly in interventional cardiology with stent implants and balloon dilation, mortality associated with acute infarct has declined by more than 40% over the last 25 years (Heart Attack Register February 2016). The risk factors that cause a heart attack in the long term, however, contrast considerably with this and thus neutralise the gains made with modern medicine. Significant successes in health promotion and disease prevention are nearly nonexistent. The classic risk factors—overweight, lack of exercise, diabetes mellitus, stress burden, excessive meat consumption—in parallel with this, have increased significantly in the last 25 years.

Why Is the Promotion of Health and Disease Prevention of so Little Appeal and so Unsuccessful?

Profit and benefit from disease prevention and the promotion of health are very difficult to prove with figures, as the return on investment is only discernible after decades. That means in a society oriented mainly to short-term profit maximisation, and with a background of increasing financial difficulties in the health service, that disease prevention and promotion of health is not really attractive for most of those involved, and thus constitutes no serious concern. At the same time, for individual interest groups, there are various aspects in the foreground:

- For cost units, for example, health insurance funds: Prevention programmes are primarily used for marketing purposes, but are seldom a first concern. A clear benefit from prevention programmes in the form of relatively expensive disease management programmes of the health insurance funds, for example, with coronary heart disease, is not easy to verify. A possible disadvantage of other prevention programmes is that good prevention programmes attract patients from high-risk groups into the insurances and may lead to higher costs.
- The direct benefits of prevention and promotion of health are not easily verifiable in a single legislative period of four years, and are thus of little effect for politicians with respect to re-election campaigning. One essential component of the promotion of health is its motivation through role model functions. Politicians generally offer few positive examples of such a role model for a health-conscious lifestyle.
- The promotion of health in schools is difficult, primarily due to a shortage of resources and competition with lesson time, but also due to insufficient specific qualifications, frequently of only marginal significance. (Through current initiatives publicised by the Bavarian Ministry, such as promoting club sport activities after 1 p.m., with parallel cutting of official physical education at school, health resources were actually more reduced.)
- Medicine itself, as a generator of an important part of the gross national product, "lives" essentially from the profits of medical interventions. The more expensive the interventions, the more lucrative they are for the provider's reimbursement.

In areas with an oversupply, e.g. in heart surgery capacity or interventional cardiology facilities, successful prevention would in contrast lower their specific demand and would be rather "bad for business"—and because it is itself barely accountable, economically uninteresting.

- Government prevention programs and legislative health measures could lead to feelings of paternalism and possible limitations of freedom in the population (The State as "Super-Nanny", see Fokus, January 2016). In addition, governmental health measures in Germany are historically still encumbered.
- Unfortunately, in Germany, the state even blocks important prevention measures in some areas. Reduction in cigarette consumption is a measure with the highest preventive effect, in particular with respect to heart attacks. Through the consumption of one packet of cigarettes a day, a heart attack occurs on average 15 years earlier, and the smoker of a packet of cigarettes per day has on average a 12–15 year shorter life expectancy. In order to prevent the loss of tax, the German government has even implemented valid EU law with great delay, only after the threat of financial penalties.

Pertinent is a long overdue prevention law, which was presented for the first time in 2004 and could only be adopted after several legislative periods in 2015.

New Approaches for Improvement and Further Development Through Motivation for Risk-Minimising Behaviour

A further chance for improvement in addition to offering costly disease-prevention programs, is to motivate people in an attractive way and to enable them to improve their health in other, more "do-it-yourself" manners.

This challenge was formulated in the WHO-Ottawa Charter in 1986 as one essential objective. In the meantime, parts of the Ottawa Charter have been adopted in the legislation of several states. One aim is to motivate people more sustainably and to enable them to take over more personal responsibility for their own health. A major emphasis was placed on the "setting approach": Health is created and lived by people in their everyday environment: where they play, learn, work and love. An essential role for the promotion of health is supported by two areas: the psychosocial environment and as the natural environment.

The Ottawa Charter of 1986 was followed, also in Germany, by various important practical initiatives: "healthy cities", "healthy schools" and the "network of health-promoting hospitals". The sustainability of these initiatives, which were introduced with great engagement, has unfortunately not been consistent. These activities have withered, inter alia, through increasing economic constraints and through the previously mentioned lack of educated understanding regarding the significance of the environment for health.

For a more comprehensive approach with the promotion of health and prevention of diseases, the following basic conditions have been defined by the WHO:

1. Stable feeling of self-worth
2. Positive rapport with one's own body
3. Aptitude for making friends and social relationships
4. Supportive environments
5. Sensibility for health
6. Sufficient medical care
7. Valuable present living conditions and hope for a healthy future

This summary of factors bears some challenges for their application and implementation in practical conditions. Other factors for health promotion can be derived from the Blue Zone Project.

The Blue Zone Project

The term "blue zone" goes back to an Italian research group which observed that, in a mountainous region of Sardinia, a noticeably high percentage of people achieved a very advanced age. The group found correlations with lifestyle habits and a close relationship with nature. Another remarkable finding was that the life expectancy in immediately neighbouring regions in Sardinia was distinctly lower, more representative of the customary average. Due to these findings, Dan Buettner, an American editor of *National Geographic* magazine, initiated world-scale investigations in order to discover other possible Blue Zones, which show particularly high life expectancy. Subsequently, five regions with an abnormally high number of persons over 100 years old were found: Loma Linda, California; Okinawa, Japan; Nicoya, Costa Rica; Ikaria, Greece; and Sardinia, Italy.

Searching for factors which could determine such a high life expectancy, the following living conditions were identified as being present in all Blue Zone regions:

- Strong family orientation
- Predominantly vegetarian diets, with more fruit and vegetables
- Restraints of the consumption of alcohol and tobacco
- A strong purpose in life
- Relatively low overall calorie intake (80% rule of satiation)
- Managing stress well
- Participation in a spiritual community
- Lifestyles with regular physical exercise
- Broader social engagement
- Involvement in a social system, which truly enculturates these values

A predominantly vegetarian diet and limited calorie intake are indicative of a more responsible way of dealing with natural resources and the environment. The fact that Blue Zone regions mainly exist on islands or peninsulas indicates that involvement with nature and environment are of major importance for these populations. Since 2013, Dan Buettner and a team of co-workers have developed a programme based on this knowledge, according to which communities and cities in the state of Illinois, USA, could develop in the direction of a Blue Zone. A prerequisite for implementing this programme was that a large part of the local inhabitants and institutions agreed to this planned development. Even if such projects are difficult to imagine in Germany and will require further scientific support, they may offer a different basis for considering alternate ways towards more sustainability in the promotion of health.

Pilot Projects for New Ways

Reacting to the low sustainability of previous cardiovascular rehabilitation and prevention efforts, a group of cardiologists, psychologists, physiotherapists and health trainers has, in the last 25 years, searched for new ways to test ideas for a sustainable promotion of health and disease prevention. To clarify the starting conditions again: On the one hand, mortality with acute myocardial infarction has been significantly lowered by measures of cardiology interventions (in the last 25 years by more than 40%). This was achieved through modern, interventional procedures (inter alia, through balloon dilation, stent implantation). On the other hand, however, most of the risk factors, e.g. lack of exercise, being overweight, diabetes mellitus and increased stress load in most spheres of life, which causally lead to heart attacks, have increased continuously. Setting the goal of converting new scientific knowledge into practical programmes, this body of abovementioned experts from various professional groups started, over the last few years, as the non-profit "München-Chiemseer Initiative", under the label of "Kardioforum-Bayern", and has initiated various projects using a more holistic approach to health promotion:

- Of trans-generational projects (such as a Youth-Seniors Olympiad, common grandparents-grandchildren trekking).

These concepts strive to motivate and encourage patients and those who are interested to be active without any public funding. In Germany, more so than in other countries, most people take it for granted that their health and treatment of illnesses can be achieved, due to the good insurance system, without any additional costs or efforts. Following this view, there is limited aspiration to become proactive for their health. As an example: Only after the introduction of essentially greater self-participation with dental prosthetics has there been a significant improvement in dental health as a result of better prevention. Apparently, this also applies precisely to health care. It seems to be true for many: only that which costs has a value.

With the abovementioned health projects we follow a modified salutogenic and resource-oriented approach. Already, the great pedagogue A. Pestalozzi has described that a successful and sustained learning may be achieved mainly within a holistic framework, taking into account heart, brain and hand. The heart stands for motivation, enthusiasm and volition; the brain stands for knowledge and comprehension of relationships; the hand stands for dealing, doing and practicing. Prevention usually signifies changes in lifestyle. These are linked with continuous learning and regular practice, until the change is anchored in long-term memory, at the earliest after ca. three weeks.

The heart, brain and hand have similarities to neurophysiological findings: The first relates to the limbic system, the second to the prefrontal cortex, the third to parts of the brain stem.

The American sociologist Antonowsky sees three similar levels within his salutogenic approach, in which he has also described prerequisites for a successful way of life (sense of coherence).

In our own comprehensive approach, the addressing and involvement of the following six pillars of our disease prevention programme is striven for always on three levels.

The Six Pillars of Our Comprehensive Programme for More Sustainability in Cardiovascular Disease Prevention

An approach which mainly addresses the risk factors of cardiovascular diseases has not proven to be very motivating and successful. Within the scope of the WHO project Health Promoting Hospitals in Prien am Chiemsee, a more holistic, resource-oriented six-pillar programme, with an emphasis on salutogenesis, has been developed. It builds on the following elements:

I. Optimisation of the “technical data” for heart health: cholesterol, blood pressure, blood sugar, body weight
II. Motivation for consequent, more intensive, daily physical activity of at least 15–30 min
III. Instruction on a diet with many fruits and vegetables, nuts and legumes like beans, lentils and peas, which corresponds to the diet on the islands, which show a high life expectancy (“Mediterranean cuisine”)
IV. Optimisation of one’s own “domestic policies” such as stress and time management, work-life balance, relaxation, humour
V. Psychosocial bonding within the family and a circle of friends, mutual appreciation and love
VI. Using the benefits of a “healthy” nature and adopt more responsibility for the environment.

Stimuli for sustainability in the promotion of health and prevention through an intensive networking and linking with questions of the environment (hereby are meant both the psychosocial environment and also nature as the environment) ensue both from the WHO concept and also from the Blue Zone concept. Health is to be achieved sustainably only through simultaneous inclusion of environmental factors and the constraints.

Bavaria, with the then new formation of the Ministry for Environment and Health, was the political trailblazer for this approach. Apparently, the time was, however, not ripe for this; health and the environment were again separated.

Can Pragmatic Ties from the Impulses of the Ottawa Charter and from the Climate Conference in Paris Be Used for More Sustainability in Disease Prevention?

At the beginning, one’s own health is closer to most people than “greater” questions of climate protection or sustainability. However, people who suffer from an illness or a genetic risk are more interested in health and, in general, more open and motivated regarding questions of environment and climate.

Here is an example which may clarify relationships between personal health behaviour and the environment for patients:

With consumption of more than 300 g of meat and sausages per week, general mortality increases moderately but significantly. The worldwide available food product resources, based on a mainly vegetarian diet and given a proper solution of logistic distribution problems, might be sufficient to double the world population. However, to produce 1 kg of meat needs 6 to 12 kg of “vegetarian” food products, which thus are no longer available for human consumption. As a result of the increasing consumption of meat and its accompanying excessive use of food resources, followed by the necessity of creating further areas under cultivation, the destruction of climate-significant regions is inevitable.

Many people, who after a certain age are no longer willing to change their lifestyle habits (e.g. change their meat consumption) for a little expansion of life expectancy, are nevertheless motivated with a prospect that they may influence the quality of life and environment of their grandchildren. This also addresses their function as role models.

The conceivable statement that, from 1970 to 2010, approximately half of the existing animal species have become extinct can make many patients more aware of the environment and may have a greater impact on the quality of life and the life expectancy of their children and grandchildren than the mere optimal medical adjustment of their technical heart data: blood pressure, cholesterol and blood sugar.

Result: Pilot Projects for More Sustainability in Cardiovascular Prevention and Promotion of Health

As cardiovascular diseases represent the most frequent cause of death, and a well-functioning cardiovascular system determines good performance and quality of life, the topic might well be of significance for many people.

1. Motivation to exercise
   Optimal intensive physical activity of 15–30 min daily can increase life expectancy by five to eight years (Copenhagen Heart Study). This has to be better presented and networked (possibly the current programme of the "Chiemsee Active Heart days" as an annex).
   Supporting this goal is a pilot project in which one activity is regularly and intensively carried out over 5–10 weeks under instruction in natural surroundings. Activities are performed in a scenically very attractive valley which is designated as a conservation area with health-promoting elements and subjects on nature and environmental protection. The project is developed by collaboration between doctors, physiotherapists and tourism experts.
   In conjunction with students of the Munich Technical University, new ideas are tested to utilise nature as a resource for the strengthening of resilience. These projects want to inspire as many age groups as possible and provide better knowledge about the value of physical activity.
   To combine health, nature and the environment is the particular objective of grandparent-grandchildren trekking. For many grandparents, their grandchildren are one of the most important topics in their lives. Moreover, grandparents are important sources of guidance for their grandchildren. This special relationship is used for a new project in which grandparents have the possibility, within a several-day hike to a nearby small mountain resort, of receiving practical guidance and information on how they can keep themselves fit in old age and protect against heart diseases. Within an adventure hike, running parallel to this, accompanied by two wilderness teachers, their grandchildren and a group of peers learn about exciting things experienced in nature and what they can do for their own health, as well as prepare healthy food on their own. Once a day, both groups meet to exchange experiences, for example, at a campfire in the evening. Thus, health and environment become a more conscious topic in their families.
2. Initiative circle health and environment
   In order to develop networking and sustainably between the fields of health and environment further, it is advantageous to be able to draw on other long-standing experiences. An "initiative circle" is set up in which people from various fields of expertise, and in particular "retirees" with more time resources, can engage.
   The enthusiasm over the result of the Paris Climate Conference raises hopes that the preservation of the environment could after all be possible. The ambitious targets of lowering the German greenhouse gas emissions by 2050 by 85–90%

will not be possible without the engagement and participation of the individual. The hesitant engagement of politics and industry will not be sufficient.
For the individual person, climate protection is, however, usually abstract and frequently associated with political trends, which do not match their own. Their own health and that of their children and grandchildren are, for many more people, of greater significance. This can be used as a door opener to engender greater interest in the environment and climate protection.
Mankind is part of the environment and without this is not viable. The environment and nature represent an essential health resource.
Healthy changes in the environment have a concrete impact on personal health. Risks for damaging the environment are almost linearly coupled with risks for our health.

Part III
The Medical Radiation Dimension

Chapter 11
Risk and Challenges in Radiation Medicine—An Introduction and Position Statement

Michael Belau, Daniel Méndez Fernández, Michael Molls and Thomas Herrmann

The adequate and sustainable handling of risk presents a plethora of challenges. This is especially true for research and practice in medicine, where proper risk management demands transparency and an awareness of the risks, challenges, and opportunities involved. To pave the way for taking long-term action for the public good, we must promote a continuous dialogue between academic, political, and public sector institutions and administrations in their role as executives of political institutions. Toward this end, scientists of multiple disciplines, practitioners, and members of Bavarian governmental institutions gathered on the premises of the German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)) in Feldafing, Germany, 14–16 April 2016, to discuss various issues involved in dealing with risk in a sensible and responsible manner.

In this position statement, the major discussion points from the working group on radiation medicine (hereinafter referred to as “the group”) are summarised, which provide useful conclusions and advice for better risk management, with a focus on radiation medicine. Within the framework of the common discussion among all groups (society and economy, environment and ecology, radiation medicine and technology, robotics, IT security), it became apparent that the various

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processes of risk management, in large part, were interrelated, giving rise to the free flow and cross-fertilisation of ideas.

The exchange of ideas within the group was organised in the form of statements, which were discussed from different perspectives among peers. Here, we summarise the major points and conclude with key messages and recommendations.

The essential, overriding risk arising from radiation treatment is the inherent danger of cancer. One cause of cancer can be seen in double-strand breaks of DNA molecules. Prof. Georg Iliakis explains in his statement that such double-strand breaks occur either spontaneously or in response to external physical (radiation) or chemical influences. After initiation of a double-strand break, the cells opt for (self)-repair mechanisms, which often follows a chaotic and unstructured process; cancer cells can emerge as a negative consequence of this process. In theory, we would need to intervene in the repair processes in a manipulative and corrective capacity. However, this also raises the question as to the extent that we could and should manipulate such processes in the context of conscientious risk management. In any case, in research on DNA double-strand breaks, the subsequent repair mechanisms are a crucial component in developing approaches aimed at significantly reducing the risk of cancer diseases.

The frequently subjective manner of dealing with risks associated with cancer caused by radiation therapies was an important part of the discussion. Prof. Klaus-Rüdiger Trott estimates these risks to be quite low, particularly for adults receiving radiation treatment. In terms of responsible risk management in tumour therapy, however, the secondary cancer risk should be part of the discussion between patient and therapist. This is especially important in the context of curative treatments, meaning treatments with a realistic chance of long-term success.

Of special concern here is radiation treatment in children with cancer diseases. In general, their risk of developing a secondary malignant disease is higher than that in adults. A number of factors contribute to this increased risk—for instance, the long latency period after curative therapy (time between radiation treatment and potential diagnosis of a secondary cancer), the higher radiation susceptibility of the different organs and healthy tissues of children, and the relatively aggressive treatments in children (combination of radiation with intensive chemotherapy).

To improve the current lack of sufficient knowledge about the relations between dose and effect, and the potentially negative consequences of therapies, we must access, structure, and analyse all available data, especially relating to therapy plans. To this end, excellent opportunities have emerged in the field of radio-oncology with the introduction of computer-assisted radiation therapy. However, these new and innovative computer-assisted radiation treatment techniques have yet to be fully exploited.

A key concern with particular relevance to society is the need to scientifically address the relation between benefit and harm. As noted by Prof. Michael Flentje and Prof. Michael Molls, the primary question here relates to the quality of the results with respect to tumour therapy in general, and clinical radiation therapy in particular. One important approach is the use of "registry" for capturing long-term data for persons who have undergone treatment with radiation using appropriate parameters. The necessary prerequisites have already been met through enactment of the cancer screening and registration law. However, there are still considerable deficits in the implementation of this law, especially with respect to therapeutic radiation treatments with long latency periods, as mentioned above. The poor quality of the cancer registries has been a major subject of debate, especially regarding accurate and reliable long-term data (e.g. with respect to side effects or quality of life). Achieving sufficient quality in the collection and mapping of the data calls for new and better methods. One prerequisite is an efficient and state-managed registry. The implementation, scientific management, and continuous financing of this registry should be the responsibility of the state. It should also be operated by a governmental institution using uniform methods throughout the country in terms of quality assurance and the specific data to be documented regarding diagnosis, therapy, and lifetime aftercare. The current status quo, wherein the implementation and operation of such registries is controlled by the individual states, will lead to a variety of state-owned registries, the merging of which will require considerable effort. One positive example can be seen in the USA, where data from cancer registries are combined with data from insurance companies at the federal level.

With regard to optimal therapy planning in interdisciplinary oncology, the dearth of research on interdependencies (from simultaneous chemotherapy and radiation therapy) was identified as a significant obstacle. Prof. Ursula Nestle and Prof. Peter Lukas illustrate this in looking at clinical cancer patients who often receive a combination of medication and radiation. Particularly in the case of drugs with "new" mechanisms of action (targeted therapies, antibodies, etc.), interdependencies between effects have not been thoroughly investigated, even in the preclinical field via experimental models. In fact, the empirical and clinical landscape is dominated by pharmaceutical enterprises which, from the perspective of clinicians in radiation oncology, frequently generate results with insufficient evidence. For instance, we can observe studies where two drugs are directly compared in two study groups using heterogeneous statistical distributions and short observation periods. However, one or the other drug (or drug combination) is nonetheless pushed toward broader clinical application (with an increasing number of patient treatments).

Furthermore, it should be noted that, with very few exceptions, in adults with so-called solid tumours, treatment regimens based solely on medical therapy—in contrast to radiation treatment alone—cannot have a curative effect. Thus, in terms of "killing" cancer cells, radiation is much more efficient than medications (by orders of magnitude). We must therefore ask ourselves why we can observe countless studies of apparently "non-curative therapy principles" (medication), and why we still fail to focus much more on radiation-based therapies, which result in long-term survival for many cancer patients (radiation alone or in combination with anti-cancer medications and or/in combination with surgery). Finally, the group pointed out that it cannot be considered helpful if therapy studies depend on a variety of institutes, boards, and laws, each propagating formal requirements that are to some extent contradictory.

In the context of ethical considerations, Prof. Peter Lukas and Prof. Ursula Nestle introduce the following three points which they regard as essential for improvement:

- Improvement and systematisation (with increased transparency) is needed in drug approval processes, along with more (and better) research on the interdependencies between treatments.
- The autonomy of ethics commissions must be inviolable, and interference by university commissions must be avoided.
- Given the high risk potential from the combination of new drugs and radiation therapies, experts from radiation-oncology must sit on ethics commissions.

These points form the basis for proposing key recommendations regarding the drafting of healthcare policy on drug regulation, and also on the regulation of clinical studies, as reflected in the fourth key message at the end of the chapter.

Early diagnosis is an important aspect of a responsible approach to the risk topic of "cancer" that dominates society and the healthcare economy. It is well established in breast cancer in particular that treatment of small, non-metastasized primary tumours (in an early stage of the cancer disease) leads to cure in a very high percentage (nearly 100%) of patients. According to Prof. Sylvia Heywang-Köbrunner, risk communication that takes place in the public domain regarding the effectiveness of cancer check-ups such as mammography screening is unfortunately often false and lacking in transparency. The actual debate neglects the fact that—based on the highest level of evidence (level 1a)—mammography screening is the only diagnostic method which has been proven to significantly reduce mortality, and is the method with by far the lowest number of false-positive results. During the discussion, two demands emerged for better risk consideration and risk communication, which are also included in the second key message:

- Risk consideration must refer to lifetime risk, and not just a few years. For example, when ascertaining the number of "lives saved" by mammography screening, the following research conditions would be considered optimal for producing reliable figures: the population of women should undergo a higher number of sequential screenings (10 screenings over a period of 20 years), and the "follow-up" should be 25–30 years (5–10 years after the end of screening). Under such conditions, highly valuable results in terms of "saved lives" are obtained.
- Risk communication must take place in a domain that is largely free of economic (pharmaceutical industry), systematic (healthcare systems), and egoistical (individual) influences. In dealing with risks and advantages of screening, the interests of women should be placed at the forefront of the political discourse.

With regard to the topic of risk communication in a general sense, Prof. Claudia Peter diagnoses radio-oncology (and other specialist medical disciplines) as having an image problem that can be attributed to the lack of trust between doctor and patient. Image campaigns aimed at better public outreach and at stimulating discussions of scientific policy within medicine could achieve positive effects.

The dialogue and interaction between doctor and patient must focus on the individual and their wish to be perceived in a subjective manner. This is precisely where it becomes clear how difficult the communication of risk can be in radiation medicine, as well as in medicine in general. On the one hand, it involves the conveyance of knowledge (an educational function) between doctor and patient as objectively as possible. On the other hand, in the discussion with the cancer patient, the doctor must be able to deal with existential insecurity and a high level of subjective perception. Here, two key aspects emerge:

- Forms of knowledge: A person suffering existential anguish will demand forms of knowledge that differ from those sought by a healthy person; hence, different formats for imparting that knowledge will be required as well. In the very complex relation between doctor and patient, the individual's attitude toward life, particularly the values and goals governing that individual's life, must occupy the focus of attention. It is then possible for the doctor and patient to jointly determine a treatment plan.
- Communication: In the case of the sick patient, it is no longer possible to speak of risk (as risk is no longer calculable), but instead of existential uncertainty and tremendous fear. Thus there are phases, for instance, when it is no longer possible to communicate with the parents of children suffering from cancer using merely objective knowledge. Here it is a matter of helping the patient deal with the flood of information.

The challenge for the attending doctor in this scenario consists primarily in two very different requirements: Explain like an expert (imparting complex specialist knowledge in a comprehensible form); understand like a human being (empathetic handling of existential, subjective fears). In risk communication, in addition to satisfying the scientifically motivated and understandable quest for greater knowledge—and hence certainty—it is necessary to explain the uncertainties to the patient and to discuss these uncertainties in a way that takes into account the individual situation and the subjective perceptions. Here, the goal is not greater certainty, but greater reflection on uncertainty.

In objective terms, the relative number of adults affected by long-term, undesirable consequences of radiation (treatment) of a severe grade is rather low. In contrast, many individuals have the subjective impression that the risks of radiation in modern civilisation—including in the field of medicine—are rather high. Obviously, there exists a significant divergence of the subjective and objective risk perception.

An important issue concerns the question of why we have such difficulty in estimating the risks of ionising radiation and what can be derived from this in terms of policy. Prof. Thomas Herrmann explains that, despite the fact that we have no sensory organs for ionising radiation, it can be readily measured with equipment in terms of dosage and biological effects. The absence of any personal "sensors" for radiation leads to an irrational fear. Added to this is the fact (and this may support the irrational fear) that there is a lack of data on risk estimation in the medically relevant range of radiation: because the risk is generally relatively low, very little data has been gathered. Finally, when science is implemented by policies in standards and laws, quantitative details/statements are lost. This gives way to a limited and irrational awareness of risk. Policymakers must consider this issue.

In this context, Mr Buchberger explores the problem areas that were identified during the discussion, which from his point of view can be presented as follows:

- The training of medical practitioners should focus more on topics/abilities in dealing with people (e.g. empathy).
- A quota for women should be introduced at the executive level of health insurance companies, university clinics, large hospitals, etc.
- Partnerships/networks should be promoted within medical professions so that joint aims can be better implemented.
- Achieving greater trust in doctors calls for a broad discussion of values in society and in the political sphere, with the effect of raising awareness and increased sensitivity on the part of politicians.
- It is also necessary to actively demand transparency and to curb the self-service mentality.

The topic of risk communication in the doctor/patient relationship also defines the first key message, which formulates the requirements for the doctor: the doctor's role must remain one of understanding. In addition to psychological skills and empathy, good patient rapport in situations of existential uncertainty necessitates a relationship of trust that must be established in a lengthy process.

Key Messages

Over the course of the discussion, the group arrived at the following four key messages as a recommendation for sustainable risk management in the context of radiation medicine:

1. For the sake of minimising risk in (oncological) medicine, health policy must ensure that the education and training of physicians is ethically substantiated and based on knowledge.
2. Politicians are urged to base any communication strategy regarding mammography screening on medical expertise.
3. Powerful governmental cancer registries are needed to enable optimal long-term care of patients in radiation medicine.
4. Within the mandate for regulation to minimise risk to patients, health policy should include constant and regular reviews of the approval requirements for new cancer drugs.

Chapter 12
The Biological Foundations of Risks from Ionizing Radiation Exposures: How an Understanding of Associated Effects Will Help Their Quantification and Mitigation

George Iliakis

Key Messages

- Ionizing radiation induces a severe form of DNA damage through clustering of ionizations: the DNA double-strand break (DSB).
- DSBs in higher eukaryotes are processed by homologous recombination repair (HRR), classical non-homologous end-joining (c-NHEJ) and alternative end-joining (alt-EJ).
- c-NHEJ and alt-EJ are implicated in the formation of chromosomal translocations and sequence alterations that can feed carcinogenesis. Thus, their selective and targeted suppression may delay the evolution of cancer.
- We develop the view that successes in research, if translated to effective radiation protection, may help to improve the public perception of IR risk.

Risks from Radiation Exposures: Reality and Perceptions

An effective strategy in the management of risks is the elimination of their sources. Unfortunately, for ionizing radiation (IR), as in many other instances, this strategy cannot be applied because IR is an inseparable component of the environment on earth and in the universe (Durante and Cucinotta 2008). In addition, IR is integrated in important scientific and industrial activities, most notably in nuclear power plants, and is thus routinely encountered in increased amounts by sectors of the

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population engaged in these activities. Accidents, like those of Chernobyl and Fukushima, increase dramatically the number of people that might be artificially exposed to IR, thus widening considerably the size of the populations at risk (Ginsburg et al. 2006; Peplow 2011).

Furthermore, IR is extensively used in medicine for the diagnosis or treatment of numerous diseases and has become a central component in the management of cancer—nearly 60% of patients receive IR in radiotherapy clinics at different stages of their treatment (Fuks and Weichselbaum 1995). The importance and gravity of the therapeutic application of IR, which is typically given locally at very high doses, becomes clear when one considers that in the western world one in three people will develop cancer in their lifespan, and that worldwide the incidence of the disease is rising. It is also highly relevant that space explorations involving manned missions at all levels, are associated with increased exposure to IR, and that the quantification and mitigation of such risks is a recognized prerequisite for manned missions to Mars (Durante and Cucinotta 2008).

Knowledge-based, and thus objective, assessment of risks from IR and means to reduce these risks are therefore urgently needed.

Compared to other risks encountered by modern societies, the risks from IR have been recognized for over 70 years, and strict normative regulations are in place that are enforced by dedicated public agencies (Hendry 2012). The goal of these regulations is the reduction of risks associated with the development of cancer by IR, a feat that is mainly achieved by reducing the maximally allowable dose during occupational activities, and by setting much lower limits for the general public. More recently, risks associated with IR-induced cardiovascular and neurological defects have been recognized and are intensively investigated and analyzed (Wondergem et al. 2013).

The available scientific and epidemiological evidence fails to define a radiation dose threshold, below which cancer may not occur in exposed individuals. As a result, current models of risk assessment are based on a linear increase of risk with dose, i.e. no radiation dose, no matter how low, is risk-free. Overestimation of risks and the resulting "overprotection" of humans are well justified when scarce epidemiology and incomplete understanding of biological mechanisms fail to provide solid foundations for alternative assessments, possibly leading to lower risk estimates. On the other hand, low dose limits increase the costs of radiation protection and generate impediments rendering impractical applications of IR that may be beneficial. Solutions to this dilemma can only be given through the generation of background information allowing precise estimation of risks associated with IR exposures.

A complicating factor in the analysis of risks associated with IR exposures and the communication of recommendations to the public, even when these are conservative, is the highly critical and heavily emotional perception they find. Risks are commonly irrationally exaggerated by the public and translated in the impossible requirement for zero exposure, hoping to achieve in this way zero risk. The negative public perception for IR has its origins in a number of grave accidents from the early days of industrial radioisotope use, as well as from the construction, testing and deployment of nuclear weapons. The massive anxiety generated during the Cold War era, along with recent accidents in nuclear power plants, further cemented these fears towards IR.

As a result of these circumstances, the perceived risk by the public of IR exposures is much greater than objective risk estimates derived from available knowledge. A possible strategy to remedy the situation is through the development of new knowledge and in-depth understanding of the biological mechanisms underpinning IR effects. Although large strides have been made in this direction during the last decades, our understanding of the molecular processes underpinning the adverse effects of IR remains scarce, and ways to successfully mitigate them through external intervention are lacking. This vacuum deprives the scientific community from evidence-based, punch-like arguments that may help to start changing public perceptions.

In this line of thought, it appears essential to strive and support the generation of hard knowledge on basic mechanisms. Scientific findings paving the way to interventions reducing the probability of cancer induction by IR are likely to contribute to more widespread public acceptance of its peaceful applications, as they are likely to generate conditions where benefits outweigh risks. In the following paragraphs, some background on the biological effects of IR is provided and recent observations are integrated in speculations as to how we may one day be able to reduce radiation carcinogenesis.

Background on IR-Induced DNA Damage—Particularly DNA Double-Strand Breaks

IR generates adverse effects in multicellular organisms by damaging individual cells (Hall and Giaccia 2006). Damage to cells is caused by the removal of electrons from their constituent molecules, i.e. by the ability of IR to oxidize them. Thus, IR operates in principle similarly to oxidizing agents present in the environment, or to oxidizing agents metabolically produced in every living cell.

The higher risk of cancer induction from IR, as compared to that of oxidizing agents, lies in the fact that in the case of IR, the ionization events are not randomly distributed in space, as oxidation events often are, but occur instead exclusively along the tracks of the ionizing particles—the constituents of IR (Fig. 12.1). Notably, the characteristics of energy deposition by ionizing particles includes events of accumulation of multiple ionizations in a small volume, i.e. the generation of clusters of ionizations (Goodhead 1989, 1994). Such ionization clusters hit with higher probability large polymeric macromolecules (DNA, RNA and proteins) in living cells, producing clusters of damage that are much more likely to compromise their biological function than single ionizations (Fig. 12.1) (Ward 1994).

Although IR damages the different classes of cellular macromolecules size-proportionally, but otherwise relatively uniformly, more than half a century of

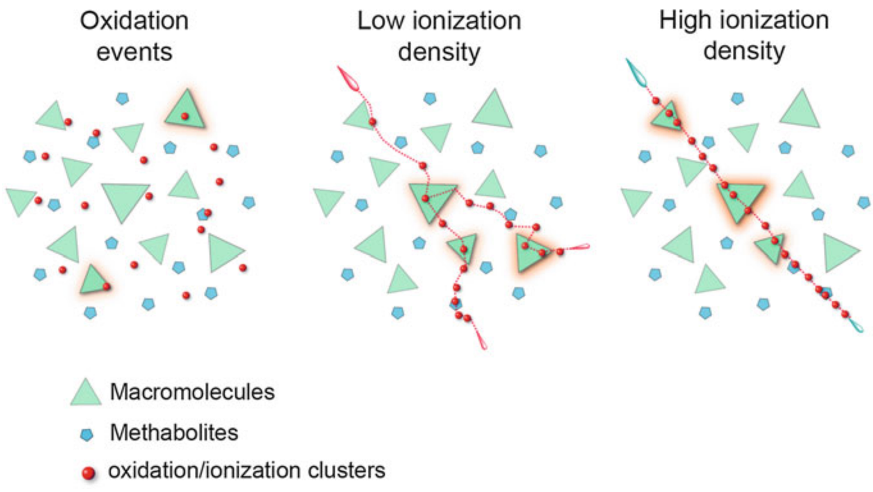

Fig. 12.1 The adverse effects of IR derive from a clustering of ionization events along the tracks of ionizing particles (low ionizing density, middle; high ionizing density, right) that hit large molecules with higher probability than small molecules, and which can generate clustered damage in large molecules. Clustered damage compromises the function of macromolecules to a much greater degree than the single events preferentially generated from reactive oxygen species. In the scheme, the same number of events (red dots) are distributed differently for the different entities depicted

research points to DNA damage as the cause of reproductive cell death, or of genomic instability that ultimately leads to the development of cancer. Not only are the DNA macromolecules constituting the chromosomes arguably the largest in a cell and thus large targets for IR, but are also present as a single copy—if one considers that the two homologs are not completely identical. Damage to these unique macromolecules is therefore bound to have serious consequences for the cell, first because DNA is used as a template for its own replication and second because it is used as a template to make multiple copies of all proteins and RNAs that are necessary for the life of a cell. Damage by IR to protein or RNA molecules is expected to have far less severe consequences for the cell, first because they are typically present in multiple copies, and second because they can be re-synthesized by the cell as long as the coding gene in the DNA remains intact.

Although IR generates a wide spectrum of damage in the DNA (Fig. 12.2), all which can affect its structural integrity and coding potential, radiation effects are almost exclusively attributed to the induction of double-strand breaks (DSBs), i.e. to the structural breakage of the DNA helix. Such breakage of the DNA molecule requires two chemical modifications in nucleotides located more or less opposite each other in the DNA strands in order to disrupt the sugar-phosphate backbone. Such modifications can be generated with much higher probability by ionization clusters than by single ionization events. Ionization clusters generating clusters of damage in the DNA, which often break the double helix, are mainly responsible for

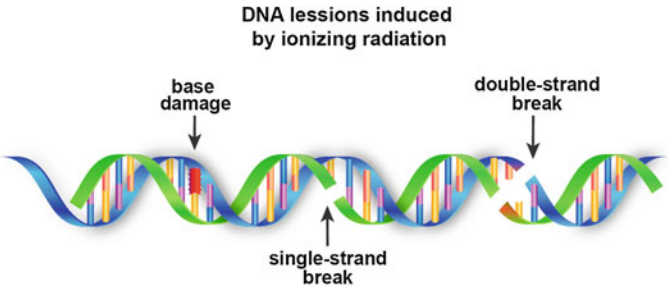

Fig. 12.2 IR can generate in the DNA base damages, single-strand breaks and double-strand breaks

the severe effects of IR as compared to common oxidizing agents, which predominantly generate isolated events (Fig. 12.1) (Ward 1994).

Damage in the DNA confined to one DNA strand is easily restored by the cell using information available on the undamaged strand (Fig. 12.2). This is the basis of the base excision repair (BER), nucleotide excision repair (NER) and mismatch repair (MMR) pathways, whose chemical elucidation was recognized by the Chemistry Nobel Prize in 2015. This fundamental principle of DNA repair is compromised when DSBs form. Restoration of the DNA molecule will not be possible on the same principles as an intact strand is not available to be used as template. Special solutions must therefore be invoked (Schipler and Iliakis 2013; Iliakis et al. 2015; Mladenov et al. 2016).

In addition, because ionization clusters often comprise more than two ionizations, it is likely that the DNA breakage comes together with other forms of DNA damage in the immediate vicinity (e.g. damage in a base, or a break in one DNA strand) increasing thus the overall "complexity" of the DSB and the steps needed for the restoration of the DNA molecule. It is relevant to point out that breakage of the DNA by IR, whether simple or complex, is always associated with chemical modifications at the terminal nucleotides, which will therefore require replacement. This is different in DSBs generated by restriction endonucleases, which leave the DNA molecule chemically unchanged and allow restoration in a single enzymatic reaction—the DNA ligation reaction (Schipler and Iliakis 2013).

The breakage of both DNA strands during the formation of a DSB, together with the chemical alterations often present in the vicinity, challenges enzymatic mechanisms specialized in the repair of DSBs and leads to their occasional failure. Such failures alter the genome in ways that are lethal for the cell, or facilitate accumulation of genomic alterations causing cancer.

Available evidence suggests that the spectrum of DSB complexity is large and that this complexity determines the probability of failure of key DSB repair mechanisms. Therefore, detailed knowledge on the spectrum of damage induced by IR in the form of different types of DSBs will be necessary to analyze their consequences and assess their risk for cancer induction. A considerable amount of work is still needed in this direction.

Background on Cellular Pathways Processing DNA Double-Strand Breaks

Considering that in most human cells the genome presents as linear, double-stranded DNA molecules organized in chromosomes with telomeres that erode, restoration following induction of a DSB will have to accomplish two tasks: First, ensure that during repair the original DNA ends are put back together, i.e. they are not joined with ends from other broken DNA molecules found in the vicinity; and second, ensure that the sequence around the break site is fully restored to its original state (Schipler and Iliakis 2013; Iliakis et al. 2015; Mladenov et al. 2016). Failure in the former task will lead to translocations that are implicated not only in cell death, but also in genomic instability causing cancer, while failure in the second task will cause mutations that will also feed genomic instability. The requirement for sequence restoration is particularly relevant for IR-induced DSBs, due to the abovementioned nucleotide loss accompanying their formation. We will now see that the three pathways that have evolved to process DSBs differ widely in their ability to successfully achieve these tasks (Fig. 12.3).

The only known DSB repair pathway that is able to carry out both tasks correctly is homologous recombination repair (HRR). It uses a complex enzymatic

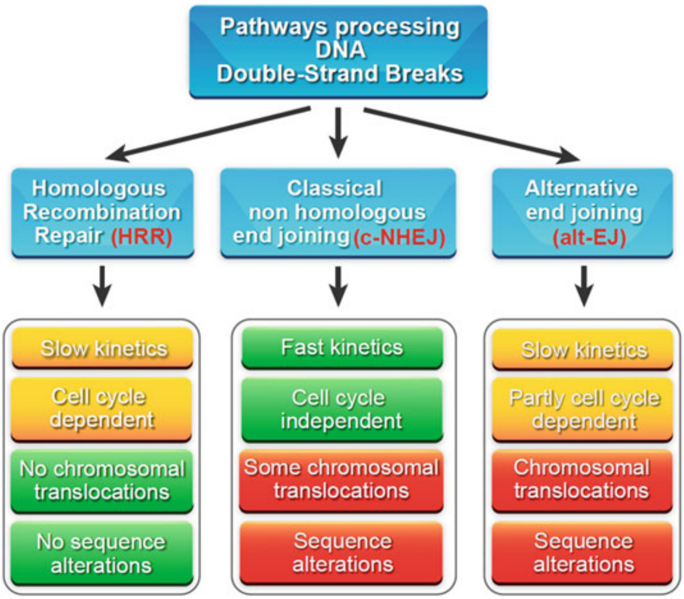

Fig. 12.3 Three distinct repair pathways are engaged in the processing of IR-generated DSBs: HRR, c-NHEJ and alt-EJ, all with widely different advantages and limitations. In the scheme, advantages are depicted using green color, while limitations are shown using yellow or red color to indicate average and high level of risks for the correct restoration of the DNA molecule, respectively

mechanism to copy sequences around the DSB from a homologous DNA molecule, mainly the one present in the perfectly aligned sister chromatid, and ensures in this way the restoration of the original sequence at the junction, as well as the suppression of chromosome translocations. The preference for a sister chromatid identifies a key limitation of this pathway: it can engage only after DNA replication during the S-or G2-phase of the cell cycle (Schipler and Iliakis 2013; Iliakis et al. 2015; Mladenov et al. 2016). The molecular concepts underpinning this repair pathway demonstrate how it manages to join the correct DNA ends, and to restore the DNA sequence at the break site. However, due to the complexity of the steps involved, HRR is a relatively slow process with half-times on the order of hours (Fig. 12.3).

A fundamentally different approach to DSB processing utilizes a much simpler mechanism, based on the mere enzymatic rejoining of the generated ends without template requirements. This mode of operation is reflected in the name of the pathway: non-homologous end-joining (NHEJ). The term classical non-homologous end-joining (c-NHEJ) is now commonly used in an effort to distinguish this pathway from another operating on similar premises that is discussed next. The mechanistic simplicity, but also the enzymatic constitution and the template independence of c-NHEJ explain its most impressive property, i.e. its high speed with half-times of only a few minutes (Fig. 12.3). It is likely that this also achieved by the functional integration of the participating proteins as a highly efficient molecular machine (Schipler and Iliakis 2013, Iliakis et al. 2015; Mladenov et al. 2016). A distinct advantage of c-NHEJ is also that it operates in all phases of the cell cycle. Despite advantages, c-NHEJ has also inherent limitations that compromise its fitness in restoring the broken DNA molecule in its original state (Fig. 12.3): First, it has no provision for exclusive joining of the original DNA ends, and indeed it is known to cause translocations. Second, because it operates in a template-independent manner, there is no built-in mechanism ensuring restoration of DNA sequence at the break site.

The increased formation of chromosome translocations in cells deficient in c-NHEJ suggests the operation of additional mechanisms of DSB processing (Schipler and Iliakis 2013; Iliakis et al. 2015; Mladenov et al. 2016). A DSB processing pathway termed alternative end-joining, alt-EJ, is now defined, distinct from c-NHEJ but still dependent on simple DNA end-joining. Alt-EJ has qualitatively the same limitations as c-NHEJ, but these limitations are quantitatively more pronounced (Fig. 12.3). First, the probability of formation of chromosome translocations is higher than in c-NHEJ, often by an order of magnitude. Thus, while c-NHEJ is generally thought to suppress translocation formation, alt-EJ is thought to be dominantly involved in the process. This has important implications for the arguments that are developed below. Second, processing by alt-EJ alters the sequence around the DSB junction to a much greater degree than c-NHEJ (Fig. 12.3).

In reviewing the above-outlined properties of the pathways processing DSBs in vertebrate cells, perhaps the most surprising and puzzling revelation is the recognition that they are not giving equivalent outcomes and are therefore no real “alternatives” for the processing of DSBs and the maintenance of genomic integrity.

Given the outlined properties it would be reasonable to assume that cells should opt for HRR whenever possible, choose c-NHEJ as a second line of defense, and leave alt-EJ as the last resort—a form of ultimate backup.

What kind of pressure paved the way to the evolution of so different repair pathways for the processing of DSBs? It is possible that with increasing complexity of the DSBs, the ability of the cell to engage a certain pathway is compromised (Schipler and Iliakis 2013; Iliakis et al. 2015; Mladenov et al. 2016). Is the pathway diversity seen as an answer to the diversity of forms of DSBs generated? Does the cell benefit from ever decreasing DSB repair pathway engagement requirements (HRR > c-NHEJ > alt-EJ), by having available pathways of increasing flexibility that can accommodate the processing of practically every DSB presented? Are the available pathways differently capable of coping with interferences from cellular processes and conditions such as DNA replication, transcription, chromatin organization, etc.? Does the cell require alternative means for processing resected DSBs that can no longer be processed by c-NHEJ? Why is DNA end resection at DSBs under different regulation than HRR? Extensive work carried out in recent years offers tantalizing speculative answers to some of these questions, but much more work is clearly needed.

What are the ramifications from the realization that only one of the three described ways of restoring integrity in a broken DNA molecule will return the molecule in its original state (Schipler and Iliakis 2013; Iliakis et al. 2015; Mladenov et al. 2016)? If two of the available pathways have a considerable potential for extensive changes to the DNA sequence and even massive genomic restructuring, is it possible that they are intimately involved in the transformation of a normal cell into a cancer cell after exposure to IR? Do they contribute to carcinogenesis in general? Does the high targeting efficiency observed in general in stem cells, as well as in some specialized cell lines such as DT40 and NALM-6, point to the fact that down-regulation of c-NHEJ for the benefit of HRR is possible? Do somatic cells, compared to germ cells, down-regulate HRR, much the same way they down-regulate the expression of telomerase for example? Are DSB repair pathways such as c-NHEJ and alt-EJ also involved in carcinogenesis in general?

Since the cell may somehow "choose" the repair pathway to process a given DSB, and since it may adapt to possible accidents likely to occur during the processing of certain types of DSBs, it is imperative to understand the parameters embedded in the underlying logic of choice, and define the circumstances that generate necessities that leave the cell with limited pathway choice or no choice at all. Such knowledge will be useful in designing approaches to intervene selectively in DSB processing with the ultimate aim of reducing genomic alterations. If a shift in the balance between DSB repair pathways were possible, even at the expense of increased cell death, measurable reduction in genomic alterations that lead to cancer may be achieved (Fig. 12.4). Such knowledge will not only improve the foundations of IR risk estimations, but may also suggest means to reduce it in a targeted manner.

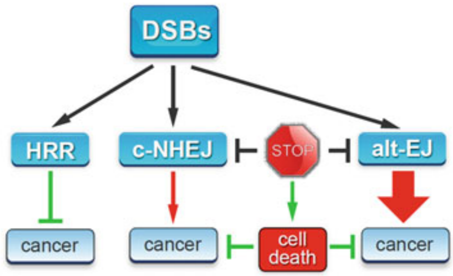

Fig. 12.4 Connections of the available DSB repair pathways with cancer are shown together with a speculative model as to how cancer risk may be reduced by artificially limiting the function of error-prone pathways

Conclusions

In conclusion, it is proposed that resources need to be invested to increase our knowledge regarding the physical, chemical, biological and medical effects of IR. This knowledge will help to improve the estimation of risk and will suggest possibilities to reduce it. It is becoming increasingly clear that the processes leading to cancer after exposure to IR have similarities to those causing cancer overall. It is therefore likely that the large investment society is making to combat cancer will also promote the mechanistic understanding of IR effects. Conversely, the field of radiation research is also likely to provide important impulses to oncology. It is certainly no coincidence that much of what is nowadays regarded as central in oncology comes from studies on the effects of IR on cells and organisms. Promoting and emphasizing goal-oriented and result-oriented research in this field will certainly be of great benefit to society. Last but not least, the compound benefit of these efforts might be a significant contribution to reducing fear towards IR by the public.

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Chapter 13
The Carcinogenic Risk in Radiation Medicine

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Introduction: Evidence for Carcinogenic Radiation Risks

Fewer than ten years after the discovery of Roentgen rays, in 1903, the first radiation-induced cancer was diagnosed in a Roentgen technologist. In many of the radiology pioneers, repeated local exposure to Roentgen rays caused skin atrophy and chronic inflammation, called roentgenoderm. Later, many of them developed skin cancer, always situated within the chronic roentgenoderm. This anatomical correlation between roentgenoderm and skin cancer was proof of causation in the radiation-exposed individual. Until 1950, radiation protection was concerned mainly with radiation-induced cancer in the individual radiologist and patient, caused by this radiobiological mechanism.

The concepts of radiation carcinogenesis and aims of radiation protection changed fundamentally through the Life Span Study in the A-bomb survivors of Hiroshima and Nagasaki, arguably the greatest epidemiological study of all times. A total of 120,000 study participants were identified in 1948 to be followed up until death; 27,000 inhabitants who were not in their city in August 1945 served as controls. In each of nearly 80,000 exposed inhabitants who survived the early effects of the bombs, the radiation doses in different organs were individually determined. In nearly half of them, the mean dose was similar to those received by modern radiology imaging procedures, the highest doses were around 5% of the doses applied to the tumour in cancer patients. The Japanese Koseki register permitted the determination of the causes of death in nearly 100% of the study participants. There has been a steady stream of publications of the results of this huge research programme. They form the most important basis of radiation risk management and of all rules and regulations in radiation protection today.

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Of about 80,000 exposed A-bomb survivors with known doses, at the time of the last analysis (Ozasa et al. 2012) 50,000 had died, and causes of death were verified. In 11,000, the cause of death was cancer. By relating cancer rates to individual doses it was estimated that overall, about 500 of the fatal cancers were caused by the A-bomb radiation, and thus the cancer rate in the A-bomb survivors attributable to radiation exposure was about 1%. With increasing latency, the absolute carcinogenic risk was increasing, approximately in line with the "spontaneous" cancer risk.

Rules and Regulations to Protect Workers from Carcinogenic Radiation Risks

The results of this epidemiological study were used to develop exposure limits for radiation workers and the general population. This was only possible by neglecting factors which affected the individual radiation risk. In 1977, the International Commission on Radiation Protection (ICRP) designed this method of risk estimation which was applicable to the average person, independent of age, sex and anatomical dose distribution (ICRP 1977). It is based on the quantification of radiation exposure as a virtual dose, called "effective dose", with the unit Sievert (Sv). This is the mean absorbed doses (in Gy) in a list of critical organs which are multiplied with fixed organ weighting factors. These range from 0.01 to 0.12, and all organ weighting factors sum to 1.0. These organ-weighted mean organ doses are then added up. The type of radiation is also weighted by factors ranging from 1 to 20. This procedure is certainly not compatible with individual risk estimation as required in radiation medicine. Organs at risk vary through life: the thyroid is most radiosensitive at the age of 3, decreases by a factor of about 10 until adolescence, moreover, sensitivity is higher in females than males; the radio-sensitivity of the mammary gland is very low in males, in females it is highest around menarche, decreases gradually in adulthood to be close to zero after menopause. By using constant organ weighting factors in risk estimation of individuals, cancer risks may be underestimated or overestimated by orders of magnitude. Another factor which dramatically varies between organs is risk dependence on dose inhomogeneity within the critical organ. All these are reasons which prompted the ICRP to warn strongly against using this method of risk estimation in individuals. The "effective dose" has no place in radiation medicine; the "dose" unit Sv may be useful in protective risk management in radiation workers or the population at large, but not in medical applications of radiation to individual patients. Unfortunately, due to lack of generally accepted alternatives, it is still used in medical radiology, both in diagnostic radiology and in radiotherapy.

The Carcinogenic Risks of Patients Undergoing Radiological Procedures

The problem is particularly urgent in *diagnostic radiology*. A patient who asks for information about the potential cancer risk from a planned diagnostic procedure is usually given a number (xx mSv) taken from tables which are designed for completely different purposes, such as for reporting the increase in radiological procedures in different countries and the associated overall radiation exposure e.g. in the reports of the United Nations Scientific Committee on Atomic Radiations (UNSCEAR). Few patient understand these numbers, and doctors feel obliged to make comparisons to everyday experiences of patients such as “this is the same as the exposure from cosmic radiation by flying from Germany to New York or the same as 2-week holidays in the Swiss Alps”. Patients will quickly recognize that these comparisons are nothing but implausible excuses playing down justified concerns. This way, much trust is being lost. In fact, these comparisons are scientifically incorrect, if not rotten. There are only few studies which directly investigated the carcinogenic risk of diagnostic radiology procedures. There is only one study which provided reliable data on the risk of children to develop leukaemia caused by pelvimetric radiological investigations in pregnancy. A large epidemiological study on cancer risk from CT examinations in childhood (called EPI-CT) is currently funded by the European Commission; however, problems such as retrospective dosimetry are severe and may lead to uncertainty in the interpretation of the findings. There is urgent need to develop new approaches for the quantification and communication of carcinogenic risks in diagnostic radiology (Brenner 2008). Currently, the ICRP is discussing this problem and new recommendations are eagerly awaited.

The carcinogenic risk problem in *radiotherapy* is different. Treatment planning begins with the definition of the “target volume”, i.e. the tissue volume which contains cancer stem cells. Because a hallmark of tumour cells is their ability to infiltrate into neighbouring tissue structure, this volume is always bigger than the tumour which is visible e.g. in radiological imaging. Only if all tumour stem cells are sterilized by a high radiation dose can a cure be achieved. On the other hand, in organs close to the target volume, high radiation doses may also damage normal tissues and lead to early or late morbidities. The art of the radiation oncologist is to find the right balance between chance of elimination of all tumour stem cells and keeping the severity of late normal tissue effects in the neighbouring normal organs and tissues at an acceptable level. Intensive research in clinical and translational radiation oncology has led to successful radiotherapy treatment planning and delivery.

Today, for most cancer diseases, overall local tumour control rates are over 50%, i.e. the treated cancer will not return in the treated volume during the remaining life time of the patient. Only if the cancer was much advanced and has spread to organs and tissues outside the treated body region before the start of radiotherapy, local tumour control does not mean cure. In the vast majority of irradiated patients, early and late normal tissue side effects, if they occur at all, are mild and do not impact on the quality of life of the cured patient. Overall, with the use of advanced, modern radiotherapy techniques, the rate of severe late normal tissue side effects, i.e. those which cause chronic pain or decrease of organ function, is low, in most types of cancer diseases less than 1% of treated patients. However, as a result of this success, which was unimaginable just a generation ago, the carcinogenic risk of radiation therapy has become a top issue in translational research: Treatment-induced second cancers may be more frequent today than severe late normal tissue damage. However, this risk of second cancers induced by treatment of a first cancer with anti-cancer drugs and/or radiotherapy is currently not included in the treatment plan optimisation. Most of these second cancers will occur only several decades after the radiation treatment which cured the first cancer (de Gonzalez et al. 2011). No wonder that the radiation oncologist or medical oncologist who treated the first cancer is rarely confronted with the second cancer which may have been induced by his successful treatment of the patient.

A plethora of detailed or large clinical follow-up studies on the factors which determine the size of this risk have been published since the groundbreaking study on second cancer risk after radiotherapy of prostate cancer by Brenner et al. in the year 2000 (Brenner et al. 2000). Most of the studies with long-term follow-up relate to patients who were treated at a time when modern, high-precision radiotherapy did not exist yet. On the other hand, many studies which examine the risk of radiation-induced second cancers in patients treated with state-of-the-art radiotherapy techniques lack the necessary follow-up since treatment-induced second cancers generally occur long after the usual patient follow-up of 5 years. Moreover, different studies use different effect criteria which make comparisons, conclusions and recommendations for clinical use difficult. Their frequency can only be determined by careful epidemiological studies, preferentially nested case control studies in large patient groups which are documented in state-of-the art cancer registries such as those in Denmark. These case control studies have to be based on detailed information about the local radiation dose at the site of the second cancer in the individual patient and in the control patients at risk. Such studies are, however, very rare (Grantzau et al. 2014). Yet, there can be no doubt that both chemotherapy and radiotherapy may cause second cancers. In radiotherapy, the risk appears to depend on the radiation dose and its anatomical distribution in critical organs. In chemotherapy, much less is known about the relationship between drug concentrations and doses in critical organs. Moreover, drugs and their combinations change very frequently and dose/exposure reconstruction long after treatment is much more difficult than after radiotherapy.

The risk of second cancer induction is particularly high in paediatric radiotherapy. Large childhood cancer survivor registries in the USA (Robison LL for the Childhood Cancer Survivor Study 2009) and in Europe (Winter et al. 2015) demonstrate that with the treatment concepts and modalities applied some 30 years ago, the risk of second cancers related to the primary treatment is much higher than the risk of failure to cure the primary malignancy. These registries have been much improved recently and now also contain detailed information on more than 30,000 young cancer patients who have been treated with and cured by a variety of multimodal treatment concepts, most of them including radiotherapy alongside surgery and chemotherapy. This aggressive treatment saved their lives but at a high cost. Many developed psychological, neurocognitive and hormonal long-term deficits as well as diseases in organs which were close to the treatment volume, such as disorders of heart function. Yet, most concern focuses on the risk of treatment-induced second cancers. One of the most informative studies on the risk of radiotherapy-related second cancer after primary cancer in childhood is that of the German Working Group on the Long-Term Sequelae of Hodgkin's Disease, in which five consecutive clinical studies on altogether over 2500 patients who had been treated for Hodgkin's disease with different radiation doses and concepts were evaluated after follow-up of between 18 and 34 years. In the main follow-up (Dörffel et al. 2015), altogether 147 s malignant neoplasms were observed; the risk after 30 years of follow-up was 18.7%. Most of the second malignancies (85%) occurred in the irradiated tissue volume. Of particular importance is the study which focussed on the incidence of breast cancer in girls treated with different prescribed radiation doses for Hodgkin's disease (Schellong et al. 2014). Twenty-six cases of breast cancer were diagnosed in 590 young women after a follow-up of more than 14 years. The mean latency of the breast cancer cases was 20 years, at a mean age of 36 years. With increasing age of the patients, the breast cancer risk rose sharply, and at the attained age of 45, the absolute risk of developing a radiotherapy-related breast cancer was about one in five patients, which is 24 times the risk in a healthy women, but similar to the breast cancer risk of a woman who carries a BRCa mutation.

The current state of knowledge does not permit the development of algorithms which can be used in routine radiotherapy to optimize radiotherapy treatment plans which combine and balance a high rate of tumour cure (local and systemic) with an acceptable severity of late normal tissue effects (such as pain which can be treated effectively, functional deficits which can be compensated, fatigue and depression). Medical care for those late morbidities may be a long-term medical duty. The looming possibility that the primary treatment may have failed and the cancer may recur, and even worse, that the treatment which destroyed the cancer may have caused a second cancer, is, besides the health risk, a very severe psychological stress for many patients. Much more research effort should focus on the wide spectrum of long-term somatic and psychological health problems of the cured patient.

Worldwide, intensive research is in progress to develop methods to reduce the risk of therapy-induced second cancers without decreasing the chance of cure of the individual patient. Quite a few have been published, but all are based, inevitably, on assumptions and simplifications, which make them interesting for research purposes but not reliable for clinical oncology practice. One of the most important deficits is the fact that most are based on the effective dose concept, which by definition should not be used to estimate risk for the individual patient.

Conclusion

1. The communication of carcinogenic radiation risks to patients in diagnostic and therapeutic radiology is unacceptably poor and needs to be improved.
2. Although in radiotherapy of adult cancer patients the risk of therapy-induced second cancers is low, there is evidence that this risk can be further reduced by including this risk in the treatment planning process, yet currently no optimisation criteria are available. This problem is particularly important in radiotherapy of children.
3. Clinical and translational research in radiation oncology needs to focus on the long neglected field of treatment-induced second cancers. Currently, there is more interest in speculative modelling than in in-depth research into the potential criteria of optimizing radiation dose distribution in particular critical organs and clinical scenarios. We need new concepts and methods to reduce the carcinogenic risk in therapeutic radiation medicine.

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Chapter 14
Benefit and Risks of Screening for Breast Cancer

Sylvia H. Heywang-Köbrunner

Introduction

Breast cancer (BC) is by far the most frequent cancer in women. In industrialized countries, it is the second most frequent cause of death (Lauby-Secretan et al. 2015).

In 2012, more than 69,500 women in Germany were affected by BC, and over 17,700 (25%) women died of breast cancer. The vast majority (84%) of BCs occur above age 50.

In recent years, a debate has arisen on the benefits and "harms of mammography screening". Considering the fact that, based on the highest-level evidence (level 1a), mammography screening is the only method for which significant mortality reduction is unequivocally proven (Lauby-Secretan et al. 2015; International Agency for Research on Cancer 2016; Melnikow et al. 2016), and the method with by far the lowest number of false-positive calls (see below), the real debate concerns a fundamental debate on benefits and harms (as well as costs) of early detection.

This debate continues, even though cancer registries show that survival of BC detected at very early stages (<1 cm) are associated with a 20-year survival greater than 90%, which decreases significantly (and almost linearly) with larger size at detection. The earliest stages such as ductal carcinoma in situ (DCIS) or microinvasive BC (Tmin) are associated with approximately 100% BC-specific survival, whereas—even with modern therapy—in 2012, 17,700 BC deaths in Germany could not be prevented.

While widely available survival data might be biased by intermingled overdiagnosis, data on mortality reduction, as mentioned above, are by principle not biased by overdiagnosis, and represent the true benefit.

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It has been estimated that approximately 50% of today's mortality reduction is due to early detection, while 50% is due to improved therapy (International Agency for Research on Cancer 2016; Vilaprinyo and 2001).

Thus, participation in mammography screening represents one possibility for reducing the mortality of BC. Like any measure in medicine, it is associated with benefits and risks.

This chapter gives an overview of benefits and risks. It summarizes arguments of the debate and discusses benefits and risks of the other options.

Fundamentals

Screening is based on the proven knowledge that early detection saves lives.

This lifesaving effect depends on how much the time point of diagnosis can be preponed and whether earlier detection in the individual case is sufficiently early, i.e. before significant tumour spread has occurred. The latter correlates with the time that the tumour is in existence and is capable of spreading cells, on the tumour volume (number of potentially spreading cells) and on the aggressiveness of the individual tumour cells. With the start of vascularisation (at a tumour size > 2 to 3 mm), the potential for tumour spread exists and appears to increase with tumour size. As is also known, the aggressiveness of a tumour usually increases during its lifetime (with increasing heterogeneity of developing cell clones); a decrease in aggressiveness could theoretically be discussed, but has almost never been observed with BC.

Unfortunately, it cannot be predicted if or when a woman may be affected, or by which type of tumour. Also, change in aggressiveness cannot be predicted for the individual case. Even for women presenting with the combination of lowest risk factors, the incidence of BC is as high as or higher than the incidence of colon cancer, which ranges around 1–1.5/1000 per year above age 50.

For this reason, mammography screening is recommended to women aged 50–69 and discussed for further age groups (Lauby-Secretan et al. 2015; International Agency for Research on Cancer 2016; Oeffinger et al. 2015; Screening 2012; Health Council of the Netherlands 2014).

Effectiveness of a screening depends on:

- Repetition of the examination. Since "today", only those cancers which have developed to a detectable size can be detected, newly developing cancers need to be detected at the follow-up examination, etc.
- Sufficiently short intervals. With excessively long intervals (due to irregular participation or the design of the screening programme), the true effect of early detection is lost, and this loss concerns faster-growing tumours first.
- Using a sufficiently sensitive method, which allows an adequately preponed diagnosis of most tumours with respect to their individual biology.

The Method

To date, no imaging modality can recognize all cancers.

No data support screening by ultrasound alone (International Agency for Research on Cancer 2016; Melnikow et al. 2016). MRI, which is known to be more sensitive but less specific than mammography, is recommended together with mammography in women at very high risk. However, no data support its use for women at low risk, and insufficient data exist for intermediate risk (Lauby-Secretan et al. 2015; International Agency for Research on Cancer 2016; Melnikow et al. 2016). Both MRI and ultrasound are very probably associated with a significantly higher rate of false-positive biopsies (factor > 3) than mammography screening and with a much higher number of recommendations for short-term follow-up (International Agency for Research on Cancer 2016).

The Debate

Calculation of the effect of any early detection is far more demanding than demonstration of the effect of therapy. This has mainly two reasons:

1. Even though BC is the most frequent malignancy in women, and amounts to 12% during lifetime (or 7% for those aged 50–69), the number of incident cancers every 2 years is low ca. 6/1000), and the effect of a single examination is small compared to other potential factors observed in a population.
2. When evaluating the effect of early detection, it must be remembered that death from BC does not occur at the date of detection, but mostly 5–15 years later. Thus, the full effect of a screening method only becomes measurable many years after the screening examination (>15 years). Furthermore, this effect it is distributed over a time period of approximately 5–15 years with small measureable effects per year.

These difficulties give room to interpretation and debate. However, it should be understood that the inherent difficulty in calculation does not imply absence of an effect.

Also, correct calculation of the true effect (or effectiveness) requires special study types and/or sophisticated evaluation methods with adequate bias control and, above all, sufficient follow-up time of 15 years and longer.

The above-mentioned debate concerns several topics, which are summarized below, but are explained in more detail in other publications (Lauby-Secretan et al. 2015; International Agency for Research on Cancer 2016; Njor et al. 2012; Puliti 2012; 2016).

Topic 1: The database. Opponents of screening (Gøtzsche 2013; Swiss Medical Board and Hrsg 2013) insist on using data only from randomized controlled trials (RCTs), since this study type is best suited for calculating mortality reduction. This is correct. However, bias exists in RCTs as well, as was illustrated by the fact that only 70% of invited women were found to participate, while up to 25% of non-invited women underwent mammography. Therefore, RCTs underestimate the effect of true participation.

Proponents of screening point out that the data from RCTs are on average 30 years old, and thus reflect neither the potential of modern mammography screening nor that of therapy. Since RCTs are, by principle, impossible to perform in parallel with modern service screening, researchers have instead used other study types with sophisticated bias control or epidemiological modelling. The latter studies include both the effects of modern diagnostics and therapy, but are by principle not accepted by opponents of screening.

Ecological studies (observation of trends) have frequently been used by opponents of screening. However, proponents of screening point out that this study type is not adequate for evaluating early detection, as overall trends cannot be adequately assigned to causes, which allows completely divergent interpretations.

Topic 2: Recalculation of the effect. Goetzsche (Cochrane Institute) (Gøtzsche 2013), the most prominent opponent of early detection, has re-calculated the effect of the RCTs by excluding six of eight RCTs based on newly defined formal criteria (type of randomisation). This has not been accepted by completely unbiased bodies such as the Independent UK Panel (Screening 2012).

The numbers needed to treat calculated by him refer to only 3.5 screening rounds,[1] on average, but are applied as though they represented "the effect of screening between age 50 and 69". This, however, underestimates the expected effect by a factor of 3, since the recommended measure concerns 10 rounds over 20 years, not 3.5 rounds.

Topic 3: Observation time. Opponents only indicate the number of lives saved during a relatively short follow-up (10–13 years after start of the screening period = 2–5 years after its end). Since BC deaths after the observation time are not counted and since cancers detected in the control group after the observation time are not considered, mortality reduction is underestimated and cases of overdiagnosis are overestimated.

Proponents calculate the number of lives saved for a follow-up time of 25–30 years (=5–10 year follow-up after the end of the screening period). This calculation is based on long-term observations available from 2 RCTs and includes some modelling which is not accepted by opponents.

Topic 4: The reference base. Screening opponents lately have exclusively referred to numbers of saved lives per 1000 healthy women screened. They object to mentioning percent mortality reduction, assuming that this overemphasizes the effect.

Screening proponents refer to the absolute number lives saved per 1000 healthy women screened and include information on the percent mortality reduction. Screening proponents argue that healthy women who are not affected by the disease

[1]This is the average number of screening rounds in the old trials.

(930 of 1000 healthy women) do not expect a mortality reduction from BC screening. The more important and desired information concerns the prognosis of women affected and the proportion of lives saved with screening per lives lost without screening.

Benefits of Mammography Screening

The main benefit of mammography screening is mortality reduction. All meta-analyses of the RCTs prove a mortality reduction of approximately 20–23% for invited versus non-invited women aged 50–69, corresponding to 25–30% for participating women (International Agency for Research on Cancer 2016).

The Independent UK Panel translated this into approximately 4.3 saved lives per 1000 invited women, or 5.6 saved lives per 1000 participants (Screening 2012).

Screening opponents recalculated mortality reduction in the old RCTs using a reduced weighting of six of eight RCTs.[2] Since one of the two remaining RCTs, a heavily debated trial, showed no mortality reduction, an overall mortality reduction of 15% results for this evaluation. Based on this, a 10-year overall observation time and 3.5 screening rounds, they report 1–2 saved lives per 1000 women screened.

Based on the analysis of both RCT data and data from modern service screening programmes, the International Agency of Research in Cancer (IARC) of the World Health Organization (WHO) concluded that for true participants, a mortality reduction of approximately 40% is expected from modern screening programmes, equivalent to approximately 8 lives saved per 1000 screened (International Agency for Research on Cancer 2016; Paci et al. 2014).

Further benefits of early detection concern the possibility for reducing aggressive therapies: fewer axillary dissections, mastectomies and chemotherapies, as well as the potential for better cosmetic results. Few data are published concerning these benefits, possibly due to incomplete documentation or ongoing changes of therapy. However, based on existing guidelines for therapy, these benefits are obvious from the better stage distribution. In Germany, initial trends confirming these benefits have been observed since initiation of the screening programme (Stang et al. 2013).

Another very important benefit, which is rarely mentioned, concerns reassurance of women with a normal screening study. Women are usually not afraid of BC, because they are invited to screening. They are afraid since they know about friends or relatives who were affected by BC or died of BC. This benefit concerns a high number of women and is considered by most women to be worth the stress of a potential recall.

[2]The different weighting between RCTs has not been accepted by most other experts. It is based on formal criteria.

Risks (=Potential Side Effects) of Mammography Screening

The risk of any screening test is a false-positive call. Whenever a possibly important finding is noted, the woman is recalled for further examinations. By definition, every recall for an eventually benign finding is called a "false-positive call". This concerns 2–3% of the screened women per follow-up round. This percentage is very low compared to most other medical tests. However, it implies that, on average, 20–30% of the screened women will once be recalled during 10 rounds (=20 years of screening). Medical side effects of false-positive recalls are minimal in modern screening programmes. Most questions can be solved by additional imaging. Due to the systematic use of minimally invasive biopsy methods (needle biopsies, which are performed under local anaesthesia on outpatients), significant side effects of biopsies are also rare. Any recall undoubtedly causes short-term psychological distress. Long-term psychological distress has been discussed in few women, mainly some who had to undergo biopsy or short-term follow-up for a benign lesion. Most women, however, consider the reassurance of benignity to be worth such unavoidable false-positive calls.

Based on all available data, the number of these false-positive recommendations for biopsy or short-term follow-up is far lower for mammography screening than for opportunistic screening or for any other imaging modality (ultrasound or MRI).

Overdiagnosis is a mere statistical term. It describes the fact that for some women preponing the diagnosis by early detection is not useful, because without early detection, they would not have known about their cancer during their lifetime and would not have died from it. This happens if a tumour or a precursor (DCIS) grows slowly or very slowly and/or the woman dies from another competing cause of death before the tumour would otherwise have become palpable. Since the woman undergoes treatment due to early detection of this correctly diagnosed malignancy but does not benefit, the associated treatment is called overtreatment and represents the true side effect.

Considering the fact that a wide variety of tumours and precursors exist and that competing causes of death increase with age, overdiagnosis is a predictable side effect of any screening measure that can effectively prepone diagnoses in a population aged 50–69.

It usually cannot be assigned to individual women, since it is usually unpredictable what would have happened had the tumour not been diagnosed. Also, the same tumour type, which if untreated might be lethal for a woman with a long life, might correspond to an overdiagnosis in a treated woman who dies early for other reasons. Thus, biologically, no entity corresponding to overdiagnosis exists.

The most important measure for reducing side effects of potential overdiagnosis is to optimally adapt therapy to the tumour type and to the woman's health status and probable life expectancy. This implies that overtreatment largely implies some tolerable treatment of early disease.

Calculation of overdiagnosis is even more demanding than calculating mortality reduction. Since adequate data (sufficient follow-up of study and control groups without any interfering interventions, correct age cohorts, life expectancy comparable to the present state) are not even available from the RCTs, sophisticated modelling is indispensable. Without adequate modelling and sufficient observation time, preponed diagnosis cannot be adequately distinguished from overdiagnosis, and rates of overdiagnosis can be largely overestimated (Puliti 2012). The extreme variations in the literature demonstrate this problem and indicate its very low level of evidence. Reasonable estimates range from 4 to 14 cases of overdiagnosis per 1000 healthy women undergoing mammography screening (International Agency for Research on Cancer 2016; Health Council of the Netherlands 2014).

When weighing the disadvantages of overdiagnosis, a mere comparison with the number of saved lives is probably not adequate. This comparison should at least also consider the important number of less aggressive treatments which become possible by early detection.

Interval cancers are not a side effect of screening. These cancers would have grown with or without screening. However, since they are not detected by the biennial screening test, they demonstrate its limitations, which also become obvious by the fact that mortality to date can "only" be reduced by 20–40%. Interval cancers are a significant limitation, since the woman observes all recommendations, but still cannot benefit from early detection.

In biennial screening programmes, approximately 75–78% of all BCs are detected at the screening examination. Approximately 12% are considered to develop newly during the interval. Due to fast growth (with respect to the interval), these "true" interval cancers already become palpable before the next screening. They could, in fact, only be reduced by choosing a shorter screening interval. The remaining 10–13% of cancers are known to escape detection due to imperfect sensitivity of mammography or a reading error. In well-controlled screening programmes with continuous training of the readers and with independent double-reading, reading errors make up a small proportion of all cancers. Cancers may not be detectable by mammography if they do not contain microcalcifications and are obscured behind breast tissue. They are more frequent in women with (very) dense tissue. While the use of additional methods could thus be discussed (for example, in women with dense tissue), to date no such international recommendation exists, due to still limited evidence of effectiveness and the expected additional side effects from other methods.

Alternatives to Mammography Screening

The main alternative suggested by screening opponents is "waiting until the tumour is palpable". This alternative is not associated with overdiagnosis or with false positives. For those women affected by BC, however, detection at a larger size must be expected (average size difference: >1 cm). Larger tumours are associated with a worse prognosis and increased need for chemotherapy. In addition, chemotherapy must be carried out in a significant number of women with large tumours in order to achieve improved survival for some.

Screening by breast self-examination has been tested in large trials. It showed no significant effect on mortality reduction, but an increased rate of false positives (International Agency for Research on Cancer 2016). It thus represents no valid option.

There is no other screening test (blood or urine test) at this time that could even come close to achieving a detection rate of early malignancy comparable to mammography. Also, a very high number of false-positive calls would result from any such test to date. Conisdering the absent information on lesion location with blood tests impairs exclusion of malignancy and might thus lead to significant uncertainty.

All international and national societies dissuade from replacing mammography screening by any other modality (ultrasound or MRI) for screening women at low to moderate risk. Reasons include a lack proof of sufficient effect and reproducibility, and the much higher number of false-positive biopsies and short-term follow-ups. Furthermore, for MRI, a significantly higher rate of overdiagnosis must be considered, as well as potential side effects of MR contrast medium (allergy, kidney failure).

All existing data demonstrate a greater effect of systematic mammography screening programmes than of "individualized" opportunistic screening[3] (Health Council of the Netherlands 2014), and lower rates of significant false positives as seen with short-term follow-up or biopsy. Also, any method that allows preponing detection will lead to overdiagnosis. Thus, opportunistic screening, which is still performed in parallel with the screening programme in some countries like Germany, does not represent a desirable alternative to mammography screening.

Conclusion

Mammography screening remains the basis of early detection and cannot be replaced by any other method to date. If the additional use of further methods is considered to further increase sensitivity, potential side effects of these methods should be considered and discussed.

Early detection represents a chance for reducing mortality. By allowing a mortality reduction of 25–40% (=5–8/1000 women who participate), the long-term effect of mammography screening compliments that of modern therapy, and both contribute to better survival (International Agency for Research on Cancer 2016; Vilaprinyo and 2001). For some of the women, it furthermore implies the chance to avoid aggressive therapies required for late stages (axillary dissection, mastectomy, chemotherapy).

[3]Opportunistic screening means unsystematic screening by one or several methods performed by radiologists or gynaecologists without special training for screening and outside the strict quality assurance recommended for screening.

Like any medical measure, it is associated with potential harms (=risks) and participating women should be adequately informed about benefits and risks. The risk of significant false-positive calls is lower with mammography screening than for any other test and the strict quality assurance of mammography screening accounts for this. Overdiagnosis (detection of true cancers, which might not have endangered the woman during her remaining life span) is unavoidable with any method that effectively prepones the date of diagnosis. Side effects of potential overdiagnosis should be limited by optimally adapting any therapy to the individual tumour biology and stage, and to the woman's health status and her individual life expectancy (as far as is predictable).

Considering that mammography screening can reduce but not eliminate BC mortality, it must be understood that mammography screening cannot warrant timely detection. However, the probability of timely detection and survival and the possibility of less aggressive therapy increase.

Based on a systematic review of all available data, weighing benefits and risks mammography screening is recommended by most international and national committees (Lauby-Secretan et al. 2015; International Agency for Research on Cancer 2016; Oeffinger et al. 2015; Health Council of the Netherlands 2014).

With respect to the existing debate, it should be demanded that:

– Participants are informed about results expected for participants, not with respect to women invited who do not participate.
– Information given should include data on the present state of early detection and therapy.
– Communicated numbers of "lives saved" (as indicated by the words) should be calculated or estimated with reference to the remaining lifetime, not for short-term follow-up. The same applies to overdiagnosis, since sufficient follow-up is crucial to correctly separate overdiagnosis from preponed diagnosis.
– Information given should include both percentages (to allow correct understanding of the context) and absolute numbers.

Overall, information about this difficult subject is demanding. Unfortunately, the propagated information is meanwhile heavily biased by aggressively distributed information from screening opponents.

Mammography screening represents one important chance for saving lives and avoiding aggressive therapies. When weighing benefits and risks of screening, those of the remaining alternatives need to be compared and put in relation.

The best possible answer to the unavoidable possibility of overdiagnosis is to optimally adapt individual therapy, not to avoid detection. The reason is that in healthy women, a forecast concerning the absence or possible occurrence of a BC, its time point or its biological importance is impossible. Risk-adapted therapy in the case of BC, in contrast, appears a realistic option today, with further potential in the future.

The most important need for optimisation concerns the improvement of sensitivity, mainly in dense breast tissue. The most promising developments in this field include stratified combinations with other methods such as automated ultrasound or stratified use of tomosynthesis, a further technical development of mammography.

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Chapter 15
"Radiation Effects" in Patient Treatment

Michael Flentje and Michael Molls

Introduction

Radiation therapy, i.e. treatment with ionizing radiation, is a key component of modern tumor therapy. In Germany, about 450,000 new cases of cancer are currently diagnosed each year. Just under half of the patients receive radiation therapy during the course of their disease. In many cases, radiation therapy is curative, and it is an essential component of the treatment plan in more than half of "cancer cures." And discomfort can be effectively alleviated, even in patients who cannot be cured.

At the time of exposure, ionizing radiation is "soundless, painless and unspectacular." Its effect shows up with a delay in biological systems. The interval and the extent of the effect depend on the particular organ, the dose and the irradiated volume as well as individual factors. Only over the long term, after years and sometimes decades, does failure becomes apparent—as a tumor recurrence, severe consequences due to the tissue tolerance threshold being exceeded or tumor induction. The public is very aware of general "radiation risks," primarily with regard to the debate over nuclear power, and the reason for avoiding those risks is evident.

However, the present article addresses the special situation of using ionizing radiation intentionally for medical benefit. Effectiveness (the desired effect is attained) and efficacy (the use of resources and undesired consequences are minimized) are in the foreground here.

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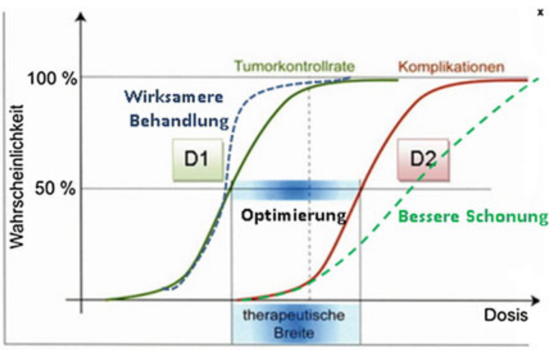


Wahrscheinlichkeit	Probability
Tumorkontrollrate	Tumor control rate
Komplikationen	Complications
Wirksamere Behandlung	More effective treatment
Optimierung	Optimization
Bessere Schonung	Improved protection
therapeutische Breite	Therapeutic scope
Dosis	Dose

Fig. 15.1 Dose-response relationship of radiation therapy; for translation of German expressions, see table given in figure

The sigmoidal dose-response relationship of radiation therapy, with opposing effects of benefit and harm, has been paradigmatically described by Holthusen (1936) (Fig. 15.1).

As a rule, then, risk management means optimizing the relationship between irreconcilably competing risks (cure and side effect).

"Uncertainties" as a characteristic of risk exist because of the interval between exposure and observable biological effect, differing individual sensitivity (on the part of both patients and tumor) and the complexity of the radiation therapy chain and interdisciplinary tumor treatment as a whole.

Risk management thus faces various challenges and must also adapt to rapid medical development.

Extensive statutory regulations, namely the German Radiation Protection Ordinance and the EU Council Directive (2013/59/Euratom), contain provisions for the protection of the population in general as well as patients. These provisions are set forth more specifically in national guidelines and in recommendations, for example, those of the German Radiation Protection Committee (Strahlenschutzkommission, SSK), and reconciled with medical progress and reconsidered if necessary.

Radiation protection for patients is set forth in two main requirements:

- Medical exposure to radiation must be justified.
- The extent of the exposure must be as low as possible to achieve the desired objective.

Risk management must therefore address two different areas:

(1) General risk/benefit ratio

  a. What is the quality of the result of medical radiation treatment?
  b. Are there technological developments or new medical findings that make radiation treatment more effective and/or better tolerated?
  c. Are there developments that avoid the use of ionizing radiation while maintaining the same degree of effectiveness?
  d. Are there interactions between modalities (primarily radiation therapy and medications) that influence effectiveness in an unforeseen way?

(2) Individual patients' risk/benefit ratio

  a. Is treatment potential being optimized?
  b. Are individual particularities adequately recognized?
  c. Will treatment failure or severe side effects be recognized in time to be able to possibly counter them or prevent similar developments in the future?

From the patient's point of view, there are three risks:

- Treatment that is not appropriate for the disease situation brings about no benefit.
- Under-dosed treatment leads to disease recurrence.
- Treatment that is too intensive leads to unnecessary side effects.

General Relationship Between Benefit and Harm

During the author's thirty years of professional experience, radiation therapy has changed in unimaginable ways. It's come a long way from setting simple fields in a patient to precision radiation treatment with tolerances of just a few millimeters. The effects of multimodal imaging, compute-supported planning of non-homogeneous dose distributions, dose escalation and changed target-volume plans cannot be precisely measured on an individual basis. The current consensus that medical progress must be proven in an evidence-based fashion using randomized studies is very strongly shaped by the medication development process. This only partially meets the special requirements of radiation medicine. Because of a lack of support or resistance to making appropriate instruments available, relevant questions are not conclusively investigated.

Technological process that makes possible the minimization of radiation doses outside of the target volume and a dosage increase for tumors that have so far been poorly treatable can be described in such an obvious and quantitative way that it needs not be proven in patient studies or cannot/must not be investigated in randomized studies. Implementation into routine clinical practice occurs gradually and continuously. However, this does not solve the question of "optimal" use and real benefit.

Effectiveness and significance for patients are revealed as quality of care across geographical areas and over time. Long-term cures and tolerability (ultra-late side effects >10 years, secondary tumor risk) are likewise not investigable in prospective studies due to their latency periods and relative rarity (patient numbers, follow-up observation, therapy standardization), as the preferred study of prostate cancer is currently demonstrating in a painful way.

Recording long-term courses in registries by means of suitable parameters would probably be more expedient. Relevant prerequisites have been created by the early cancer detection and cancer registry law (Krebsfrüherkennungs- und -registergesetz, KRFG; 9 April 2013). However, there are still significant deficits in implementation that affect radiation medicine in particular: limited recording period, no reliable reporting mechanism, lack of interlinking with non-tumor-related data that would be important to morbidity and risk constellations.

However, the problems go above and beyond just the effects of radiation, as cancer therapy is increasingly carried out in an inter-disciplinary and multimodal fashion. Ever more frequent warnings from the pharmaceutical industry, because of unexpected severe and very severe complications due to the interaction of new targeted substances with radiation therapy, are a clear sign of inadequate risk management or learning that takes place after the damage has already occurred.

There is currently an almost exponential increase in new drugs that intervene in central cellular homeostasis signaling pathways, which are also essential for modulating the effects of radiation.

This differs fundamentally from tumor chemotherapy, with which extensive experiences have already been made, and which involves a relatively small number of substances. The number of new medications and the short half-life until the development of imitators/successor substances make valid assessment difficult. These new therapeutic agents usually require ongoing medication, unlike classical chemotherapy, meaning that the probability of coinciding with radiation therapy is greater.

In practice, special problems and a high potential risk of interactions between ionizing radiation and drug therapy of tumors arise for the following reasons:

(1) Sequential use by different treatment providers;
(2) Comorbidities in individual patients intensify or mask interactions;
(3) This can lead to over-reporting (individual case observation) as well as to
(4) Under-reporting due to a lack of experience on the part of the physician confronted with the complication and a low number of cases;
(5) Unintended combination, because of therapeutic changes that become necessary in the course of the condition.

In this context, the recall phenomenon (asynchronous occurrence of a reaction with application of a second modality) is especially critical.

However, interaction with radiation therapy is not part of regulatory drug approval.

The relevant studies take place too late, are not funded and cannot address the particular problem of unplanned and metachronous combination. The significance increases with intensification of many tumor therapies, increasing multimodality and diversification of drug therapy in particular (including immunotherapeutic agents with delayed and prolonged activity).

Individual Patient Relationship Between Benefit and Side Effect

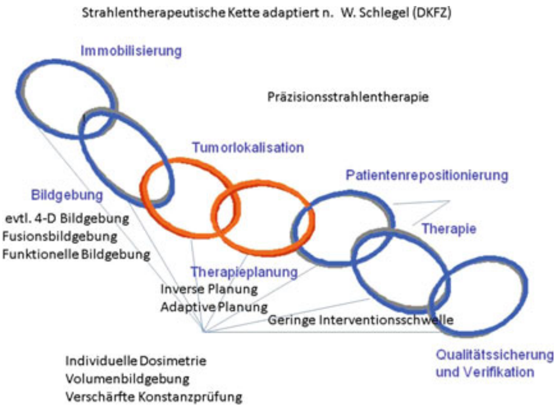
When journalists in Hamburg uncovered a cluster of severe complications after a specific radiation therapy plan in the Eppendorf University Hospital, it soon became clear that lack of follow-up care in particular, and/or a lack of feedback from affected patients, were the reasons why a novel, complication-ridden therapy plan had not been recognized and changed sooner.

Because of long latency periods, however, these will only help future patients, and not current ones. Therefore, well-coordinated quality management that minimizes known risks in the process is necessary as a second pillar. This is especially significant because individual radiation treatment consists of a chain of very complex individual steps that are conducted by different specialized groups and parties with complementary expertise (Fig. 15.2).

Over the years, this experience has set in motion an intensive discussion as well as quality assurance and/or process quality improvement measures.

Decisive steps included:

- Evidence-based guidelines for determining a therapeutic corridor;
- The individual radiation therapist’s obligation to provide follow-up care in order to monitor both effects and side effects on his own patients.
- The obligation to set up an internal departmental reporting system to recognize errors and critical events, including rules for external reporting (CIRS).
- Setting up external audits at regular intervals (medical sites as per Section 83 StrSchV [Strahlenschutzverordnung, Radiation Protection Ordinance]) that monitor the medicophysical and medical quality of radiation treatment on site and make suggestions for improvement.



Strahlentherapeutische Kette adaptiert n. W. Schlegel (DKFZ)	Radiation therapy chain adapted from W. Schlegel (DKFZ)
Präzisionsstrahlentherapie	Precision radiation therapy
Immobilisierung	Immobilization
Tumorlokalisation	Tumor localization
Patientenrepositionierung	Patient repositioning
Therapie	Therapy
Qualitätssicherung und Verifikation	Quality assurance and verification
Bildgebung	Imaging
evtl. 4-D Bildgebung	Possibly 4D imaging
Fusionsbildgebung Funktionelle Bildgebung	Fusion imaging Functional imaging
Therapieplanung	Therapy planning
Inverse Planung Adaptive Planung	Inverse planning Adaptive planning
Geringe Interventionsschwelle	Low intervention threshold
Individuelle Dosimetrie Volumenbildgebung Verschärfte Konstanzprüfung	Individual dosimetry Volume imaging Intensified consistency testing

Fig. 15.2 Individual radiation treatment consisting of a chain of very complex individual steps, Bille and Schlegel (1999); for translation of the German expressions, see table given in figure

Summary

The description and quantification of risks of radiation medicine and analysis thereof require observation over very long periods of time and integration of complex data. This goes above and beyond the capacities of individual treatment providers and even large institutions.

Meaningful risk management means that suitable instruments for measuring the quality of results must be continuously developed and utilized more rigorously. Differences with respect to pharmaceutical research must be realized and accepted.

Only in this way can technological progress in radiation medicine be translated into real treatment in an adequately safe and speedy fashion.

The expansion of regional and national cancer registries can achieve part of the documentation of long-term effects and their evaluation. However, this will only be successful if the willingness to interlink with other databases (e.g. morbidity data from health insurance companies) increases.

However, general registries are not capable of answering special questions (e.g. new technologies, changed dosage plans, medication interactions, etc.) quickly, since additional parameters not originally foreseen in the registry database must usually be recorded for this purpose. In order to estimate the actual extent of effects, prospective recording in the context of dedicated care research is necessary.

For both approaches, cross-sector expertise (IT and big data mining, epidemiology and care research, data protection and radio-oncology) is necessary and should be brought together in a dedicated consortium in a dialogue among treatment providers, patients, cost-bearers and health policymakers.

For established processes, it will be decisive to have procedures that ensure the best treatment for individual patients by recording and reviewing the process quality of the "radiation therapy chain." This must be recognized as an integral part of radiation treatment.

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Chapter 16
Risk Management in Radiation Medicine: Administrative, Legal and Ethical Aspects of Research in Radiation Medicine in Germany

Ursula Nestle and Peter Lukas

Key Messages

Research is a key to assess and minimize risks in medicine. Therefore, clinical trials are a prerequisite. However, their legal framework has intersections between conflicting risk cultures. Hereby, research is hampered and significant risks (e.g. lethal complications after combination of radiation and new drugs in oncology) may not be well addressed.

Clinical Trials in Radiation Medicine

Medical research is the cornerstone of evidence-based medicine, minimizing treatment risks by the knowledge obtained in clinical trials. In order to minimize the risk to patients within trials versus other, for example commercial interests, a large legal framework has been established and recently internationally harmonized. Similarly, radiation protection of individuals and society must be maintained and is regulated by another internationally harmonized legal framework regulating the use of radiation in medicine. As clinical radiation medicine research is touching both topics, the problems of intersecting risk cultures can be learned here.

In the following, we point out three examples for such problems: the risk for the research landscape in Germany, the combination risks of radiation and drugs in oncology, and the changing position of ethics committees.

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Research Involving Radiation Medicine in Germany

The requirements for the conduction of clinical trials do not make a difference between commercial and non-commercial research. The legal framework is driven by the highly relevant idea to protect individual patients when participating in a trial. Clear standards and safety requirements (e.g. the guideline on good clinical practice of the international conference of harmonization; ICH-GCP) guide researchers to high-quality conductance of studies, ideally leading to valid answers to relevant questions. These guidelines regulate the application of a drug tested alone or in the context of other drugs, and their aim is to internationally standardize the requirements for drug approval.

On the other side, the application of radiation in medicine underlies respective laws (e.g. Euratom and consecutive national regulations), which aim at the protection of individuals and society against radiation. Research involving radiation in medicine, e.g. on evaluation of new tracers for diagnostic imaging or new treatment methods involving radionuclides or percutaneous radiotherapy, is regulated here.

When trials include both drug application and medical radiation exposure, they underlie both regulatory frameworks and hence must respect both risk philosophies. This leads to a situation in which the same scientific question may be assessed and regulated twice, with different requirements. As an easy example, a scientific project addressing the use of a drug together with standard radiotherapy may be regarded as research in the drug administration context and not as research in the radiation protection context. However, when both frameworks regard a project as research, the administrative organization of the study approval processes in Germany, together with different risk focuses and philosophies, may lead to conflicting constraints and to multiple reviews and revisions before the approval of the trial. Sometimes, different regulatory bodies are not informed about the requirements of their counterpart and propose conflicting corrections. Due to this time-consuming process, German researchers are often not included in international research projects, because the regulatory frameworks of other countries offer more efficient solutions for this dilemma.

Beyond the obvious disadvantage for German researchers, the problem is that patients will here be advised using data from trials conducted in foreign countries, possibly underlying less strict safety and quality control.

Risk of the Combination of Drugs and Therapeutic Radiation

For the approval of drugs in oncology, it is not mandatory to test the drug in the context of therapeutic radiotherapy. Furthermore, due to the administrative obstacles, additional trials on the combination of drugs and radiation therapy are often omitted by the research community. After approval of a drug, its combination with therapeutic radiation medicine in clinical reality is, however, often inevitable.

A patient with multiple painful metastases needing effective pain control, for example, may need both stabilization by radiotherapy for local palliation and systemic treatment to prevent or slow progression at other sites. Both treatments can then be regarded as standard approaches and are approved or even recommended by international guidelines.

Recently, after the approval of a new generation of anti-cancer drugs, there are increasing numbers of reports about severe complications after their intended or even accidental simultaneous or sequential combination with therapeutic radiotherapy. From a regulatory view, these complications are subject to individual reports to the authorities. However, prospective comprehensive data would be needed to assess the actual incidence and hence the severity of this problem. Obviously, there is no commercial interest to obtain such data after successful drug approval. The instrument of health services research (*Versorgungs-forschung*) would therefore be appropriate, which however lacks initiative and funding. We here see an urgent need for action due to the severe risk potentially affecting thousands of patients with cancer.

Changing Position of Ethics Committees

In the recent harmonization of European laws, the position of ethics committees assessing clinical trials has significantly been changed. Now, only one ethical committee, in the country of choice of the investigator, is responsible for the approval of a trial. Together with the time limits given (if not kept, the trial is regarded as approved), this places enormous pressure and responsibility on the ethics committees. On the other side, in order to be able to give independent statements, the committees are usually manned by honorary persons with limited time resources. Furthermore, they may still be somehow dependent on university bodies. This situation may lead to a lack of thorough discussion of proposed trials, and hence increase the risks for patients in clinical trials.

In the context of radiation medicine research, there is an additional issue: for an ethics committee confronted with complex radiation-related scenarios, the presence of committee members with respective know-how should be mandatory. Due to the recent regulatory changes, this is not guaranteed, posing an additional risk to patients—and researchers—involved in trials, as outlined above.

Conclusions

Radiation medicine research in Germany faces several urgent issues involving the process of administrative approval of clinical trials, the problem of combination toxicities between new oncologic drugs and therapeutic radiotherapy, and the shortage in manpower and expertise of ethical committees confronted with recent regulatory demands.

Chapter 17
On Dealing with Risks in Modern Medicine and Communicating Them Effectively

Claudia Peter

Knowledge Production in Modernity

On Dealing Reflectively with Modern Knowledge Dynamics

Modern societies are distinctive in that they are societies invested in change. Not only are modern social conditions constantly changing, but above all, so is the stock of knowledge, for example, in the individual scientific disciplines, and along with it the criteria for weighing trade-offs and making decisions (see Beck and Bonß 2001; Beck and Lau 2004).

In posing the question of how to deal with this unstoppable dynamic, it is not just a matter of keeping pace with constant advances in knowledge. That would be putting the question too simply. As knowledge advances, so too grow the ambiguities, the doubts and alternatives, all of them forms of non-knowledge or uncertain knowledge (Wehling 2006). In science studies, it has been accepted for some time that the kinds of ignorance grow in parallel with the increase in knowledge.

Once we are clear on the dependency relationship between knowledge and non-knowledge, the question becomes how, against the background of the indisputably huge volume of knowledge, we will come to terms with the fact that we can never know everything. For, hand in hand with dealing competently with knowledge today goes competent handling of non-knowledge or uncertain knowledge. Or, to put it another way, how do we deal with the fact that the propensity for error, the insecurities, and the uncertainties do not diminish, but grow larger, as in

- The propensity to mistake what is actually the relevant knowledge here that I need for making a sound decision

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- The insecurity in making the right choice, for example, in selecting the right therapy
- The uncertainty that comes from never fully knowing whether we have done the optimal thing.

To act competently, therefore, certain knowledge must first be differentiated from uncertain knowledge and non-knowledge (Engel et al. 2002). These distinctions are also highly relevant for medicine—both in the area of modeling and in clinical practice area (Peter and Funcke 2013).

- We speak of uncertain knowledge if it can only be assessed subjectively, not objectively, in its consequences, or if causal links are only partially explained or are still hypothetical.
- By contrast, if the consequences are not assessable either subjectively or objectively, if they are not known or were not known at the time of occurrence (of a damaging event), or if the limits of knowledge are effectively reached (as happened with the world's first human transplant), we say it is non-knowledge.

Transposing this distinction to the field of medicine, we have to admit that in many areas of application, we need to speak of uncertain knowledge. Even scientific knowledge, hence also new medical knowledge, is uncertain knowledge.

While admitting to this is normally not a problem for pure science—largely unburdened as it is by action and application (and it does take self-critical reflection for research processes)—in medicine such concomitant self-reflections on how to think about uncertain knowledge are not yet routine but are highly relevant nonetheless. Hence, what would be a fitting way of dealing with non-knowledge—with these ambiguities, alternatives, the never-quite-wrong-but also-never-quite-rightness in twenty-first-century modern medicine?

Not Greater Certainty, but Reflection on Uncertainty, Is the Goal

Every new knowledge production generates new areas of specified ignorance, because wherever research or multiple applications answer old questions, new questions arise. Non-knowledge, however, also becomes cognizable where contradictions, ambivalences, and ambiguities appear. Knowledge and non-knowledge are thus generated equiprimordially. Thus, along with the newly won valuable knowledge, with every knowledge production concomitant new (possibly risky) non-knowledge phenomena originate. The notion of being able to generate more certainty through new knowledge therefore has to be rejected as outdated and oversimplified (Ewers and Nowotny 1987). Instead, the question arises in what way which consequences may pose risks.

- For medicine as discipline: In deciding on the legality and legitimacy of new medical research, is it a matter of collectively consequential trade-offs. Which consequences are riskier: those stemming from the newly produced non-knowledge or those from researches abstained from (cf. Scherzberg 2013; Augsberg 2013)? Whom to hold liable for unintended consequences (cf. Heidbrink 2007)?
- In turn, for the patient: Every diagnostic or therapeutic decision is based on knowledge that is paired with non-knowledge. It involves risky decisions against the background of an individual patient's specific history. It is not only about a therapy's benefits in the narrow sense, i.e., agreeing to or refusing a therapeutic measure, but also about the social knowledge dynamic tied up with it. How do the knowledge and non-knowledge in each case interrelate, whether I turn down the measure or else expose myself to its risks?

Communicating These Risky Trade-Offs in Clinical Practice

Doctor Meets Patient—Medical Expertise Meets Everyday Knowledge

In all scientific disciplines, newly created knowledge sets off social dynamics, such as acceptance or reservations by those impacted or participating. Thus, beyond the sphere of rationalized observation proper to the scientific sphere, medicine must also open itself to the issue of which social dynamics may be precipitated by its new medical knowledge, such as new therapeutic approaches. When it comes to specific diagnostic or therapeutic decisions for doctor and patient to make, such as taking part in a mammogram screening or (not) agreeing to undergo radiation treatment, what role does this knowledge dynamic, with its attendant uncertainties, play? In the first place, how to describe the personal constellation in which each side is subject to its own relevance structures? In a doctor–patient conversation, what is at issue is different from that which a legislator or regulatory authority would have to weigh when authorizing new medical research or approving new therapeutic approaches. These types of judgments rely on models based on correlation and causality calculations. When a doctor and patient talk, what matters instead are the relevance structures of the ordinary lifeworld (Schütz and Luckmann 2003), the testing of a medical intervention in the realm of social practice, in a patient's specific subjective world.

While the knowledge forms used to depict medical models can be described as correlation and causality relationships, knowledge forms in everyday life cannot be captured either correlatively or causally, but in principle *only* as social meaning contexts. People can be viewed within science, medicine included, as composed of molecules, cells, or organs, but they will be extremely alienated by being objectivized as and with numbers in this way.

Clinical practice, on the other hand, does not live in the inner scientific sphere; it is instead a zone in which the doctor, representing medicine, encounters a patient who belongs to the everyday lifeworld. What this calls for is a work of translation as a common undertaking, as to how

1. Medical knowledge ought to be formulated such that it can connect with the patient's secular knowledge
2. General, case-spanning *objective* knowledge can be construed in a way that is uniquely useful to individual patients in their particular life environments.

It has already been noted (Paul 2006) that this *objective* knowledge is probabilistic knowledge that cannot be used to dispense an individual prognosis. Hence, the question remains how that knowledge can be processed, if not into a definite prognosis then into an orientation for patients that can help them make what it is hoped will prove to be the right decision in both the short and long term.

Explain like an Expert, Understand like a Human: How the Doctor Can Talk with the Patient

There is no way around it: the patient in this situation cannot be understood as anything but an individual, as a subject. He or she cannot be conceived of as a causal construct—that would disregard our basic understanding of what it means to be human. The person confronting a difficult choice of applying a risky diagnosis or therapy to himself can only be understood as a human being in his social context of meaning. A patient cannot be perceived as anything but a unique individual who can be comprehended, not as an object to be explained as in model building. He is in a specific biographical situation, on which much normally depends: he has positive as well as negative prior experiences, he has convictions on which he orients his (future) life or that his life has to measure up against, and he has values that matter to him and are his yardsticks. All these are contexts that surround him and provide the basis on which he acts, interprets, and decides. These social complexes can only be grasped verbally, explored in conversation—from the treating physician, to the relatives and other interested parties, they can only be understood in proximity. For the doctor–patient talk, too, human communications and the basal human capabilities for understanding each other (in rapprochement) offer the only feasible common ground for seeking interchange in these decision situations.

As a Doctor, How Do I Communicate the Risks in a Medical Treatment to My Patient?

A modern society that is invested in change is a society prepared to take risks. Accepting risks makes it possible to try new ways, to have new possibilities bear fruit. But risks are Janus-faced; not only do they have a promising side, there is also the fraught one where potential harm can make itself conspicuous.

As a segment of modern society, medicine is also primed for change. It is good that we can treat diseases today that proved fatal for earlier generations or which condemned them to a life as invalids.

But when we set out on new therapeutic pathways, they are always risky: in one case, they may look like a success story, while in another case, they may have unfolded to a different effect, with complications or other negative consequences setting in. Therefore, when we are asked to deal rationally with risks—because we are all primed for dynamic medicine (instead of treading water)—then the question becomes: how do you rationally approach the weighable and the imponderable risks that come with every medical treatment? How are we to talk about these risks? What constitutes successful communication of risk?

Let us take a step back and observe a typical scenario: on the one side, we have an expert with years of experience who is continually learning and so keeps pace with the dynamic. On the other side are people who find themselves in the extraordinary situation of, say, a potentially fatal diagnosis overtaking them. For the one side, what must be discussed is part of daily work, it is part of life as is, it is daily professional routine, while for the other side it feels as though life has gone off the rails because of what just transpired.

If we now assert that a fitting communication in this kind of situation cannot simply consist of a knowledge exchange, of passing on information—one side imparting new knowledge to the other—but must instead become a mutual, proportional sharing leavened by sympathy of what is happening, then it becomes apparent that more is being shared here than simply (new) knowledge about risks. The question is: what exactly is being shared here and what is it—after the sharing—that one side and the other must bear proportionally every time?

Concepts: Risk—Danger—Insecurity and Uncertainty

When Is It Proper to Talk of Risks and When of Danger?

Let us begin with a thought excursion to a place that is important for cultural and social scientists, and with which they often start their work: precisely defining concepts.

- Risks are understood as probability statements that can be calculated for larger data sets. To talk about risk, you need many instances whose risk probabilities can be calculated.

From the patient's perspective (or that of his relatives), he/she is a unique case. Attempts at calculation here lead nowhere. If we want to make assessments and find ourselves on the level of an individual case, then we no longer talk about risk, but about dangers that are informed by doubt and uncertainty. It is also possible to say that the risks turn into dangers again, or the risky decisions are dangerous, because they can have unforeseeable consequences and because the outcomes are not certain, so that insecurity grows.

- Dangers simply are not calculable. They cannot be depicted by an abstract framing in rationality and objectivity postulates, but instead are subject to being weighed idiosyncratically by the individual actors, who determine for themselves their degree, doubtfulness and uncertainty.

Three examples will suffice:

1. When a state like Bavaria, in response to climate change, wants to assess the chances of flooding, then this involves true risk assessment, since it concerns a population group on a defined territory.
2. It is also about risks or risk communication when the idea is to educate healthy citizens about the risks of radiation therapy, perhaps with publicity campaigns or informative brochures.
3. On the other hand, if it involves a specific sick individual, a patient under treatment, who is acutely ill with a potentially fatal disease and needs to make a decision, then we are confronting dangers, because a hard and fast calculation is not feasible in an individual case. From his/her perspective, he/she has to cope with the insecurity of how to decide and the uncertainty about the impact it will have on his/her life going forward (chances of being cured and effects of the therapy).

If a doctor–patient talk is about an operation or radiation treatment, for example, then we have a specific case. In the discussion between the doctor and the patient (or his relatives), they must together clarify

- Which dangers are perceived by which side
- What the odds are for each danger.

Up to this point, it is *just* informing, the mutual sharing of knowledge. This changes into sympathy, the sympathetic taking on of the reciprocal share, provided it is then clarified

- Which dangers the patient is prepared to bear up under or which dangers are too much for him or her
- Which prospects are actually important to him or her
- If dangers do ensue, how the patients will want to be supported.

Nota bene: the patient must be empowered to make his own assessments, his own trade-offs; he or she must make certain decisions on their own that they cannot be relieved of; but then they also have the right, if they want to determine their share and bear it, to get the required support. As the physician, I cannot guess or read in their eyes what kind of support they need. The sooner patients can put their own needs into words, the better can I look after them.

Without question, conversations like these have all the hallmarks of an imposition, because of the demands they make; but they are also binding since they are of a procedural nature as a series of conversations (and not as a single talk), and they must give the patient the chance and time to become aware of his current overburdening and himself find a way to deal with it.

It now also emerges clearly what a rapid development patients have to go through in a few weeks, how much disquiet—viewed biographically—enters their life as they try to come to terms with a multitude of new questions that they never before asked themselves. It is a stressful time because, on the one hand, it is characterized by this flat-out dynamic of the own coming to terms, and on the other hand, it is distinguished by also having to wait (out): how the treatment is working, how the illness progresses, if it will end in a cure, disability, or even death. It is also an externally imposed ordeal, a time of waiting.

On What Does Each Side Base Its Decisions?

With this look at the patient's side and her perception of the situation, it dawns on us that there are more basal dimensions beyond being well informed and knowing a great deal that help us get through such situations in good shape. It is the personal convictions, the attitudes, the visions of a good life and biographically grounded experiences that now must prove themselves capable of bearing up under the load. As sociologists, we call these convictions and attitudes that are based on experience and testing *everyday knowledge*. This is also rational knowledge, whose relevance measures itself by being tested in daily life and not by some abstract rationality.

And yet, the uncertainties and doubts that we recognize, that we become aware of, have different temporal structures: we become conscious of some immediately, others only gradually, some we get used to over days, weeks, or months, yet others we never get used to; they remain anxiety-causing and overtaxing. Which doubts and uncertainties cause the most stress varies from person to person, which is what makes counseling patients so challenging.

In reacting to risks or dangers, people do not start from the same point: someone who has led a life of change and variability may cope better than someone who conceives of any change as an imposition. Also, someone who grasps dilemmas quickly and comprehensively has an advantage over someone who thinks that the absolute (in terms of the unambiguous) is always the best and can always be determined.

For the physician this signifies having to recognize what state the patient is in, which type she is, in order to be able to provide this person with appropriate counseling and support with respect to the problems and questions worrying her. In place of a knowledge transfer in the sense of informing a patient, it is my view that what matters more is negotiating values in terms of *what is important to you.* Thus, Bogner (2005, 2013) has detected a trend away from a pure knowledge communication toward value questions in many fields of modern medicine. In the era of a multiplicity of options in medicine as well, he speaks of a *deliberative medicine* (ibid.) that can no longer do anything less than make decision *jointly* with the patient.

To come to a fitting understanding in such a situation, it is important to find out from the patient how he or she perceives insecurity and uncertainty:

- How much imposition can you bear? How much uncertainty?
- Where do you need certainty and how can we support you in this?
- What if everything does not go the way we all hope it will and for which we do our best?
- What are your limits that you do not wish to exceed?
- What situation do you not want get into?

If physicians are ready and able to provide this kind of counseling and support, then they can also expect that the patients will step up to face these questions.

Conclusions

1. The principal societal tendency toward individualization also carries patients along and, through them, the system of medicine and consulting physicians. How physicians interact with this broad spectrum of individualized patients will (in the future) determine what image people form of medicine, based on whether doctors succeed in adeptly treating patients that differ in their approaches to life, values and convictions, sometimes even diametrically so.
2. Apart from this societal trend, it will be important to reflect in two ways on the dynamic of the constant flux of knowledge:
   - As a dynamic within the scientific sphere comparable to that in other areas of science
   - As impact assessment of this scientific knowledge on social practice, on the lifeworld of patients as the ones affected. In this, we must acknowledge medicine's special standing vis-à-vis other areas of science: on the one hand, because fewer groups are affected than in the case of systemic risks, such as environmental ones; on the other hand, however, because the consequentiality can be trenchant, since it typically involves life-threatening risks, as is the case with all potentially fatal illnesses.
3. With regard to reflecting on the rapid advances in medical knowledge, we need to be more mindful of the relationship between knowledge and non-knowledge. This is because a highly modern medicine not only produces knowledge that must be transmitted in the sense of informing patients, but also generates non-knowledge that calls for skillful handling as well. Similarly, medicine must take responsibility for the doubts, irritations, insecurities, and uncertainties that multiply in patients precisely because of the newly imparted knowledge.

4. This dealing with various forms of non-knowledge, the insecurities and uncertainties, has to be appropriately designed for being communicated. To that extent, the need for a narrative-based medicine, for a negotiated medicine, will remain as great as ever; the temporal challenges of making enough time for conversation will grow, not shrink.
5. For the physician, skillful assessment and communication of risks means she must be not only a good scientist, but also a good conversation partner who can engage with the patient on what is relevant to his everyday existence.

There is a definition of education (German: *Bildung*), of individual development (German: *Bildungsprozesse*), that fits all, experts and laypersons, doctors and patients alike: If we understand education as a process of building the self in response to the demands of (professional) life—in other words, as the non-linear development of people—then, like the socialization theorist Geulen (1987: 4) wrote, we can also grasp education as *changing an individual over time*. In this sense, we can hope that both sides, the doctor as well as the patient, will emerge changed from this mutually experienced situation.

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Part IV
The Technical Dimension

Chapter 18
Sustainable Risk Management in Technics, Robotics and Cyber-Security: An Introduction

Maximilian Roßmann and Tobias Hafner

When conducting an interdisciplinary discussion about the risks and opportunities of robotics and cyber-security, it quickly becomes obvious that this complex of themes will have an impact on all aspects of human life and society, as well as the sustainability of civilization. Opportunities and risks are linked closely. Nonetheless, humans grow up in a technology-driven world, so the goal of this reflection can only be defining responsibilities and measures for conscious and pragmatic risk management concerning application of innovative technology including robotics and cyber-security. This paper aims to reflect on some of the related concerns and fears also illustrated by cartoons:

- Is it fair to consider that robots will take over to a point coming close to enslavement of individuals? Will humanity lose the capacity of self-determination?
- With the power of technology, a minority of wealthy people might rule over the majority, since
  - The increasing digitalization enables total control of entire life areas.
  - The cutting of access to digitalization leads to irreversible dependency of other countries.
- "The dependency on fully automated functioning of technologies has risen to a point where the breakdown of those technologies (especially in energy supply) would lead to a crash of our society" (Luhmann 1998, p. 532). Exemplary

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concerns here include: Who can still read paper printed tourist maps in case of a network failure? Who will still be able to actively steer a car in 50 years?

- The need for security of people may lead to a state of passive "non-acting" and blocks any kind of innovation.
- Already defined user interfaces and ports may reduce other possible ways of interaction and therefore limit cultural diversity.
- Dissatisfaction and distrust may further grow and split societies, since:
  - Impact and risks of technology are not noticed and discussed in a reasonable way.
  - The discussions about impacts and risks of technology do not lead to pragmatically usable results for further development of technology.

It seems obvious that the sustainable treatment of technical risks requires responsibility. Especially in the area of the fourth industrial revolution—autonomous driving, artificial intelligence, data networks and smart cities—it seems clear that besides all ecological and financial dimensions, some cultural, political and even ethical fields might also be endangered through thoughtless innovation—or will at least change rapidly (Fig. 18.1).

The following thoughts give an overview of some basic ideas about sustainable risk management, particularly: risk-research, participatory risk assessment and resilience as strategy.

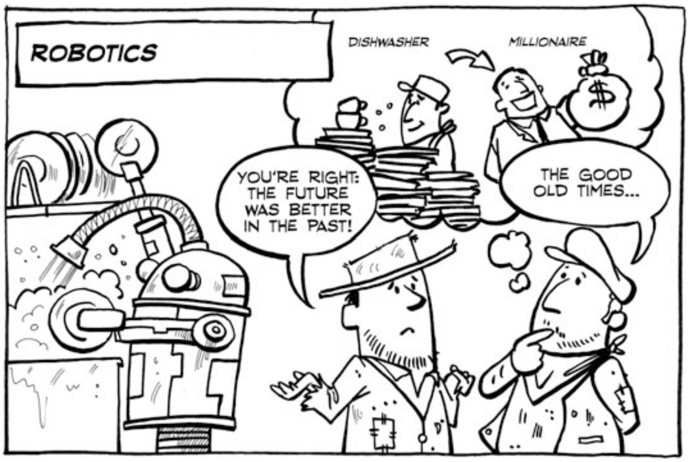

Fig. 18.1 "Act always so as to increase the number of perspectives." (Foerster 2002)— How will this be possible for the number of potential jobs and type of work for all social classes? (Cartoons based upon ideas of the authors and were illustrated by Lee Barlage)

Apocalypse and Utopia—Known and Unknown Risks in Sociotechnical Systems

To be able to attain maximum benefit to society from the fourth industrial revolution, consciousness must be raised about different risks of technology and its application in society. Obviously, there is always a risk of technical failures (see point e of the Memorandum, Part V of this book). This fact seems so constitutive for technology, that Luhmann defines technology as "a functioning simplification in the medium of causality" (1998, p. 524). To describe the risk of technical failures, it is necessary to study limits and premises in order to apprehend the probability of material, production, and application errors or improper model aspects. These inner risks must be researched in order to optimize innovative products, including its production and application to some acceptable level of security. For example, the risk of stolen or manipulated data can be reduced by good encryption, which requires reliable tools, discipline, the right working surface and correct application. For example, email encryption with "Pretty Good Privacy (PGP)" is worth nothing without some good password and a privately held private key. The success of so-called crypto-parties (www.cryptoparty.in) shows that learning basics of digital privacy and email encryption is nearly possible for everybody and that everyone can contribute. This illustrates that lifelong learning, open information and education are essential and possible.

Another type of risk comes from the under-determination of technology and its application. Technology is usually developed to solve a specific problem or have a certain function, but when transferred to another context in our complex society it might have unknown side effects, risks and opportunities. The introduction of the internet, for example, was originally created for military reasons. At that time, the impact on the economy, democracy, spare time, sports and culture in our day was beyond imagination.

Nowadays, the environmental rebound effect associated with autonomous driving can hardly be predicted. Emissions will decrease in total or car traffic will become more comfortable. Will this support sustainable development? At this time, who knows? We cannot predict the reaction of people facing an increasingly digital future. And the complexity rises enormously when people are faced with their own predictions and promises. We use the terms "Industry 4.0" and the "Internet of Things" to summarize, name and discuss unprecedented large-scale societal end economic expectations through the newest innovations of, for example, drones, autonomous driving and robots (BMBF 2014). We can only try to explore and assess the present perception of future evolvements, but we should also be aware that this might be pure speculation (e.g. Gransche 2015) .

The possibilities of risk-research reach from quantitative and normed long-time tests, statistics and simulations to the more qualitative kind through Delphi studies and expert interviews (ibid.). Time and money usually set strict limitations to research; therefore, it is important to decide which data, method and information make sense to deal with uncertainty (Heijungs and Huijbregts 2004).

In communicating the obtained results of this risk assessment, it is also appropriate to point out which effects are taken into account and which can be waived.

Another way to imagine possible technical development is through utopias and fictions that paint a plausible narrative of ongoing trends and technical ideologies. This kind of "non-scientific" research helps to visualize and experience a specific world of fears and benefits—in addition to all written statements and collected and calculated probabilities. This narrative reflection is helpful to identify and raise awareness for important risks and opportunities—moral terms and judgments attain more substance (e.g. MacIntyre 1995). *The Circle* by Dave Eggers, for example, shows how naive self-measurement, lack of privacy and illusion of transparency lead to voluntary subjection in a totalitarian system (Eggers 2014). Unrealizable promises and the good will of the protagonists show fatal results in the face of technical possibilities. Another popular example of this narrative reflection on the meaning of digitalization in everyday life is the series "black mirror" (Ströbele 2016). Watching fictional movies and reading fictional books should supplement the abstract discussions about digital ethics. There is also the question of how far we can create and influence the technical evolution. We must keep in mind that nearly every research paper and every organization will claim that their technological ideas will have positive effects on values like freedom, sustainability, happiness, security or real democracy—to advertise their specific research and products. These fictions of "present futures" have an impact on conceiving of reality and thought to the occurrence of "future present" (Esposito 2007). Taking the hermeneutic methods more into account in order to support orientation is now reflected as the "hermeneutic extension of Technology Assessment (TA)" (Grunwald 2015; Lösch et al. 2016).

This brief overview of technical risks shows that technological progress is always coupled with risk. But the opposite is also true in a technology-driven world. Deciding against a certain technological development could be an even greater risk. We live in cities that withstand the forces of nature through flood protection systems, lightning conductors and hospitals. We are used to travelling longer distances by train or car. And if we don't want to, the internet opens up opportunities to be linked with the "world" by making distances seem to disappear almost completely. In a first step, the precautionary principle could give good orientation (Callon 2011). This should not be confused with rejecting uncertain innovation. A general stop to the development of technology is out of the question, because the contemporary use of resources is not sustainable. We can only co-determine our future by participating in the worldwide competition in robotics and cyber-security. We must keep in mind that, for example, autonomous driving could lead to important advantages in energy usage, reduced traffic accidents, time efficiency and mobility of older people, and so on. However, we may not be blinded by these promises and forget the technical and sociotechnical effects and risks that need to be recognized and solved in a technical, responsible and democratic way. To sum up: there is no zero-risk plan in technological progress, but insisting on the status quo might be an even higher risk. Therefore, progress needs to be discussed in the context of all variations and alternative scenarios (Fig. 18.2).

Fig. 18.2 Our need for safety is a risk in itself? (Cartoons based upon ideas of the authors and were illustrated by Lee Barlage)

Participatory Risk Assessment

As mentioned above, no new technology comes without risks. For example, a flood protection dam can only be specified to some quantified hydrological risk. The availability of an advanced information systems enhances costs. Sustainable risk management takes on the challenge to identify acceptable trade-off of efforts and the acceptable risk. This is complicated by the fact that costs, benefits and other results of technological risks are not perceived and evaluated in the same way by the individual shareholders, decision-makers and engineers. On one hand, there are well-defined ways to calculate the objective risks of a technology. On the other hand, there is the subjective assessment of individuals that also depends on emotions, socialization, knowledge and other contexts. For the upcoming transformation to "Industry 4.0" and the "Internet of Things," ethical aspects like "freedom of choice and autonomy of users, privacy, transparency and fair distribution"must be taken seriously (BMBF 2015; cf. Bendel 2015). The ongoing discourses in applied ethics shall necessarily be mentioned here, but cannot be adequately discussed in this text (Fig. 18.3).

Following the principle of deliberative democracy and in the tradition of the enlightenment, decisions should be legitimated by respecting and weighting all available arguments, views and information in a rational discourse (Habermas 2008). Participation takes place on different levels—from participation events to discussions and information distribution by mass media. The primal aim of this process is to take the best decisions by respecting all relevant arguments. Different fears, different impressions and chances should be made available, transparent and understandable through the use of a broad portfolio of visualization, participation and communication—also through narratives like mentioned before. A communication offer should

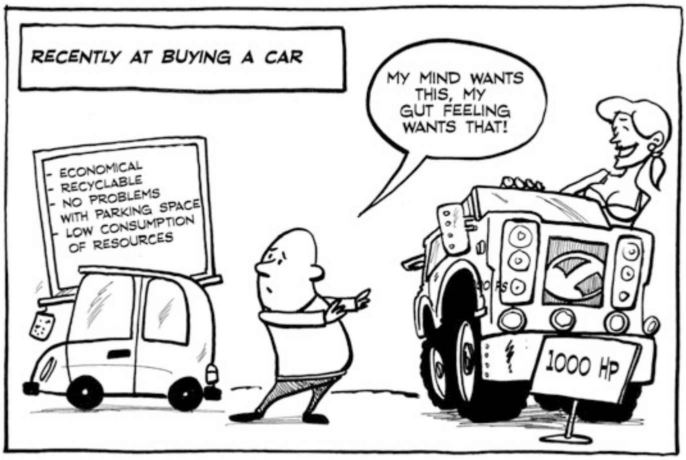

Fig. 18.3 Sustainable risk management needs decisions, but which one?—Mind or gut? (Cartoons based upon ideas of the authors and were illustrated by Lee Barlage)

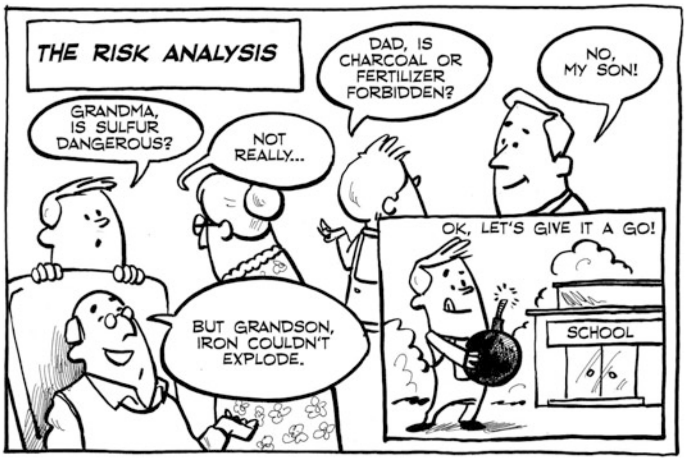

Fig. 18.4 Risks have to be analysed and communicated in their entirety. This is amongst others the claim of politics and science. Based on this, the society is able to take decisions. Rhetorical public participations about single isolated aspects are a gateway for lobbyists and complicate sustainable decisions (Cartoons based upon ideas of the authors and were illustrated by Lee Barlage)

be free of lobbying and at eye level with the peer group. This idea of deliberative democracy places high demands and thereby gives a normative orientation for the pragmatic realization within possible limits. The idea of participation is not only to take the best decisions possible, but—more pragmatically—the legitimization and stabilization of a decision through the process of decision-making (Luhmann 2013) (Fig. 18.4).

Other limiting factors are motivations and possibilities of laymen to deal with the diversity and complexity of technical risks in a way that enables well-founded opinion. Nonetheless, uncertainties of innovation still need to be taken into account and tolerated to some point. This can only be possible by the assumption of reliance in a good and independent science system. Authenticity, impartiality and correct presentation of facts and scientific knowledge are the existend foundation of ethical standards in science (Weber 2002), which legitimates the authority of scientists. As a result, scientists are also obliged to name and publish possibilities and limits of the further predictions, risk management and possible decisions. Because of the looming danger of diffusion of responsibility, the responsibilities and steps of the technical realization must be made obvious from the outset. Without possible reliance on the science system, the single citizen could feel overburdened rapidly. The rejection against technical innovation paired with a loss of shared perspective for the assessment of knowledge could split society. Risk awareness and a sense of responsibility are the premise for autonomous life in a technology-driven society—on the one hand, in the form of knowledge about possibilities and limits of personal influence and decision, and on the other hand, about the limits of forecasts.

Resilient Structures as Strategy for Facing Unknown Risks

Sustainable risk management aims to evaluate risks from the viewpoint of environmental, economic and societal long-term consequences and subsequently guard, perceive and multiply options for decision-making. Resilient structures in sociotechnical systems raise their stability and prevent the spreading of local shocks to the whole system. Shocks are enclosed inside designed so-called bulkheads. The system is designed to recognize failures, repair and—at best—help to optimize the system. For example, a signal error inside a cloud network should not influence the control and braking systems of an autonomous car—neither should a system failure in one particular car spread into the whole vehicle fleet. The same risk can also be discussed for autonomous planes with the slight difference that a plane needs to land safely when its communication system fails. New knowledge about the sociotechnical system can be learned out of a shock—either from the position of an external observer, or by installing a self-learning system—which then could also cause other problems. Resilient systems offer diversity of options that makes it possible to reinstate normal working status despite unknown errors and shocks.

In this sense, democracy and the freedom of action can also be seen as a higher structure of sociotechnical resilience. Therefore the conditions of democratic elections, free press, independent judgment, free research, education and individual judgment must be guarded in the wake of the fourth industrialization—through data security, data economy, independent media infrastructure, sustainable labour market policy, digital literacy and a respectful trade-off of technical monitoring, paternalism and individual freedom. In a systemic view, it is important to create a gentle feedback loop between actors who cause risky action and the results of their

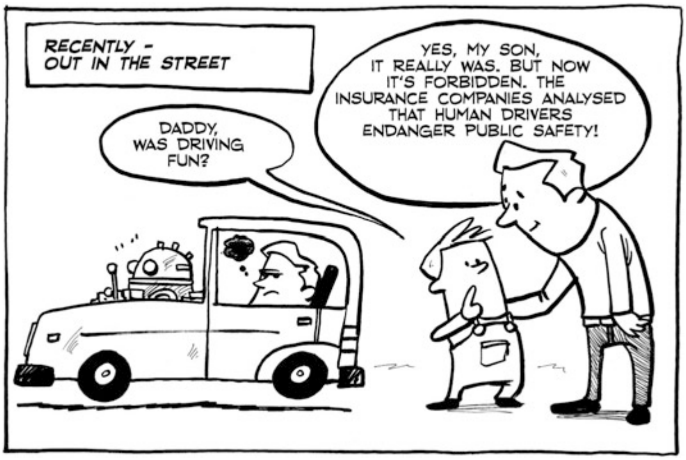

Fig. 18.5 How do we want to live?—Through which occupations do human beings define themselves? Do we want to automate processes that may represent "quality of life"? (Cartoons based upon ideas of the authors and were illustrated by Lee Barlage)

actions. The cyber-security attack against the German parliament demonstrated the importance of this policy. Further, the economic costs of stolen data show profit-orientated organizations the importance of cyber-security. It is often the lack of awareness and cognitive feedback that causes a lack of motivation to take digital challenges seriously. In order to motivate people, researchers, politicians and organizations to change, we may not just claim, but we should create the feedback, for example, in the form of publishing evaluations, stories, examples of good practice or limited technical access for bad security systems like missing virtual private networks (VPNs), missing encryption and signatures or bad passwords. In the end, no machine can take the responsibility from us to decide how we want to live (Fig. 18.5).

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Chapter 19
Complexity, Risk, and Technoscience

Klaus Mainzer

Key Messages

The global problems of mankind (e.g., energy, mobility, urbanization, nutrition, financial markets, communication) are a cross-over to specialized disciplines of science and need interdisciplinary studies in systems science and technoscience (1). In sociotechnical systems, information and communication technology (ICT) is growing together with societal infrastructures (e.g., smart grids, smart cities), in order to handle the complexity of human civilization (2). In the age of big data, ICT promises support of knowledge sharing through global online participation. However, big data technologies only deliver technical support, not competence of interdisciplinary problem-solving. The increasing complexity of our civilization needs reflection on the foundations and laws of systems dynamics in order to guarantee safety and reliability, which is considered in Chap. 3.

Globalization and Systems Dynamics

In the age of globalization, the Earth system grows together with human civilization. Climate and ecological systems can no longer be separated from human civilization, but depend on industrial growth and energy policies (Fig. 19.1). Global communication networks and infrastructures as well as financial dependencies of banks and states are driven by nonlinear dynamics of complex systems. One of the main insights of nonlinear dynamics is the emergence of systemic risks which are caused by the interactions of many factors and players in the whole system of Earth.

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The emergence of systemic risks from complex systems dynamics is a challenge for control tasks in engineering sciences as well as regulation and governance in social systems. We need modeling in systems science with early warning systems in the technical and natural sciences as well as economics and politics. In higher education, the awareness of global networks must be supported by interdisciplinary courses of systems science. Systems science offers a common language of natural, engineering, economic, and social sciences which is necessary to communicate with different disciplinary backgrounds of education.

Interdisciplinary courses of systems science must start with basic concepts of modeling: Models are formal descriptions of systems in different sciences. They refer in particular to natural systems in astronomy (e.g., planetary systems), physics (e.g., atomic systems), chemistry (e.g., molecular bonds), and biology (e.g., cellular networks), but also to social systems in economics (e.g., financial markets), sociology (e.g., social networks), and political science (e.g., administrative organizations). When engineers analyze a technical system to be controlled or optimized, they also use a mathematical model. In mathematical analysis, engineers can build a model of the system as a hypothesis of how the system should work, or try to estimate how an unforeseeable event could affect the system. Examples are extreme events and risks emerging in complex systems. Similarly, in control of a system, engineers can try out different control approaches in simulations. Simulations are often represented by computer programs and tested on computers. In the natural sciences, the validity of models is tested by derived explanations or predictions which are confirmed or falsified by observations, measurements and experiments. A hypothetical model is a more or less appropriate mapping of reality.

A *mathematical model* usually describes a system by a set of variables and a set of equations that establish relationships between the variables (Gershenfeld 1998, Mainzer 2007a, Yang 2008). A *dynamical system* is characterized by its elements and

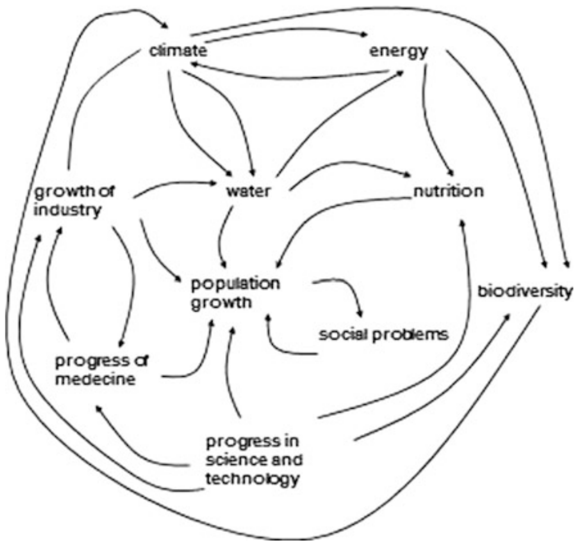

Fig. 19.1 Nonlinear dynamics of the Earth system and human civilization

the time-dependent development of their states. The *states* can refer to moving planets, molecules in a gas, gene expressions of proteins in cells, excitation of neurons in a neural net, nutrition of populations in an ecological system, or products in a market system. The *dynamics* of a system, i.e., the change of system states depending on time, can be mathematically described, for example, by time-dependent differential equations. In a more intuitive way, a conservative system is "closed" with respect to external influences and only determined by its intrinsic dynamics. A dissipative system can be considered to be "open" to external influences, e.g., air or other material friction forces. Models of conservative and dissipative systems can also be applied in ecology and economics. In higher education, it is necessary to illustrate basic concepts of systems science by intuitive examples of application:

Case Study: Conservative and Dissipative Systems in Ecology

At the beginning of the twentieth century, fishermen in the Adriatic Sea observed a periodic change of numbers in fish populations. These oscillations are caused by the interaction between predator and prey fish. If the predators eat too many prey fish, the number of prey fish and then the number of predators decreases. The result is that the number of prey fish increases, which then leads to an increase in the number of predators. Thus, a cyclic change of both populations occurs. In 1925, the Italian mathematicians Lotka (1956) and Volterra suggested a dynamical model to describe the prey and predator system. Each *state* of the model is determined by the numbers of prey fish and the number of predator fish. So the *state space* of the model is represented by a two-dimensional Euclidean plane with a coordinate for prey fish and a coordinate for predator fish. The observations, over time, of the two populations describe a dotted line in the plane. Births and deaths change the coordinates by integers, a few at a time. To apply continuous dynamics, the dotted lines must be idealized into continuous curves. Obviously, the *Lotka-Volterra model* is closed to other external influences of, e.g., temperature or pollution of the sea. If these external forces of "ecological friction" were added to the model, its dynamics would change the cyclic behaviour.

Case Study: Conservative and Dissipative Systems in Economics

In 1967, the economist Goodwin proposed a conservative dynamical model to make the nineteenth-century idea of class struggle in a society mathematically precise (cf. Goodwin 1990, Mainzer 2007b). He considered an economy consisting of workers and capitalists. Workers spend all their income on consumption, while capitalists save all their income. Goodwin used a somewhat modified predator-prey model of Lotka and Volterra. This *conservative model* supports the idea that a capitalist economy is permanently oscillating. Obviously it is superficial, because it does not refer directly to the functional income shares of capitalists and workers or to their population size. But it is mainly its conservative character that makes Goodwin's model seem economically unrealistic. Thus, the model has been made more realistic by the assumption of "*economic friction*". In reality, an economic system cannot be considered as isolated from other dynamical systems. An economic model of coupled oscillatory systems is provided by international trade. In other cases, economic systems are influenced by political interventions. We will come back to these examples later on.

The Lotka-Volterra equations are a simple, but still nonlinear formal system which is fine for educational tasks. Students learn to model the interaction of prey and predators in zoology as well as economics. Modeling in this way is a top-down procedure from mathematical equations to applications by appropriate interpretations of variables. In a bottom-up approach, we start with a sequence of measurements and ask what the data themselves can tell us about the laws of dynamics. Sequences of data are called *times series*. Time series analysis is used to find types of appropriate equations fitting the data, or to compare the predictions of mathematical models to measurements made in the field of research.

In an ideal case, *time-series analysis* delivers a computer program providing a mathematical model fitting the measured data. But these data-generated models have a severe shortcoming, because they work without any understanding of the physical system. In practice, model building is combined with times-series analysis. Model building is based on knowledge of a physical system, while time-series analysis can be used to detect features of a system, inspiring model building.

For students, it is often inspiring and motivating to learn more about the historical context of scientific discoveries and developments. During the centuries of classical physics, the universe was considered a deterministic and conservative system. A system is said to be *deterministic* when future events are causally set by past events. The astronomer and mathematician P. S. Laplace assumed the total computability and predictability of nature if all natural laws and initial states of celestial bodies are well known. The Laplacean spirit expressed the belief of philosophers in determinism and computability of the world during the eighteenth and nineteenth centuries. In this historical period, mechanics was a universal paradigm of research. Mechanical machines dominated the first period of industrialization. Laplace was at least right about linear and conservative dynamical systems. In general, a *linear relation* means that the rate of change in a system is proportional to its cause: Small changes cause small effects while large changes cause large effects.

At the end of the nineteenth century, H. Poincaré discovered that celestial mechanics is not a completely computable clockwork, even if it is considered a deterministic and conservative system. The mutual gravitational interactions of more than two celestial bodies (*many-bodies-problem*) can be illustrated by causal feedback loops analytically represented by nonlinear equations which are sensible with respect to tiny perturbations. Causes and effects are no longer proportional:

Tiny deviations in digits behind the decimal point of measurement data may lead to completely different forecasts. This is the reason why attempts to forecast weather fail in an unstable and chaotic situation. In principle, the wing of a butterfly may cause a global change of development (*butterfly effect*). The butterfly effect is an immensely important insight for students, in order to understand the nonlinear dynamics in nature, economics, and society.

Typical phenomena of our world, such as weather, climate, the economy, and daily life, are much too complex for a simple deterministic description to exist. Even if there is no doubt about the deterministic evolution of, e.g., the atmosphere, the current state whose knowledge would be needed for a deterministic prediction contains too many variables in order to be measurable with sufficient accuracy. Hence, our knowledge does not usually suffice for a deterministic model. Now, in higher education, statistics and probability theory come in. They also deliver basic knowledge for interdisciplinary modeling in systems science.

Actually, very often a stochastic approach is more situated. Ignoring the unobservable details of a complex system, we accept a *lack of knowledge*. Depending on the unobserved details, the observable part may evolve in different ways. However, if we assume a given probability distribution for the unobserved details, then the different evolutions of the observables also appear with specific probabilities. Thus, the lack of knowledge about the system prevents us from deterministic predictions, but allows us to assign probabilities to the different possible future states. It is the task of a time series analysis to extract the necessary information from past data. Again, in higher education, we should support interdisciplinary studies by intuitive examples:

Example: Power Laws and Risks

In the simplest case of statistical distribution functions, a *Gaussian distribution* has the well-known shape of a clock with exponential tails situated symmetrically to the far left and right of the peak value. Extreme events (e.g., disasters, tsunamis, pandemics, worst case of nuclear power plants) occur in the tails of the probability distributions (Embrechts et al. 2003). Contrary to the Gaussian distribution, probabilistic functions $p(x)$ of heavy tails with extreme fluctuations are mathematically characterized by *power laws*, e.g., $p(x) \sim x^{-\alpha}$ with $\alpha > 0$. Power laws possess scale invariance corresponding to the (at least statistical) self-similarity of their time series of data. Mathematically, this property can be expressed as $p(bx) = b^{-\alpha}p(x)$, meaning that the change of variable x to bx results in a scaling factor independent of x while the shape of distribution p is conserved. So, power laws represent *scale-free* complex systems. The Gutenberg-Richter size distribution of earthquakes is a typical example of natural sciences. Historically, Pareto's distribution law of wealth was the first power law in the social sciences with a fraction of people presumably several times wealthier than the mass of a nation (Mainzer 2007b).

An important part of the modeling process is the *evaluation of an acquired model*. How do we know whether a mathematical model describes the system well? This is not an easy question to answer. We must become aware of these methodological needs and failures. Usually, the engineer has a set of measurements from the system which are used in creating the model. Then, if the model was built well, the model will adequately show the relations between system variables for the measurements at hand. The question then becomes: How do we know that the measurement data is a representative set of possible values? Does the model describe well the properties of the system between the measurement data (interpolation)? Does the model describe well events outside the measurement data (extrapolation)?

The mathematical rigor and numerical precision of risk management and asset-pricing tools in economy has a tendency to conceal the weakness of models and their assumptions to those who have not developed them and do not know the potential weakness of the assumptions. Even practitioners in economy, finance, or even medicine are often not aware of the conditions and limits of their applied models. In the last financial crisis of 2008, the failings of so-called experts were obvious.

Models are only approximations to the real world dynamics and partially built upon *idealized assumptions*. A typical example is the belief in normal distribution of asset price changes completely neglecting the importance of extreme events. Considerable progress has been made by moving to more sensitive models with *fat-tailed Lévy processes* (Mandelbrot and Hudson 2004, Mainzer 2013). Of course, such models better capture the intrinsic volatility of markets. But they might again contribute to enhancing the control illusion of the naïve user.

Therefore, market participants and regulators have to become more sensitive towards the potential weakness of risk management models. Since there is not only one true model, robustness should be a key concern. *Model uncertainty* should be taken into account by applying more than a single model. For example, one could rely on probabilistic procedures that cover a whole class of specific models. The theory of robust control provides a toolbox of techniques that could be applied for this purpose.

In macroeconomics, data mining is often driven by the pre-analytic belief in the validity of certain models which should justify *political* or *ideological opinions*. The political belief in deregulation of the 1990s is a typical example. Rather than misusing statistics as a means to illustrate these beliefs, the goal should be to put theoretical models to scientific tests like in the natural sciences.

A chain of specification tests and estimated statistical models for simultaneous systems would provide a benchmark for the tests of models based on economic behavior. Significant and robust relations within a simultaneous system would provide empirical regularities that one would attempt to explain, while the quality of fit of the statistical benchmark would offer a confidence for more ambitious models. Models that do not reproduce (even) approximately the quality of the fit of statistical models would have to be rejected. This methodological criterion also has an aspect of *ethical responsibility* of researchers: Economic policy models should be theoretically and empirically sound. Economists should avoid giving policy recommendations on the base of models with a weak empirical grounding and should, to the extent possible, make clear to the public how strong the support of the data is for their models and the conclusions drawn from them.

A neglected area of methodology is the degree of connectivity and its interplay with the *stability of the complex system*. For supervision, one must learn to analyze the network aspects of the financial system, collect appropriate data, define measures of connectivity and perform macro stress testing at the system level. In this way, new measures of financial fragility would be obtained. This would also require a new area of accompanying research and education that looks at agent-based models of the financial system, performs scenario analyses, and develops aggregate risk measures. Network theory and the theory of self-organized criticality of highly connected systems would be appropriate starting points (Scheinkman and Woodford 2001, Mainzer 2013).

Such scientific analysis must be supported by more practical consequences. The hedge fund market is still widely unregulated. The interplay between *connectivity*, *leverage*, and *system risks* needs to be investigated at the whole level. It is highly likely that extreme leverage levels of interconnected institutions impose dangerous social risks on the public.

On the macroeconomic level, it would be desirable to develop *early warning schemes* that indicate the formation of bubbles. Combinations of indicators with time series techniques could be helpful in detecting deviations of financial or other prices from their long-run averages. Indication of structural change would be a sign of changes of the behavior of market participants of a bubble-type nature (McCauley 2004).

Obviously, there is no single causal model as definitive mapping of reality. But that does not mean a complete denial of mathematical tools and models. We have to consider whole *classes of possible stochastic models* with different weights. They must be combined with a *data-driven methodology* and insights in the factual human behavior and its diversity. Therefore, *psychological* and *sociological case studies* of human behavior under risk conditions (e.g., stakeholders at stock markets, pilots in aircrafts, surgeons in risk surgeries) are necessary. For students of economics, trained in the traditional doctrines and dogmas of economic rationality, it is important to become aware of bounded rationality. In experimental economics, decision behavior is already simulated under laboratorial conditions. Even *philosophical ethics* can no longer only argue with arm-chaired considerations and a priori principles, but must relate to empirical observations of factual decision behavior. That is done in the new approaches of experimental ethics. We argue for this kind of *interdisciplinary methodology* which opens new avenues for mathematical modeling in science. In this case, robust stochastic tools are useful, because they are used under restricted conditions and with sensibility for the permanent model ambiguity.

Information and Communication Technology (ICT) and Sociotechnical Systems

Thus, the complex sociotechnical challenges of human civilization can no longer be handled without interdisciplinary education of engineering sciences with social sciences and humanities. Examples are efficient concepts of traffic and mobility, complex and intelligent energy networks (e.g., smart grids), urban infrastructures, and megacities which are sometimes called cyber-physical systems. The success of large-scale infrastructure technologies sensitively depends on the societal, political, and social framework. Therefore, we need integrated research and education of engineering and social sciences with humanities. Integrated research and education leads to sustainable innovation.

Reminder of the Internet as Complex Dynamical System

In a technical co-evolution, global information and communication networks are emerging with surprising similarity to self-organizing neural networks of the human brain. The increasing complexity of the World Wide Web (www) needs intelligent strategies of information retrieval and learning algorithms simulating the synaptic plasticity of a brain (Berners-Lee 1999). The Internet links computers and other telecommunication devices. At the router level, the nodes are the routers, and the edges are their physical connections. At the interdomain level, each domain of hundreds of routers is represented by a single node with at least one route as connection with other nodes. At both levels, the degree distribution follows *a power law of scale-free network* which can be compared with cellular networks in biology. Measurements of the clustering coefficient deliver values differing from random networks and significant clusters. The average paths at the domain level and the router level indicate the small-world property.

Smart Grids as Complex Dynamical Systems

Global information networks are growing together with societal infrastructure. Current examples are complex smart grids of energy. Many energy providers of central generators and decentralized renewable energy resources lead to power delivery networks with increasing complexity. Smart grids mean the integration of the power delivery infrastructure with a unified communication and control network, in order to provide the right information to the right entity at the right time to take the right action. It is a complex information, supply, and delivery system, minimizing losses, and is self-healing and self-organizing (European Technology Platform Smart Grids: http://ec.europa.eu/rsearch/energy//pdf/smart-grids_en.pdf).

Smart grids are complex organizations of networks regulating, distributing, storing, and generating electrical power. There are amazing analogies in natural and technical networks which should be analyzed by students in interdisciplinary studies. The structure and dynamics of smart grids have surprising similarity with complex protein networks in systems biology regulating the energy supply of a cell. The intelligence of smart grids increases with their ability of self-organizing information processing for optimal energy supply. In communication networks, appropriate prices of optimal energy supply could be automatically negotiated by *virtual agents*. In smart grids, the energy system grows together with ICT in a kind of symbiosis.

Example: Automatic Negotiations of Virtual Agents

A well-known problem with wind mills and solar cells is the unpredictability of production depending on changing weather conditions. In intelligent networks, the need can be locally satisfied by virtual negotiations. A model assumes the following rules and conditions of negotiating virtual agents (Fig. 19.2: Wedde et al. 2008):

1. The need for renewable energy can be satisfied either in a local regional subnet or between subnets. Reserve capacity is used only in exceptional cases.
2. Energy must be adjusted between different voltage levels or different groups of balance on the same level.
3. Producers are also consumers and vice versa.
4. Negotiations on local energy supply are automatically performed by agents of producers and agents of consumers. They are coordinated by balance group managers working in parallel and synchronized in time on each level.
5. In the model, the negotiations start in periods of 0.5 s. The negotiations as well as the distribution of negotiated energy are expected to be finished before the end of each period. Bids and offers arriving in the meantime are negotiated in the next period.
6. At the beginning of each period, each client decides whether he/she takes part as producer or consumer or not. He/she decides with respect to the current difference between the states of demand and production.
7. Bids and offers occur in frameworks of prices with respect to amortization and maintenance. In the model, there are no long-range contracts or discounts for big and future acquisitions which can occur in reality.

The algorithm of negotiation assumes a framework of prices for each level of negotiation. Each balance group manager on each level accomplishes a cycle of coordination of 10 turns. Each turn takes 1 ms. After each turn, the balance managers test in parallel whether bids and offers are sufficiently similar. If they are sufficiently similar, a contract between the partners is concluded. A fixed amount is added until the stock or demand is spent. The negotiation strategies of a client are

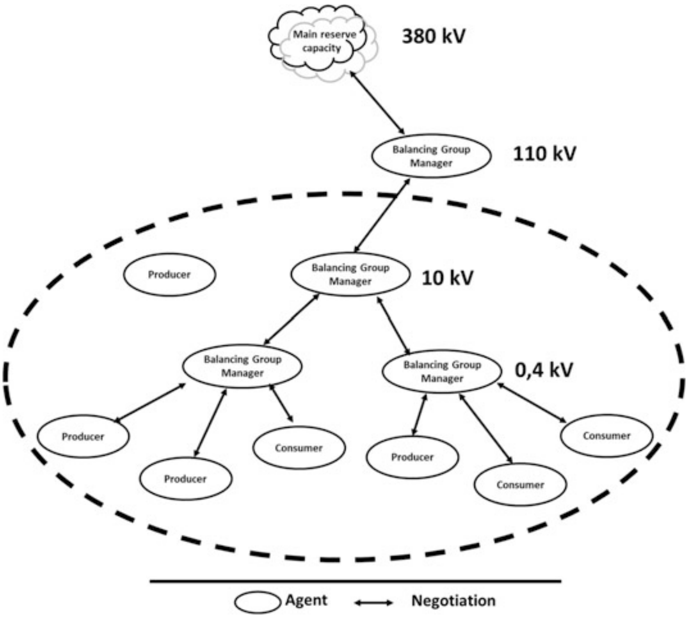

Fig. 19.2 Smart grid with circles of balance and assigned agents

given by an opening bid, an opening offer, and parameters of priority and strategy. After *n* turns, the unsatisfied agents adapt their bids and offers with respect to an exponential law of behavior which is useful to realize a fast convergence between bids and offers. The negotiated price is the arithmetic mean between similar values. Unsatisfied clients are passed on to the next level of negotiation. On this level, the framework of prices is reduced to a constant relation. The needs and interests of finally unsatisfied clients are satisfied by a central reserve capacity (but with very bad prices).

Short-term fluctuations of consumption in the ms to min interval, which are affected by sudden and unpredicted local or regional causes, are not only observed as perturbations in households, but they can endanger the stability of large transport networks. In our model, these critical situations are avoided by the activation of agents after each cycle of negotiation. It is assumed that many electrical appliances (e.g., refrigerator, boiler) can temporarily work without power or with a battery. In these cases, reserve energy can be used for other purposes. The reserve energy is more competitive than the traditional one, because of low costs of transport and storage in the network. Additionally, the balance managers act on each level in parallel in the shortest time.

In this way, smart grids with integrated communication systems accomplish a dynamical regulation of energy supply. They are examples of large and complex real-time systems according to the principles of cyber-physical systems (Lee 2008). Traditionally, reserve energy which is used to balance peaks of consumption or voltage drops is stored by large power plants. The model of Fig. 19.1 solves the problem by dynamically reacting strategies of negotiation in proper time. The main problem of changing to renewable energies is the great number of constraints depending on questions of functionality as well a security, reliability, temporary availability, tolerance of failures, and adaptability. Cyber-physical systems with local and bottom-up structures are the best answer to the increasing complexity of supply and communication systems (Cyber-Physical Systems 2008). In a technical co-evolution, mankind is growing together with these technical infrastructures in a kind of superorganism.

Example: Internet of Things

Increasing computational power and acceleration of communication need improved consumption of energy, better batteries, miniaturization of appliances, and refinement of display and sensor technology (Weiser 1991, Hansmann 2001). Under these conditions, intelligent functions can be distributed in a complex network with many multimedia terminals. Therefore, the paradigm shift from concentrated computer power in a single computer to distributed computer functions in many functional devices was called *ubiquitous computing*. In a next step, together with satellite technology and global positioning systems (GPS), electronically connected societies are transformed into cyber-physical systems. They are a kind of symbiosis of man, society, and machine. Communication is not only realized between human partners with natural languages, but with the things of our world. Cyber-physical systems also mean a transformation into an Internet of Things. Things in the Internet are equipped with sensors and intelligent computer functions enabling them to communicate with one another.

A commercial application is the concept of Industry 4.0: Industry 1.0 was the industry of steam engines. Industry 2.0 was the world of Henry Ford with assembly lines of production, as in the car industry. In Industry 3.0, industrial robots were additionally applied at an assembly line, replacing human routines by automata. But, Industry 4.0 means the Internet of Things in industry. Work pieces are communicating with their work bench, transport systems, logistics, and marketing, in order to organize their production and sale. On-demand production and tailored design according to individual preferences will become the standard procedure in Industry 4.0.

Complexity and Big Data Technology

The increasing complexity and globalization of humankind is connected with a huge amount of information and communication networks (Mainzer 2014). There are two main drivers of ICT: *Moore's law* of increasing computational capacity and *big data*. For many decades, it has been verified that, according to Moore's law, the computational capacity of computers is doubled in periods of 18 months with increasing miniaturization and price-reduction of computational devices. In the meantime, the computational speed of supercomputers is measured in petaflops (peta = 10^{15}, flop = floating point). Big data means a giant mass of data which is also measured in peta size. Google, for example, processes 24 petabytes per day, i.e., six thousand times the data stored in the US library. Beyond transactional data stored in relational databases, there are less structured data of weblogs, social media, email, sensors, and photographs that can be mined for useful information. Thus, Big Data means an amorphous and messy mass of structuralized, less structuralized, and unstructuralized data which cannot be stored and processed by traditional databases and algorithms (Mayer-Schönberger and Cukier 2013).

New algorithms like *MapReduce* (which is used by Google's search engine) or *Hadoop* (programmed in Java) are applied with great success to find correlations and patterns in a data mass. MapReduce uses the functions "*map*" and "*reduce*" which are well-known in functional programming. The function "*map*" separates a messy data mass in several partial packages of data which are mined in parallel computation. The function "*reduce*" integrates the partial results of data mining in a final result. Thus, big data algorithms process all data in a messy data mass, in order to compute correlations and to derive predictions. That is quite different to classical search procedures of statistics using representative samples which are extrapolated for predicting. Further on, a main difference to traditional search procedures is the use of metadata. Metadata allows complete ignorance of meaning and contents of messages and data. In the case of e-mails, only the sender and receiver must be known. Signals of mobile phones and GPS data are also used as metadata, in order to localize the changing positions of persons. In 2009, Google could predict the emergence of an epidemic many weeks before public health officials could react by contacting physicians' offices and extrapolating statistical samples. The Google search machine only computed correlations in changing behavioral patterns of people. Thus, big data technology is not interested in artificial intelligence, but only the application of rapid algorithms to huge data masses, in order to compute probabilities of correlations.

In business and markets, it makes sense to get quick information about probabilistic correlations and tendencies without knowing the causal reasons. Big data algorithms can calculate the probabilistic profile of products and preferences which can be used for improving profit expectation. In economics, big data opens new avenues for chains of economic values. People may earn money by selling or loaning data sets, by offering their skills and know-how as data experts, or as entrepreneurs with new business ideas of data application. Big data is the raw oil of the future, but with unlimited possibilities of recycling. In different contexts, data sets can be used for different predictions in different fields of application. But big data is about *what*, not *why*. This is an important point which must be discussed with *students in interdisciplinary courses*.

Example: Big Data Correlations in Medicine

Big data technology can be used to make better diagnostic decisions when caring for premature babies. The software processes all patient data in real time in parallel measuring of several quantities in 16 different data streams, such as heart rate, respiration rate, temperature, blood pressure, and blood oxygen level, which together amount to around 1260 data points per second. The system uses parallel computing to detect tiny changes of health states of premature babies. By that, it was possible to predict an infection 24 h before symptoms appear. Actually, at that point of time, very constant vital signs are detected prior to a serious infection. The software tells *what*, not *why*. What big data indicates is a correlation of all data, not causality. Nevertheless, big data saves lives as an early warning system.

However, there are clear *limits of big data technology in education* and elsewhere. Big data mining can only detect correlations in huge data sets to predict more or less probable trends. Big data production is not sufficient for good science, business, and governance. But why should we worry about causal laws, when rapid search machines find answers and solutions, before we discover and understand their reasons? In a century of extreme acceleration and progress, only quick reactions and decisions seem to be successful. Therefore, Chris Anderson, former editor-in-chief of the magazine *Wired*, claimed "*the end of theory*". Big data makes scientific methods obsolete. But his message of the "end of theory" is not only stupid, but even a dangerous technological ideology:

During the last global financial crisis in 2008, many people used financial instruments promising rapid profits without understanding the conditions and foundations of their mathematical foundations. They ended in ruin and catastrophes. In medicine, data correlations without causal explanations deliver no understanding of diseases (e.g., cancer). If you ever have seen the complex molecular interactions in a cell through a microscope, then you obtain high respect for the complex mechanisms and laws of life which must be understood for sustainable healing. Big data itself is founded on *theory* in computer science. We must understand the logical and mathematical foundations of algorithms and formal systems, in order to recognize the possibilities, but also the limits of software engineering.

Data correlations without philosophy and systems theory deliver no understanding of complex problems. In short: theories without data are obviously *empty*, but big data without systems theory and philosophy is *blind*. Technoscience aims at sociotechnical systems. However, without knowledge of complex systems science, sociotechnical systems cannot be governed.

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Chapter 20
Risking the Future of Automotive Industry

Gernot Spiegelberg

Context Statement

Changes in lifestyle, electrification, autonomous driving and car sharing open up both opportunities and risks, depending on the way we deal with such trends. In this context combined with the trend to digitization the business in automotive may change extremely. The new product may not be the car itself but more services like mobility as a service (MaaS). In consequence the shape of the car, the lifecycle and the way of development and production will change with big influence to related industries. Who will be the big players in this scenario?

What May Change in the Future?

There are many things that will change in the future. Global megatrends will show us in which direction the world will move. Sustainability in using the resources of our home base Earth by generating renewable energy, urbanization with growing population especially in Asia, and demographic change requires new understanding of daily ways of living.

People are changing their behavior regarding their work–lifestyle balance and their focus on what they want to spend their money on. A sharing economy may increase as people prefer to use services, but to have their own devices in private ownership. It has become increasingly important to live in an environment free of pollution, noise and traffic. Additionally, all of this mobility will play an important role, and people will want to travel with greater flexibility.

In this regard, new trends in automotive transport may help fulfill the requirements. In parallel, we discuss themes such as electrification, autonomous driving

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and car sharing as a mobility service. Each of these three will meet one of the requirements the global megatrends will create.

Electrification will be based on renewable energies generated by photovoltaics (sun), wind and waterpower. Also, car batteries may help to stabilize the power grid with bidirectional connection of the batteries while cars are parked. Consider that 50 cars connected to the grid may deliver a power peak of nearly one megawatt (by connection with 22 kW at charging point) and can be shared at the stock market (Spiegelberg 2009).

Traffic management to reduce traffic jams and a car-sharing economy focused on mobility as a service will have a deep impact on intercity traffic and the design thereof on a medium time scale (Fig. 20.1). Autonomous driving is a new trend in automotive development to substantially increase the performance of cars, and will support elderly people and the younger generation as well in their understanding of being mobile in the future.

All three mentioned themes seem to be interdependent, since each can be developed separately. However, the combination of these three may change significantly in terms of advantages for society and the environment; they may also rearrange the mobility behavior and the automotive business in parallel.

This may include opportunities, but risks as well, depending on the way we deal with this. Disruptive technologies and business cases are disruptive only to those who are not aware of them; they are not disruptive to those who have a strategy to create a new solution or new kind of business in this area.

Lifestyle 4.0 Will Require New Solutions

To deliver the best products industry has to produce, there must be a deep understanding of the requirements needed. The main focus should be on people's desire. This is not based only on the existing technology and evolution of products running the last hundred years. Furthermore, perhaps it doesn't fit the advertisement where companies show people what they should own as being a right or a commonly accepted part of the society. These kinds of products may meet the interests

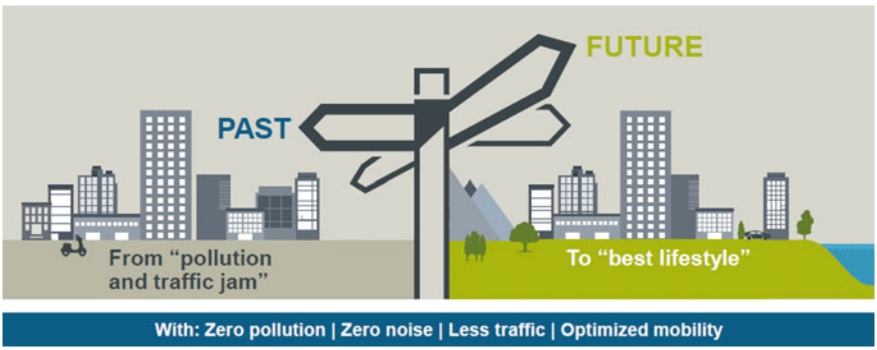

Fig. 20.1 Sustainable development of mobility: an anticipated scenario

of companies in maximizing their outcome more than the customers'. In a changing world, where the self-conception of lifestyle evolves, new technologies and new arrangements should create new products with an associated sustainable business plan for the medium and long run.

What Kind of Lifestyle May Evolve?

Human longevity has greatly increased over the last several decades, and people are living longer than ever before. Elderly people, the silver generation, need more and more support to manage their daily lives, because they want to stay mobile and self-determined as long as possible.

In parallel, the younger generation, Generation Y, wants to be connected at all times. Social media such as Facebook, Twitter and others are important, while entertainment, information and communication remain the main focus. More time is spent shopping in nice surroundings even though daily requirements for food and goods are not fulfilled. In a world where digitalization is growing, people can order goods via the internet. They do not have to be mobile themselves to obtain the required goods by delivery services.

In addition, the working environment begins to change. With the internet and a secure connection to one's company, much of work can be handled from a private home office. The information is traveling, not the person himself. This may be an advantage as it avoids travel in overfilled public transportation, loss of time in traffic jams and searching for a parking space.

What Does This Mean for Mobility as Part of Future Lifestyle?

In our daily lives, people must travel to accomplish tasks in business or to procure goods, but they really don't enjoy travel. On the other hand, people want to be flexible in the ability to travel anywhere when they want to be at that location personally to meet persons or places. Therefore, people want to avoid travelling when they must travel, but they want to have a convenient solution if they want to travel. Thus the situation could arise in which the question should not be "what does mobility of the future look like" but more "what will be the future of mobility".

It seems that one answer could be: the future of mobility is immobility (Fig. 20.2). This means avoiding travel whenever it is not really necessary. For this solution, a strictly new understanding for required technologies has to be found in the area of communication and digitization. Information will travel instead of the people themselves; live meetings and chatrooms, for example, are used for this today, and future technologies such as personal avatars may support this further.

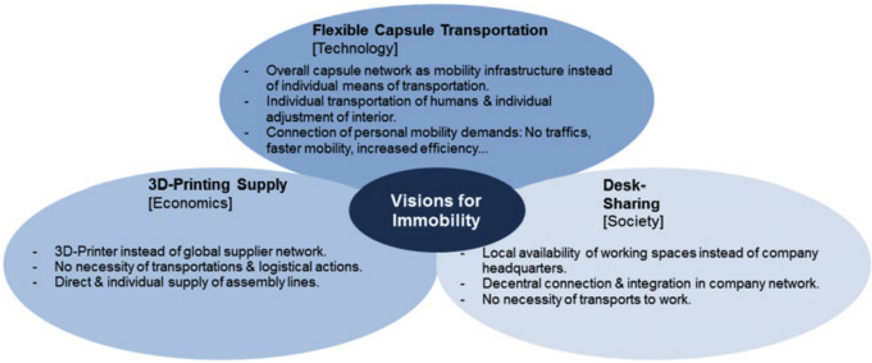

Fig. 20.2 Graphical representation of the vision for immobility

But what kind of mobility will meet the interest of the customer who wants to travel? Is it the behavior our society showed in the last 50 years based on the flexibility of private ownership of cars?

From Private Ownership to Mobility as a Service

Increasingly, elderly people want to stay mobile but aren't really able to control a car by themselves. It will be a matter of safety for them and other participants in traffic to give to these elderly people the best support to stay mobile without any danger. Autonomous driving will be a promising solution. The autonomous car will have the ability to transport elderly people to their desired destination without the passenger needing to manage traffic, traffic lights, pedestrians and parking procedures. The car will do all these tasks autonomously.

A different argument is made by the younger generation, Generation Y. It appears that more and more young folks decide not to get a driver license. The cost of a car is too high, and traffic density and parking problems in cities present considerable difficulties. Ownership of a car seems to be nonsense for them, and the joy of driving does not pertain to driving a car in a city. However, a key argument is the costs related to the time a car is used in private ownership. With an average of 15,000 to 18,000 km per year, the car is very often used less than 5% of its lifetime, but the owner must pay 100% the car costs including tax, insurance, tires and maintenance. And to park the car, an additional parking fee is necessary.

This leads to the trend of increased car sharing. However, the problem with driver licenses and parking spaces will always exist. The young driver can't do what he really prefers, i.e., being connected and communicating with friends or being entertained.

One solution may be to combine both previous arguments, doing away with private car ownership and develop flexibility in transportation, with autonomous cars delivered by a service provider. These cars will fetch the passenger whenever he wants and transport him wherever he wants to go. They will be included in combined traffic but with higher comfort than public transportation delivers today. And this will be managed by a service provider who delivers the best service in the transportation of passengers. He may read the time schedule of the customer from his personal digital assistant (PDA) and knows at what time the customer must be at what place, and will manage everything based on the personal profile, depending on how much comfort is required.

If this service will deliver more comfort and more functionality such as entertainment, information or free working time during travel for the same price, the customer will choose that option (Fig. 20.3).

However, this will then change plenty of things: todays relations between car manufacturers and customers will then be between the customer and the mobility service provider, who intends to maximize the relationship by delivering the best service at the lowest price. The risk for the original equipment manufacturer (OEM) could be in assuming the position of a Tier 1 supplier, i.e., member of a supply chain, supplying components directly to the OEM.

First, the new mobility provider would need fully autonomous fleets of cars. Therefore, a car must be able to act best in its environment. It can do this by several architectures: full functionality for autonomous driving inside the car, controlled only by the environment and its infrastructure, or a combination of both. To obtain this quickly and at low costs, citizens will not need to rely on governments to invest in infrastructure; they will find their own solutions as a combination (Fig. 20.4).

Furthermore, the car itself will change (Sulzmann et al. 2005, Spiegelberg 2008a, b). First, the total costs of ownership must be as low as possible. Cars equipped with a combustion engine will not fulfill this, as combustion engines represent high complexity with too much maintenance and limited fuel supply; pollution in cities will be an additional cost factor and disadvantage in the mid-term (Buitkamp et al. 2013).

Electric cars with a range of up to 100 km may fulfill the strategy of a mobility provider much better. Also, it is much easier to control an electric drivetrain with

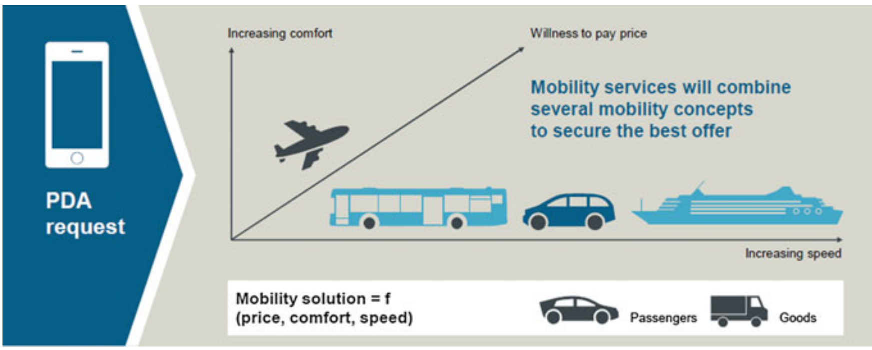

Fig. 20.3 Transportation managed by personal digital assistance

autonomous ability than a combustion engine drivetrain. It will be more similar to a robot, which will be connected to a cloud network and controlled by the mobility provider with the task of transporting customers from location A to B. An electric motor can also be integrated into wheels so that the concept of the car can change with better performance in packaging and interior space.

In this context, one may imagine a device which will be flat for reduced air resistance during high speeds and foldable for easier entrance and exit, and in parallel, transportation of the customer inside buildings to meet the entrance of a train or a plane, leaving in the back when the customer steps out of it. Such a device will be a smart autonomous agent in the Internet of Things for transportation, operated by the mobility provider and controlled via cloud connection. Again, here, the argument will count: more functionality at the same price will be an advantage (Fig. 20.5).

And there will be new requirements from the customer's point of view regarding service while he is being transported: entertainment, obtaining information and the ability to use the time for work. There may not be further need for "fun to drive" but

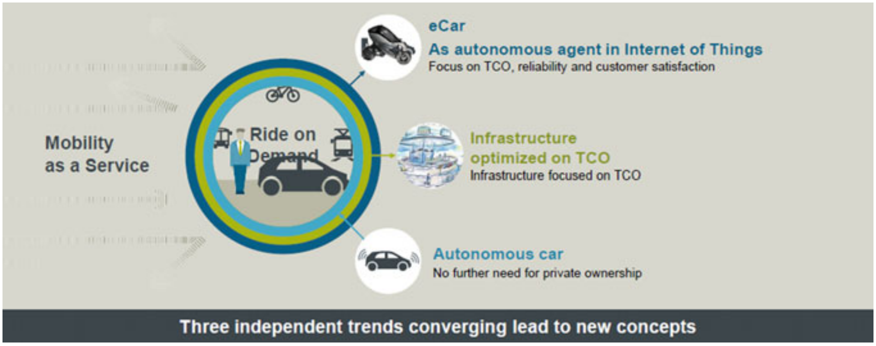

Fig. 20.4 The three trends leading to innovation in transportation

Fig. 20.5 Artist view of a fully automated car on the road (left) and in parking mode (right)

Fig. 20.6 Parameterized transportation seat, based on the personal profile of customers in the cloud, may fulfill the requirements of passengers in mobility as a service regarding body size, entertainment and connectivity

more "fun during transportation". For this, the customer wants to take all his personal belongings with him, but with the highest comfort, and this kind of comfort must be based on his personal profile stored in the cloud network (Mercep et al. 2013).

Digitization will help with connectivity to the cloud for providing entertainment and information. Solutions where the customer does not have to carry real devices may support a new way of service. The transportation device will be configured personally by software on demand upon purchase by the customer. Additional service will be provided by the transportation seat in which the passenger will travel. The passenger will receive the same surrounding in any of the devices in combined traffic, based on the contract with the mobility provider (Fig. 20.6).

In this case, it isn't important in which kind of car you are sitting but what kind of service you will get, similar to the situation in airlines, where it doesn't matter whether you are sitting in an Airbus or Boeing, but more with which airline you travel.

Design of Cities We Want to Live in

In fact, leaders of several large cities are attempting to optimize city design to improve the lifestyles of the inhabitants. Green areas without traffic jams, parking spaces, pollution and noise become increasingly relevant to them.

City leaders are attempting to avoid not only emissions and noise, but also the hassle of parking cars. Considering that most of the transportation of individual people via private cars equates to a vehicle use rate of 5%, greater efficiency can be achieved via the car-sharing option, which has a use rate of 70 to 80% of the vehicle's lifetime.

Much intercity territory could be regained with the advent of autonomous cars combined with mobility as a service. Only if the car is not in private ownership it can run from one customer to another and stay mobile instead of needing to park. This will result in future city leaders being great promoters of mobility as a service and receiving numerous advantages. Such advantages will include many fewer cars in the city for personal transportation and much lower parking space need. Also, and of note, based on the business and focus on total cost of ownership (TCO), mobility providers will make a change to electrical cars. Cities will become greener, and parking spaces will become areas dedicated to the wellness of the city's inhabitants (Fig. 20.7).

Opportunities in Design, Development, Manufacturing and Business of These Autonomous Agents in the Internet of Things

What does it mean for the established business of OEMs, their products, customer relationships, development, manufacturing and business?

First, as mentioned above, the concept of the transportation devices will change in that we will no longer not use the term "car". The "car" will become a compartment in which to carry people in comfort and with functionality defined by its interior equipment, capable of moving people from point A to point B autonomously. With this device, the dynamics of movement during transportation will not be felt while passengers are sitting inside doing other things, rather than controlling the movement of the car. They perhaps will not have any visual relation to the environment in which they are moving, but instead will be listening to entertainment or doing work. Therefore, the movement of the vehicle must be as smooth as possible, a completely different approach from the cars of today.

And the lifetime of the car will decrease substantially. Assuming these devices will be used 70 to 80% of their lifetime, they will not last as long as they do under the 5% use rate of today. Therefore, the vehicle's lifetime will decrease from 10–14 years to 2–3 years. This leads to a business and development process comparable to consumer electronics, but with increased requirements for safety and security (Reichelt et al. 2005).

Development processes must be extremely shortened to meet these goals. Simulation must be used much more to first develop the digital model of these devices, including their behavior and activity in the environment as an autonomous device based on software functionality (Schenk and Spiegelberg 2005). To hasten the development V-shape, the integration process must be eliminated as much as possible and must be based on a fundamental integration platform to obtain a faster time to market (Stähle et al. 2013). Also, the automation for production must be orchestrated in advance, with parallel simulation to manufacture the product in the shortest time and without failure.

In Fig. 20.8 the running process for Industry 4.0 should and will respect this.

Fig. 20.7 Artist view of cities transformed to cloud-based transportation concepts

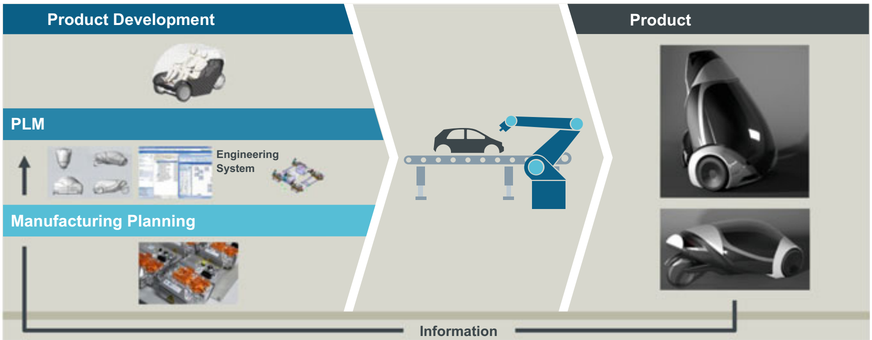

Fig. 20.8 Simulation will have an important role to decrease time to market of products

Last but not least, the device will have new abilities, including deep learning. With this, the car will learn its own orientation, activity and behavior in the environment, but also its disadvantage in some situations. This knowledge can be fed back to the development process and could be integrated into the next development phase to increase the performance of these devices. In this case, development will be done more in the virtual world than in the real world as it is today.

To play a significant role in this changing world of future mobility there is the question whether this process can be driven by migration or will be created by disruptive behavior of the actors. Will the established car manufacturer be able to change as much as needed and fast enough to meet with the requirements a service business will generate?

Will today's car manufacturer succeed with a bottom-up approach where he tries to defend existing business based on his branded cars by addition of service steps like car sharing up to mobility as a service where the customer relation is focused on the brand of the OEM? Or will a new service provider win an approach where the strategy begins top-down (Fig. 20.9), with the focus on a service-oriented customer relation with the clear understanding of what the customer really wants during transportation, with no history in building cars?

In this last case, cooperation between new partners could best fulfill this need, and every partner could do his very best. Without any history in car manufacturing and existing business in service stations for maintenance, these new partners will create and define a new concept of transportation device with performance, meeting the lowest TCO for the service provider.

What difference in the design of the car will occur, and what consequences will this have for the performance of the service? Who will win this race, only time may tell. But it could be an important impact for the automotive industry of today.

What kind of approach will the newcomers execute in this area?

As an example, we could imagine the situation running in Silicon Valley where the story starts in the data world. Based on the behavior of people being active in the internet, the process "big data to smart data" will extract the personal profile of each inhabitant of this world. With this knowledge, the requirements of customers in mobility as a service could be combined and a strategy for the needed performance will be generated.

The cooperating partners in this story may be, for example:

- Tesla to build a car which is more a driving iPad than a car concept of today.
- Apple will design the human machine interface to read the data of communication between the passenger and the system to obtain the passenger's behavior data. This will be done not based on the human control during driving (because it is autonomous), but more on the interaction connected with the entertainment and infotainment during transportation.
- Uber and Amazon will provide the performance to manage the logistics for transportation.
- Google will read the data to convert them from big data to smart data.

Will new mobility providers react to or create a new kind of business?

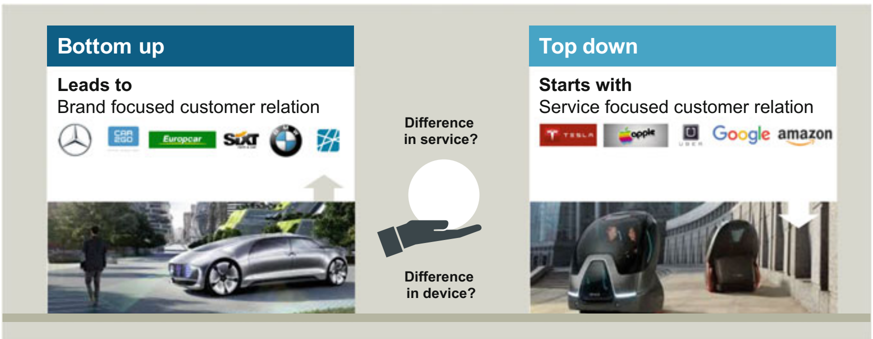

Fig. 20.9 A strategic top-down approach may generate a disruptive change in automotive business

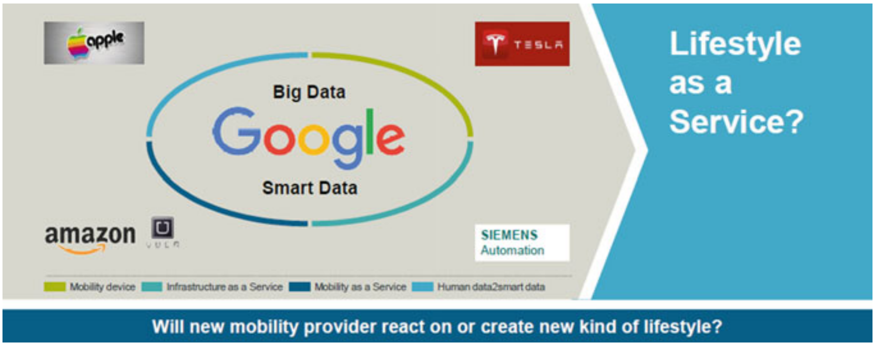

Fig. 20.10 A top-down approach of several strategic partners may generate new, innovative business in the world of smart services, including lifestyle as a service

Every partner will win in this cooperation, because the market will be open with high scale to service a large number of customers. Tesla, Apple, Uber and Amazon will directly participate in the business of mobility as a service, so they will create this new scenario.

But the greatest advantage may be had by Google (Fig. 20.10). They will have an additional connection to the customer via this mobility service to obtain the customer's behavior profile communicating via the system with the internet, and could generate new kinds of smart services based on this. Knowledge of human behavior and exigencies could lead to a complete service for people's entire lifestyles, from beginning to end of life. Thus they combine big data with smart data as the digital model of every person participating in society. Business could be maximized, with the closest customer relations based on this data. Therefore, this smart data is the true gold of the future.

What Is the Risk for Us in This Changing World?

As mentioned above, the success of a strategic approach by newcomers may be based on a cooperative partnership of several performing companies. A new vision oriented towards a common interest to launch a new business isn't only focused on the existing market of cars sold, but much more on the customer relationship based on services. In this case, the car may no longer be the main profit center in this business; it becomes a cost factor. This means that the benefit may lie at an upper level, and the business strategy will be focused there. The car will only be a part of transporting people, with more and more commodity with fundamentally changing requirements. It could be produced by everyone fulfilling the task best as a Tier 1 supplier.

The cooperation of several partners in Germany and Europe may be necessary to create a new way of delivering the best service in mobility. And combined traffic will play an important role in this mobility service. To provide the best comfort for the customer, a seamless transportation from place A to B—wherever these places are located—based on all of these intermodal partners must be found. New concepts must be based on a common vision, not on a defensive approach. Otherwise, this business may be fetched by new providers who will create a greenfield approach without any history in the automotive industry, but more in connected data exchange with "big data to smart data".

The world will change; therefore, let us change the world. Without taking this opportunity, we run the risk of being changed by others and leaving the business on which our lifestyle is based.

All pictures are based on a presentation at the Fiware Summit, Malaga 12/2016.

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Chapter 21
The Smart City Concept: A Review Concerning Sustainable Risk Management

Michael Kelnberger

Context Statement

The smart city concept is commonly understood as an approach to solving the existing and future socioeconomic challenges of urban spaces by means of technological innovation and cooperation over a wide variety of segments. Comprehensive knowledge of smart cities requires an understanding of benefits as well as of risks, challenges and concerns. This implies an awareness of the problems of the digital divide, awareness of changes, and acceptance of potential benefits based on civil empowerment and participation. As stated in paragraph "k" of the general recommendations issued by the participants of the workshop on Sustainable Risk Management (see Part V.1) "*a democratic culture of sustainable risk management is an important instrument to assign the adequate trade-offs between efficiency, effectiveness, resilience, and fairness of decisions*". In the following, these recommendations are further elaborated and discussed using the smart city concept as an example.

Introduction

The world's urban centers have taken on increasing importance and power as economic engines of growth. With more than half the world's population living in cities, the vast majority of the world's economic output is being produced in urban areas (Newcombe 2014). Likewise, global and hereafter smart cities become not only the center of economic, social, cultural and political activity, but also the source and origin of innovations (Müller-Seitz 2016). The generation of innovations

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represents itself as a central challenge for a smart urban government since the innovative capacity of an urban region is generally perceived as an indicator for social and economic prosperity (Müller-Seitz 2016). Consequently, the traditional competition between cities appears to move progressively to the smart city domain. The numerous existing smart city rankings serve for companies as an indicator of economic prosperity and as a location factor. The higher the ranking, the better the circumstances, and the conditions for entering the market (see model below "Benchmarking"). The smart city in turn wants to attract citizens, investments and international businesses, which will contribute capital and boost local growth (Anthopoulos 2014).

With a population expected to grow as well as the economic importance to continue during the decades ahead, city leaders face numerous challenges as far as infrastructure and service delivery is concerned. Among the most pressing problems are housing shortage, urban climate, transport and logistic, mobility and energy supply (Newcombe 2014). Besides these hard factors, the city administration has to take countermeasures against social inequality and segregation as well as increasing stress/complexity and disenchantment with city politics (Jakubowski 2016).

One of the most promising solutions to these increasingly complex urban problems is making cities smarter through intelligent information and communication technology (ICT). Smart cities, beyond their problem-solving interest, therefore, logically comprise an extensive and emerging market accounting triple-digit billions (Rohling 2015; Anthopoulos 2014). Global players consequently have a particular interest to expand in the smart city sector. IBM, for instance, installed the so-called Centro de Operacoes in Rio de Janeiro for the 2014 World Cup and the 2016 Olympic Games, where officials sit behind personal computer screens and a giant screen handling the incoming information on the city (Newcombe 2014). Once such an intelligent operations center and the associated technical infrastructure are up and running, the city finds itself in a certain state of dependence (Marshall 2014). On the one hand, the city needs the expertise of the private sector, but on the other hand, the city—and consequently its citizens—loses sovereignty and privacy. Moreover, transnational companies are often accused of acting only in their own interest, profit sidelining the city dwellers and their needs.

There's no doubt that a smart city is a complex matter with multilayer conflicts of interest. Various actors have tackled and want to tackle miscellaneous topics with the best outcome in their own interests. Not surprisingly, those responsible seek a generally accepted concept for a smart city they can rely on. Although such a formalized concept hasn't been published yet, it already exists as a model by Jaekel, which draws near to the high demands and requirements. The presented model in this chapter (see Fig. 21.1) is the consequent enhancement of the original. In addition, for a better understanding of this text, the model will serve to locate the specific treated aspects and illustrate the theoretical discussion.

For the following sections, the focus will be on the risks and opportunities arising from the implementation of smart city concepts instead of on the alleged infinite possibilities of smart cities. While ideas of a smart city might differ from nation to nation and need a case-by-case analysis, the challenges during the implementation occur throughout the various realizations of the idea and can be

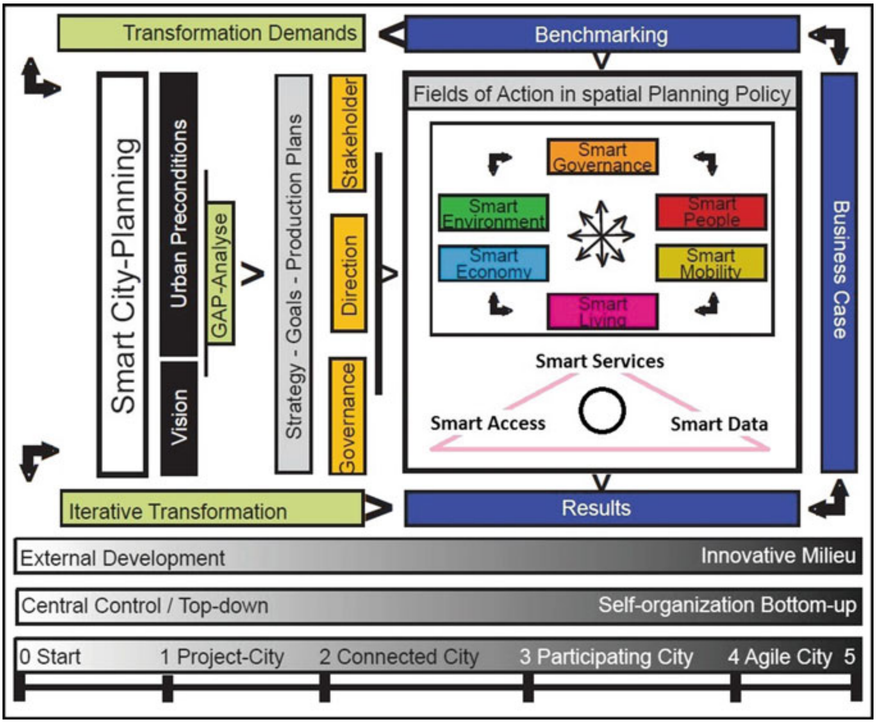

Fig. 21.1 Transformational model of a smart city *Source* Jaekel 2015, transformed by the author

therefore summarized across the board. Table 21.1, which presents smart city risks and answers, gives an overview of the most urgent risks and chances. It portrays the paper's structure and guides the reader trough the theoretical discourse, which also tries to point out possible solutions to the described problems. In particular, the necessary interplay between city planners and the community shall be highlighted.

Both the model and the table with their respective detailed explanation shall give an overview of the current knowledge concerning the sustainable risk management of a smart city. They combine the present available scientific insights about obstacles as well as key success factors. Understanding the risks and challenges, that a practical and concrete implementation implicates, city planners can take appropriate precautionary and preventive measures.

Transformational Model of a Smart City

The scientific literature still discusses the exact meaning of the term "smart city," since generally valid guidelines about how to plan and implement a smart city concept are lacking.

Table 21.1 Smart city's risks and answers or challenges and chances

Problems, risks or challenges	Solutions, answers or chances
Digital divide, equal opportunities	Digital education, holistic concept
Acceptance, over-engineering	Participation, empowerment, citizen sourcing
Resistance to change and fault tolerance	Discussion and error culture
Decision making	New modes of government, public value
	Strong leadership
Political stability, will and openness	
Lack of social technological innovations	Incentives for start-ups, innovation clusters
Financing	
Lack of knowledge and expertise	Support program, collaboration and partnership, business modeling
Incompatibility of systems and devices	Improvement of in-house expertise and collaboration with extern partners
Rapid technological change	Interoperability, cross-systems planning
	Resilience
Lack of security	Safety measures
Systemic risks	Contingency plan
Lack of control and sovereignty	Principle of subsidiarity

Source Nam and Pardo (2011), transformed by author

The following definition is proposed to describe a smart city as "*an approach to solve the existing and upcoming socio-economic challenges of urban spaces by means of technological innovation and cooperation over a wide variety of segments*" (Manville et al. 2014). In this context, the German Federal Institute for Research on Building, Urban Affairs and Spatial Development executes a project that aims to develop a "Smart City Charter 2040" (Jakubowski 2016). Concerning this matter, Michael Jaekel, a respected city planner, has already designed the "Transformational Model of a Smart City" (Jaekel 2015; Fig. 21.1), which gives an idea of what the transformation process from a common city to a smart city might look like. This model suggests that a smart city initiative presents itself rather as a circular than a simple one-dimensional process.

Additional emphasis is placed on gap analysis and urban preconditions, which shall ensure that the concept fits the city's character. In particular, the complementary barometers now allow one to consider the whole process and subdivide the city's development into comprehensible steps. The longer the project runs, the higher the level of citizen participation, city-intern expertise, decentralization and rate of innovation. In general, this "transformational model" concept strives for a holistic approach—smart government, economy and people—instead of only satisfying certain interests.

Digital Divide and Its Meaning for Acceptance

Many urban administrations take a rather technical approach, implementing many new information technology concepts (ITC) into the city's infrastructure. However, the usability factor of technological tools that are developed assumes a certain already existing familiarity with the technique. For instance, in countries where the average age is rather high, it needs to be considered that large segments of the population are not familiar with digital solutions and therefore will tend not to use them, despite having them available, even when those devices respond to actual needs (Fontana 2014).

Digital Divide, the Holistic Approach, Acceptance and Participation

The level of technological education of the young generations differs from the elder. In addition, the latter need more effort and time to acquaint themselves with new applications. This actuality is especially urgent for several reasons. First, many technologies could preferentially assist senior citizens. Second, technological change often overstrains these people—fear of the unknown and uncertainty—and reduces the familiarity of their cityscape (Lombardi and Vanolo 2015). They experience the change as extreme and stressful, resulting in a return in the privacy of one's home. Consequently, electronics should be implemented as simple as possible plus as complex as necessary and be explained to their users. This means that smart Services, created thanks to smart data, need smart access—generally intelligible and practical—to deliver benefits to the community (see Table 21.1).

In addition, the full provision of technological infrastructures by the private sector, instead of adaptive and purposeful measures of the municipality, may enhance urban fragmentation in two ways. First, in the former case, as described above, elderly people and humans with a low technological knowledge retrench or are not capable of participating in the city life as any other urban dwellers. Second, in many cases, a smart city project and its over-engineering have led to functional separation between sealed-off technological enclaves and leftover marginalized spaces (Lombardi and Vanolo 2015). That spatially fragmented development, of course, also multiplies the formerly mentioned social digital divide.

The latter interpretation seems to be confirmed by the fact that almost two-thirds of the municipalities pursue smart city projects, but mainly "*in the context of their participation in specific bids*" for public funding (Fontana 2014). These are certainly to be considered positive for the financial and innovative opportunities they offer, but expose the risk of undertaking occasional or sporadic initiatives that are not included in a clear strategic vision, as could be observed in the case of Munich, participating in the EU project "Smarter Together" (see Table 21.1: "Project City" and "External Development"). However, it is too early to evaluate the results that can be achieved in this manner. Another risk worth highlighting is that these projects, once the funds allocated to them are exhausted, get abandoned "*making their socio-economic impact extremely modest and ephemeral*" or forward disruptive urban development (Fontana 2014). Therefore, the smart government should always sight out a holistic smart city concerning all parts and segments of the city as well as the complete social stratum (see Table 21.1: "Fields of action"). This is also key and a precondition to enable citizens' acceptance and, equally important, participation.

The example of Munich where workshops, initiated by the city administration, started with about 50 civil participants, demonstrates that participation can be achieved via adequate information and empowerment of the citizens. However, at the end of the first round of the workshops, the participation's figure near zero shows that information overload with a"school-like" character tends to result in querulousness and disinterest. The on-site-devised concept of the so-called city-lab respects both information and participation, and balances them. Locations like that, which should exist in every greater urban district, serve as a meeting point for city planners, citizens and companies to discuss and decide the past and upcoming changes. The city-lab allows city dwellers to gather information, experience true-to-life background and practical trial and error, while exploring for example new smart services.

Citizen Sourcing and the Error Culture

Empowerment and participation of citizens, firms and other stakeholders in a bottom-up process becomes an essential requirement for the long-term success of smart cities. If the community is not involved, the smart innovation projects remain the domain of the few and risk being perceived elitist (see Table 21.1: "Top-down"). It is inconceivable to initiate an operation that involves major changes in the lives of citizens without their being adequately informed, prepared and motivated. Information is the key both to acquire consent and to disseminate the benefits to the whole community. In fact, "*coproduction of value occurs for Smart Cities as part of the services provided by the local government*" for the territory, and as a consequence for the citizens. This means that the local government is strongly advised to operate in terms of public, participatory governance (Merli and Bonollo 2014).

To adopt solutions by consensus with the members of the public has several obvious advantages. In the first instance, ideas are generated and brought forward, which otherwise would never have been explored by "*citizen sourcing*" (Müller-Seitz et al. 2016; see Table 21.1: "Innovative Milieu"). Moreover, the citizen's involvement often fosters their free engagement—bottom-up sharing of data instead of top-down sensing—and allows ready allocation of necessary funding for the implementation. These co-determined solutions will also be accepted in the long-run analysis. Indeed, in smart cities, the power balance seems to have changed and it seems clear that "*citizens need their governments and governments need the intelligence and the cooperation of their citizens*" to function (Kresin 2013).

From a social point of view, a smart city is a city whose community has discovered how to learn, adapt and innovate, with a particular focal point on achieving social inclusion and citizen participation in urban management (see Table 21.1: "Agile city"). With regard to methodological issues, the main risks and limits concern the only "*apparent openness of the planning process and the purely fictitious involvement*" of civil society. This corresponds to a "*decision-making process that is circumscribed to the narrow political and administrative boundaries*" or, no less seriously, to a privileged and non-transparent alliance among influential powers (Fontana 2014).

On the contrary, in order to be useful to the development of a smart city, it requires a strategic vision that is specific, clear and selective, and a system of governance that is authentic, open and engaging (see Table 21.1: "Vision"). After all, it should not be ignored that citizens must not only be made aware of the existence and availability of a service, or its ease of use. Their attention should also be called to the concrete failures and damage that the service itself can cause to each of them individually and to the community (Fontana 2014).

Unfortunately, that has not happened yet. Moreover, it appears that the population demands and assumes faultlessness when it comes to technology. A possible explanation for such a behavior might be the defenselessness of individuals as well as lack of control, which leads to the non-acceptance of failures. They assume that they cannot influence the change, which itself appears to become faster and more far-reaching than ever before. In consequence, it is more comfortable and convenient to rely blindly on technology than to deal with this subject. Instead of bearing this helplessness, which is not true acceptance, the smart city should strive for smart people, willing to engage themselves and capable of discussing and understanding the risks as well as to live an error culture. The described city-lab could help again here.

The Thought-Terminating Cliché of Efficiency

To meet this target, it is necessary to examine the meta-level. The following aspects point out that the lack of an error culture and the unconsciousness are partly in-house-made problems. First, it is easier and faster for the city planners to reach a decision without discussing possible problems with distressed citizens. Second, the efficacy and efficiency serve as a thought-terminating cliché to scotch every doubting or request. Third, the term "smart" sets new standards for what is right and what is wrong.

The planning of urban life is comprehended as a managerial function, which aims at improving efficiency, and therefore it is "*deprived of political dimensions*" (Lombardi and Vanolo 2015). This means that the smart city may increasingly become a common and facile agreed target, a kind of "*metaphor unifying and universalizing the problems of cities*", without proper critical discourse, "*without 'politics', intended as debate between different positions*" (Catney and Doyle 2011). Likewise, this technocratic rhetoric can "*take humans out of the loop and turn them into passive rather than active agents*", which could promote the self-governing type of the smart city if politicians share this view (Rodriguez-Bolivar 2015).

Considered as another crucial point, many smart approaches presume that all the ambiguities, the "*disorder and disorganization of daily human life are potential forms of inefficiency*", and therefore "problems" to be tackled (Lombardi and Vanolo 2015). It dominates the understanding and interpretation that smart technologies and the quest for efficiency in general will always produce positive and desirable outcomes. The "*mantra of efficiency may reduce the capability to envisage radical alternative imaginaries*", to invoke the freedom to experiment alternatives, to debate or even contend for pursuing alternative forms for our workaday social space: also defined by Henri Lefebvre in 1968 as "the right to the city". However, we also have to consider that "inefficiencies" are expressions of human society, and certainly no one would wish for a "*dehumanized future*" (Lombardi and Vanolo 2015).

Even though the word "dehumanized" seems too strong, there is no doubt that people rely on their smartphone, which makes plenty of decisions for them. Even more pronounced, the smartphone unnoticeable steers the user into certain directions. The danger is that these mechanisms "*diminish the diversity of things*" to which one is exposed, potentially leading to an unintentional and relatively "*invisible isolation from new experiences*" (Flade 2016). "Smart people" does not mean that people use their smartphones always and everywhere.

Data as an Excuse for Moral Decisions

As cities' knowledge increasingly relies on data streams from sensors and analytical software to interpret the content of the data—the amounts of data not only introduce extra security and privacy risks but also lead to information overload—there appear two remarkable consequences (Choenni et al. 2016). First, the figures, the data or the deviation from the standard decides what is precarious and what is not. Everything is treated as a technical problem, which in turn can be addressed through technical solutions. Secondly, and even more striking, the data's results serve as an excuse for decisions that normally raise ethical and accountability concerns. Similarly, one can argue that smart city projects run the potential risk of "*operating as devices of moral legitimization of entrepreneurial projects*" (Lombardi and Vanolo 2015). If the adhesion to smart projects, the adaptation to smart environments and the participation to urban smart living is a moral obligation, there is little room for critical thought and political negotiation. Urban environmental management practices are compelling in the way in which they "*convert technical policy into personal concerns and ethical arguments*" or codes of social behavior: the criminalization of waste, the validation of surveillance or the obligation of energy efficiency. Finally, the inner language of smartness imposes a strong semantic twin-track strategy: what is not "smart" is inherently "stupid" or "fatuitous". Questioning the appropriateness of smart cities and smart technologies would be similar to "*questioning 'capitalism' or 'modernism' in the late past*". The myth of technological perfection and absolute efficiency may provoke "illogical" or "irrational" dissent. The image of a "*technological, green and just Eden is so appealing*" that the smart city concept is becoming common knowledge (Lombardi and Vanolo 2015).

New Modes of Governance and Leadership

The opposite of such a technocratic policy contains three elements: cross-functional management, the public value and the city's character. Instead of quick, unquestioned and almost atomized decisions made by a few, the social idea of a smart city seeks an assembly of experts, politicians and citizens around one table, and a discussion about the activities and their potential as well as risk. The participants are thus able to create and perform new modes of governance to develop tailor-made solutions for each city. Regardless of whether city dwellers, members of the city administration or companies present a solution or only an initial idea, with the aid of proper visualization and expression of multiple points of view, the traceability of arguments can be improved and decisions made with a deeper understanding of the material.

Hence, the mixed composition of the smart city management board, consisting of representatives of government, community and economy, is key for a successful smart city concept. This cross-organizational management with policy coherence and integration can further target more appropriately challenges like policy inconsideration or the misalignment between goals and projects.

Despite this, it still needs someone who is liable for positive and negative consequences, in possession of an overview as well as detailed knowledge and who can combine government and governance, to lead the smart city project. Even though the use of technologies rises, there is and will always be a deep longing and desire for trustworthiness and reliability. The leadership of the smart city project—including the representation of values and risks—can be similarly described to the governing mayor. Besides technological challenges, finding the political will can count as the sticking point for each smart city initiative. In addition, the close cooperation of the different divisions of the municipal administration is not self-evident and needs both wise coordination and strong leadership. Assessing needs in collaboration with the citizens as well as with the internal administration and external stakeholders, the managing director requires political backing and support of the department for public relations (Newcombe 2014; see Table 21.1: "Direction").

Public Value

It stands to reason that all activities shall serve the most important aim, the public value. The strategic management should not rate the success of a single measure based on numeracy or Euros but rather by means of its contribution to the common good (Müller-Seitz 2016). The higher sense of every single step—"*the activation of processes of collective learning, the higher cohesion among social actors and better ownership of new policy initiatives*"—or the actual achievement of positive results is to increase the public value (Fontana 2014).

The public value is also the main counterargument against technological solutions from global players, which can be implemented in every smart city project around the world. As mentioned earlier, technological innovation is an essential condition for any smart city project. However, such projects run the risk of failing if they are designed to "*respond to a technological innovation rather than to an actual need*" (Fontana 2014). These projects are likely to propose answers to needs that are not felt by the citizens, perhaps neglecting others that are of greater importance for everyday life. Especially nowadays, where the rate of unemployment of young adults in many countries exceeds 20–25%, the question arises whether the city administration shall integrate technology in lieu of human beings. In other words, cost efficiency competes with socially valuable jobs and human interactions, for instance, water sensors versus a gardener or surveillance cameras versus security staff (Flade 2016).

Consequently, the enterprise's smart city concept can result in an excellent design and might be effective, yet it lacks, as already mentioned, the wisdom and support of the citizens. The fact that there is a predominance of projects focused on specific fields of activity rather than on a comprehensive model of a smart city, can be interpreted in different ways. On the one hand, this can be a strength if it means that only the aspects considered as most relevant and critical to the specific urban context are selected. On the other hand, it can be a point of weakness if these projects are not part of a clear strategic and holistic vision.

The latter interpretation seems more likely, as the areas of activity that are addressed in the smart city projects are often common to several cities, not presuming, at least ostensibly, a character that is tailored to the city's character (see Table 21.1: "Urban Preconditions"). Since these projects heavily correspond to the activities that are publicly funded, they seem also to "*reflect an opportunistic behavior rather than strategic choices*" which are broad and forward-thinking (Fontana 2014). This adds to the fact that in several cases the only chosen area of activity is the development of ICT. Instead of a sort of a smart city template, considering the existing urban system allows the municipality to attract and use resources as well as the economy to grow and produce long-lasting results (Jakubowski 2016).

In fact, experiences in the EU seem to indicate that many smart cities have been developed according to their own characteristics and environment. In these cities exists "*no single definitive way in which all players behave and work together*" (Alcatel-Lucent 2012). They operate under, above-named, new modes of government.

Lack of Socio-Tech Innovations and Its Meaning for the Smart City's Resilience

In-House Expertise and Start-Ups

A smart city can be just about anything to anybody, and therein lies both its usefulness and jeopardy. While cities will doubtless become digitally smarter, one should remember that the focus should lie on social technological innovation (Marshall 2014).

One strategy to meet that target might be to offer incentives to cultivate in-house expertise and a strong innovative sector with start-ups, which address the city-intern problems. Evolved, generally deployable solutions, however, can be exported and generate additional revenues. The basic requirements encompass firstly workshops with both groups, the creative people and the smart government, to convey the long-term vision and clarify in which frame or sectors innovations are needed the most. Combining this measure with financial aid, additional competitions like "the best three smart city ideas of the year x" could function as an inducement and stimulate universities or other research institutions to foster their effort to become an integrated part of the smart city project. Moreover, such an inter-divisional liaison follows the crucial element of trans-sectoral cooperation of smart cities. To include the aspect "smart economy" and to be economically successful, it is key for every urban administration to attract the creative class.

Once again, citizens' diversity, profession and way of thinking should be considered as a source of ideas and treated with tolerance. Their competence and experience can aid development of better solutions and services (Kresin 2013). Some citizens may even have important competence that the city does not possess. By listening to the people, potential problems can be addressed early and precisely. Thereby the risk of failure can be reduced (Gil-Garcia et al. 2016). However, to release theses resources, the government has to budget the promotion of a start-up scene. This also implies job postings instead of cutbacks in hiring and pay for city workers, even if the cost of doing government business keeps growing and putting pressure on budgets, e.g. technical infrastructure and public safety (Newcombe 2014). Partnership or support programs like the "Smart Horizon 2020" of the EU can help to set up the network, which should self-finance through city-intern businesses and the export of smart city solutions in the long-term (see Table 21.1: External Development → Innovative Milieu; Business Case).

Resilience

Another advantage of this approach is that the problems of deficient knowledge, the incompatibility of systems and rapid technological change can be treated with one condensed method. Through collaboration and exchange with citizens, external partners and representatives of other cities, the in-house expertise will improve. Furthermore, through in-house-made solutions combined with cross-system planning, the compatibility of the devices as well as the resilience of the entire system are ensured. It is imaginable that the more diverse those linkages are, the more opportunities will be generated, and the more the risks will be spread. In turn, the higher diversity will lead to less vulnerability to economic shocks, and thereby contribute to urban resilience (Wall 2015; Bloesch et al. 2015).

The smart city is hence capable of determining and dictating the art and speed of the transformation. For achieving the objectives of creating and promoting identity in socially disadvantaged, deprived quarters, improving participation and developing spatial resilience areas, it is inevitable to enhance the decentralization of the urban development and to foster urban quarters as planning and action areas, like the above-specified city-lab (ReißSchmidt 2016).

Lack of Security and Sovereignty

Security and Systemic Risks

Sensor technology relies on the Internet and the associated cross-linked systems, which have become increasingly vulnerable to hackers or generally to attacks (Newcombe 2014). The more compact the network and interconnectedness is, the higher are the so-called systemic risks for a system shutdown. As a chain is only as strong as its weakest link, the failure of a single component can cause the collapse of the whole system instead of shutting it down properly.

Another risk appears in the form of misuse—to capture nearby conversations and video surveillance—or simply to faulty treatment due to the increased technological complexity.

The smart city has to assure certain security safeguard principles, which refers to having reasonable technical and organizational safeguards, a contingency plan to protect systems and data against various risks such as "*loss, unlawful and unauthorized access/use, destruction, modification, or disclosure*" (Choenni et al. 2016). In addition, users often allow applications to access their data set without knowing how their information will be actually used and without being aware of the risks associated with sharing their data. It is the smart government's duty and task to ensure transparency. Otherwise, citizens will become suspicious and reluctant to use smart services that are intended to ease their daily life. This may have a negative impact on the economic growth of a city and its ambition to become a smart city (Choenni et al. 2016).

Lack of Sovereignty

In a crisis scenario, characterized by "*privatization and externalization of urban utilities and services*", the smart city might be framed as a new sort of capital urbanization. Cities have to be aware of risks of "*private-led provisions of public services*", where public sectors are merely co-opted in a marginal position or just assist privates (Lombardi and Vanolo 2015).

Specific ICT concepts for the public administration should be designed in accordance with the strengthening of local democracy and local self-governance, avoiding privatization and economization of the municipal services (Reiß-Schmidt 2016). Neither the technocratic extreme in which the initiative is promoted by entities to which the municipality does not even participate nor the bureaucratic overloaded administration alone can implement the far-reaching change (Rodriguez-Bolivar 2015). Solving societal problems is not purely a question of developing good policies but over and above a managerial question of "*organizing strong collaborations between government and other stakeholders*" instead of the pursuit of smart city projects from organizations outside the local administration (Torfing et al. 2012). What is essential, in any case, is the exercise of the function of leadership by local authorities, which presupposes their competence and legitimacy and results in the construction of truly shared and consensual scenarios (Fontana 2014).

Conclusion

Given that a smart city is technically possible and politically feasible, a crucial and critical question for each community is whether the citizens want to establish a smart city concept and, if so, in what way they want the city to be smart. What is the social desirability of their smart city? The cost- and labor-intensive implementation of a smart city concept only makes sense if all participants share the same vision.

Comprehensive knowledge of smart cities requires an understanding of benefits as well as of risks, challenges and concerns. This implies the awareness of the problems of digital divide, awareness of changes and acceptance of chances caused by civil empowerment and participation.

Moreover, despite the deep resources of large cities, the direction of the smart city project should build strong relationships to the start-up sector instead of doing all by oneself. Likewise, the management board should strive for a holistic concept, instead of single technological-based projects. Not until the cooperation and network with external service provider functions well can the smart city can reach the next levels: connected, participating and, in the end, an agile city.

For the success of an operation, it is key that politicians, administration officials and municipal service providers cooperate closely. The lack of knowledge and in-house expertise combined with unclear or overlapping responsibilities and infighting thwart committed employees as well as the whole project. Consequently, training courses and continuing education, strong leadership and political support are decisive to comply with the plan and accomplish the goals. Those trainings should also take the topics of IT security and systemic risks into account.

While most people see the smart city as a concept striving for efficiency, the fit between the human being and the urban space should come again more to the center of attention. The city is not only the background of the townsfolk life, but coins in particular their daily life and therefore should be based on the principle of user-friendliness and livability. Therefore, it is indispensable to look at the urban precondition and tailor the smart city concept to the city, not the inverse.

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Chapter 22
Dark Clouds over the Digital World

Daniela Korhammer and Konstantin Grambow

Context Statement

Digitization, the Internet and the collection and analysis of data at a large scale provide many chances for our society. Environmental models can be built from large amounts of sensor data and natural disasters forecasted. Mining medical data can reveal unknown interdependencies and help in understanding diseases as well as in providing more personalized treatment. Overall, digitization makes it possible to increase the time efficiency of many tasks. Since digitization is a subject of great economic interest, the possible benefits, especially the personal ones, are very well advertised and sometimes overrated while possible negative effects receive little attention. Many of the risks of the digital world are also neither visible nor tangible and thus are easily overlooked. This chapter is focused on the risks associated with the generation, networking and analysis of vast amounts of data. It calls for sensible and responsible regulation following the principles of sustainable development.

Introduction

The idea of big data promises to improve and revolutionize every aspect of our lives. Big data, a buzzword promoted primarily by the media, is an abstract and unspecific term describing all aspects of handling big, or rather enormous amounts

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of data. Advances in hardware and statistical methods, as well as the availability of vast amounts of data have enabled the emergence of this field.

Computing performance continues to grow in an exponential manner. As all parts of the computing infrastructure, including processors, storage, network and sensors, are becoming cheaper and more powerful, it has become possible to acquire and store data without giving thought to whether or not it could be relevant. At the same time advanced statistical methods help in making sense of these large amounts of data by finding patterns and interdependencies. In the past two decades these algorithms have continued to become ever more powerful and make it possible to find the face of a person in any number of photos in a matter of seconds, to extract information from written text or speech or to estimate where a person wants to go next based on their usual behavior. Knowing that these algorithms exist and that they are continuously improved is crucial to understanding the risks associated with big data. Finally, big data depends on the availability of vast amounts of data. The generation of such data has been facilitated by the Internet and even more so by smart phones and other devices equipped with sensors that upload data into the cloud—devices that are part of the Internet of Things.

The term Internet of Things (IoT) describes the idea that all kinds of things, from the obvious smartphone and fitness trackers to less expected glasses and clothes, are equipped with sensors and sometimes actuators and are connected to the Internet. In the IoT everyday objects provide information on their status and that of their surroundings to remote objects. For example, parking spaces "know" whether or not they are occupied, a garbage bin senses whether it is full. Via an IP connection this information can be accessed from anywhere in the world. Lights can be switched on and off and the heating set to a certain temperature level from abroad. While estimates vary, Cisco expects 26.3 billion (total) networked devices in 2020 (up from 16.3 billion in 2015) (Cisco 2016).

The immediate use for the owner of having a "thing" networked is not always as apparent as the advantage this has for the vendor or other parties, who receive detailed information about the location of the item, the way it is being used, and more importantly, about its user. In many cases the success of such IoT devices is not due to their problem solving capabilities, often not even because they promise a higher level of comfort. Many, such as gesture controlled TV sets, appear as gimmicks and spark curiosity because of the fascination with what is technically possible. The need for the "thing" to have sensors and be connected to the Internet may be hidden in a gimmick. The data that is transferred via the IP connection, however, will likely be much more than what is needed to provide the advertised features. If not legally regulated, there is little reason for companies to collect less than all the data they can get.

There Ain't no Such Thing as a Free Lunch

Any form of progress, any minimization of a certain risk, any service, comes at a cost. The cost can be monetary, it can be time, a loss of privacy, the amount of CO_2 emitted into the atmosphere or any other personal or external cost. And of course it can be a combination of those. This insight is neither new nor very complicated, nor is it easy to disprove. Still, there is little awareness that services on the Internet, such as search engines, email, social networks or information, cannot be completely "free". With the enthusiasm for new technologies and the belief that these technologies will make every aspect of our lives better, the costs are ignored or negated.

Large companies offer various services to billions of people worldwide at no charge, at a quality and with a functional range that often exceeds that of their non-gratuitous competitors. It is quite obvious that the development and operation of these services is resource- and cost-intensive and someone must be paying for it. In the abstract virtual world, we are sometimes blind to such matters.

Protection of Data Privacy

In a blissfully ignorant way, we use our data to pay for these services. The data is converted to money by selling advertising spaces that minimize the usual wastage through personalization. To this end, data is collected on many channels. Companies, such as Google, know who we know and how often we talk to them, the content of our emails, what we buy, which websites we visit, where we are and where we want to go. They know things before we know them, e.g. how likely we are going to be interested in a product or enjoy a movie. Their knowledge about us even exceeds that of our partners: 300 Facebook likes suffice for algorithms to know us better than our spouses (Youyou et al. 2015). With every digital trace we leave, advertisements can be more personalized and the value of our online profiles rises.

The right to privacy is protected by the EU "Convention for the protection of individuals with regard to automatic processing of personal data" (Council of Europe 1981). Specifically, the convention and other legal documents of many countries protect "personal data", or sometimes "person-related data". The specification of personal data is difficult as big data makes it possible for almost any kind of data to be person-related. Smart meters, for example, that record the consumption of electric energy in small intervals and communicate the information back to the supplier, can provide intimate details on the behavior of the household members. The same holds true for timestamps of phone calls or messages, even if the content is unknown. With higher resolutions of satellite images, even those increasingly contain personal data. Nevertheless, the collection of many of these types of data is of public interest.

Protection of data privacy and big data are incompatible, at least when person-related data is concerned, and any attempt to have both must be a compromise between the two. Anonymization is not a sufficient solution for this trade-off. Deanonymization is often possible, even if directly person-related data is removed (Wondracek et al. 2010). Since the goal of analyzing large amounts of data is to find correlations and hidden factors, it is also possible to recover personally identifying information, even if it had previously been removed. The AOL scandal of 2006, when the search engine queries of thousands of people were poorly anonymized and revealed to the vast public is one example. Research dealing with how datasets can be fully anonymized exists (Ji et al. 2014); it can, however, be bypassed by connecting multiple datasets. In most cases, anonymization of data sets is of no interest to the data processor, anyway, since it directly contradicts the goals of the analysis (personalized advertising, analysis of human behavior for profit optimization, combating crime, adjustment of insurance premiums, questions of credit rating and so forth).

A paradigm shift can be observed, even in research: Previously, the purpose of a data analysis was defined before the acquisition, the amount and types of data followed the purpose. The recorded data reflected the investigator's expectation of which data was relevant. Big data means that any data that can be recorded digitally is stored, in the hope of finding hidden correlations and interdependencies. Whether or not a factor is relevant will be shown by the data analysis. Even if big data inherently means that the sample size is large, the samples can still be strongly biased. As with all statistics, careful interpretation is crucial.

For a long time, experts have been warning that personality profiles could be used not only to advertise products but also to influence elections. A much discussed article in a Swiss magazine on psychographic micro-targeting for the 2016 US presidential election brought the discussion to a wider audience. According to the article, the company Cambridge Analytica was hired to influence the election using psychographic methods. The company claims to have sent out 175,000 slightly different messages micro-targeted at individuals for the arguments to be in line with their psychological profiles. The same company was hired for the Brexit referendum (Grassegger and Krogerus 2016). Of course, it is impossible to quantify how large the influence of micro-targeting of such messages was. However, for a close election result such manipulation can likely make all the difference. Personalization of such messages is not new and can be performed on simple features, such as gender, age and ethnicity. The possible effect, however, likely increases with the level of personalization. It is clear that this puts our democracy at risk, and it shows that micro-targeting is not only about advertising different products to those who might be interested in them. Instead, it can be used to sell the very same product (or presidential candidate) to different people by approaching them in the right way.

Personalization is not only used for advertising but also makes online (and increasingly offline) services more attractive. A typical example: The Google search for "golf" shows very different results depending on whether a car enthusiast, a geographer or a golf player sends the query. Personalization helps us filter the flood of information within news or Facebook messages by showing only those messages that the algorithm believes are of interest for the particular user. The algorithm takes some control over how we see the world and creates a "filter bubble" (Pariser 2012). Of course we have always opted to read one specific newspaper rather than another because it was more in line with our views. Our social contacts were never uniformly drawn from the population at large but have always been biased by many factors, including our social status and political orientation. What makes the filter bubble created by personalization different is that we have less awareness of it. We have not even opted to have our search queries personalized and we do not know why the algorithm shows us certain results rather than others. This filter bubble could aggravate the notion of a "post-truth society" where facts are no longer of importance. If one likes to believe that the earth is a disk, the filter bubble will make sure that we find only the contents that claim to prove that this is the case (Roll 2016). While the data is filtered by interest, it is not necessarily filtered by quality.

Of course this is the consequence of a service, not of abuse. The lack of transparency of the search algorithm, however, also makes room for deliberate manipulation, censorship or discrimination only by moving relevant search results away from the first page. Google alone has a search engine market share of approximately 93 percent in Germany (StatCounter GlobalStats 2017), giving the algorithm some control over what we believe exists. It has been shown (Epstein and Robertson 2015) that biased search rankings can shift the voting preferences of undecided voters by 20% or more. This quasi-monopoly in web search means that the success of practically any company depends on a high search engine ranking: One has to pay to be seen.

Some argue that since data can be viewed as the "new oil", companies should pay users for their data, e.g. using micro-payments (Lanier 2014). This could be an important step for users in gaining more control over their data but it does not solve the aforementioned societal problems. Instead, if selling one's data is a source of income, the right to privacy becomes a question of social standing. Can you afford not to sell your data?

Even years after Edward Snowden's revelations in 2013, the "nothing-to-hide" argument is still popular and the claims that terrorism can be fought through public surveillance are widely accepted. This may be a paradigm of risk management based on emotional argumentation. The information gathered through governmental surveillance creates an imbalance in the distribution of power and opens the doors for manipulation and future non-democratic systems. The Charter of Fundamental Rights of the European Union declares rights such as the "Respect for private and family life" and the "Protection of personal data". These fundamental rights should not be questioned. Instead, they need to be interpreted in the context of new technologies.

In many countries all telecommunication meta-data is currently collected and preserved for varying time spans, disclosing intimate details on the private lives of all citizens. In December 2016 the Court of Justice of the European Union ruled that such collection and retention of all communication meta-data without reasonable suspicion is unlawful (Court of Justice of the European Union 2016). This judgment is important as it confirms that the fundamental rights of our society cannot be undermined for speculative chances in combating crime. The calls of politicians to loosen the protection of data privacy for the sake of economic interests should be equally viewed as disregarding these fundamental rights.

IT Security and Hacking

A vast number of IoT devices are already flooding the market. At the same time new vulnerabilities, often serious ones, are detected in these popular devices on a daily basis. According to a report on the IoT published by Hewlett Packard (HP) in 2015, 7 out of 10 tested popular IoT devices communicated without transport encryption (HP Security Research 2014). Beside the obvious risk of leakage of very private data, especially in the area of "smart homes", the fusion of the real and virtual worlds means that the risks are also becoming increasingly "real": cogeneration plants (i.e., combined heat and power generation) may be manipulated by hackers (Stahl 2013) and cars can easily be remote-controlled (Greenberg 2015), posing a direct threat to the passengers. In the race to be the first one to throw a new product onto the market, IT security is not an integral part of product development but is, at best, considered at the end of the development process. More generally, an increasing amount of data in the cloud means that there is more which can be stolen.

Apart from companies and government agencies, criminals are the third party interested, either in the data directly or in manipulating the data, the sensors or the actuators. Wherever sensitive data is transmitted or stored, high security standards must be followed. Moreover the principle of data minimization needs to be followed to reduce the amount of data that can be misused or leaked.

Mature Use of Technology

Personal and confidential data is being handled every day in all work fields and in our personal lives. Digital data can easily be copied and is connected to the Internet in many ways. As our jobs are becoming less stationary, confidential information is often handled on private computers, smartphones and uploaded to cloud services. This is problematic not only concerning person-related data but also regarding the internal information of companies. Even simple online productivity tools and apps, such as to-do lists, notebooks or scanning software, disclose knowhow and other sensitive information to the cloud service provider. When such data is concentrated in few large cloud service providers, these providers also gain a competitive edge from the knowledge that other companies create and become an attractive target for cyber-attacks. The fast pace of digitization and the increasing complexity of consumer electronics make it impossible for the average user to truly understand the technology, the connected risks and their possible consequences. Quite the contrary–the seeming anonymity of the Internet makes them feel safe.

Our lack of media maturity is the business model of companies and institutions which aim at influencing our behavior and opinions. How can we still become responsible users of these technologies? How can we protect those who are actively and passively affected? How can we maturely deal with technologies that we do not understand as they constantly change and adapt to us and our behavior?

Schools already present measures for increasing competence in the use of digital media. Yet, education for the responsible use of digital media is needed for users of all age groups and must include legal and ethical problems. How should teachers handle student grades on their private computers? Do childcare workers have the right to take photos of kids with their smartphones and upload them into the cloud? Anyone who handles the data of others needs to be aware of the consequences. Of course this can only be achieved in part, as the pace of innovation makes it impossible to keep up.

Ethical Questions and Liability

Automation and the analysis of big data raise many ethical questions, especially that of discrimination and the question of liability.

Insurance companies, banks and employers are all interested in reducing risk by having better estimates of our health status, creditworthiness and personal traits. While factors such as gender or age have previously influenced insurance premiums, big data makes it possible to include many other (seemingly irrelevant) factors, enabling automated discrimination.

Even by making conscious choices, individuals cannot necessarily safeguard their own privacy. When family and friends credulously hand over emails, address books and photos to cloud providers to save against loss and deletion, they share the data of others who have likely not given their consent. Companies such as Facebook build "shadow profiles" of members and non-members from data that other users share (ZDNet.com 2013). By having access to the address books of members, a map of contacts can be obtained, even of non-members. Such maps, together with location data on few friends, can reveal the location of a privacy-conscious person (Sadilek et al. 2012).

Interestingly, the authors of the aforementioned paper "*recognize that there are substantial ethical questions ahead, specifically concerning tradeoffs between the values [their] automated systems create versus user privacy. […] However, [they] believe that the benefits of [their friendship- and location-predicting algorithm]—in helping to connect and localize users, and in building smarter systems—outweigh the possible dangers. There are many exciting practical applications that have the potential to change people's lives that rely on location and link prediction.*" Obviously, applications of public interest exist. The authors name disease prevention and containment as one such example. The developers of such systems, however, cannot be expected to be the best judges with respect to weighing the chances and risks of their innovation. The trade-off between big data and data privacy needs ethical committees to define the borders (see Part V.1 “Memorandum”: “General recommendations” and Part V.2 “Specific Recommendations”).

When important decisions within fully automated processes are left to algorithms, a generally accepted optimization goal needs to be formulated that defines how decisions are made. Automotive traffic can serve as an example: When humans are faced with an unanticipated event in traffic, they can only act intuitively. A machine, however, may be able to simulate possible actions and evaluate their possible outcomes within microseconds (given accurate sensing). In order to calculate the optimum decision, however, a fixed rule is needed of how the outcomes are compared. While the human reaction may in retrospect be categorized as “human error” the underlying rule of the machine’s reaction is subject to ethical considerations and may touch many ethical border cases.

Autonomously acting algorithms also raise questions of liability. The algorithms are designed and used by people and can only be as objective as their design and the data they are fed. The question of liability needs to be settled and the roles of all involved parties must be clarified before control is handed over to the algorithm.

Only a few machine learning algorithms, such as decision trees, yield results that can be easily interpreted by humans. Popular (deep) neural network algorithms gain much of their power from their complexity, inherently making it very hard for humans to understand the active principles. These algorithms do what they are trained to do. Therefore, bias in the data they are trained on, or an incorrect formulation of what they should learn, can lead to unexpected failure. Whoever takes on responsibility for such an algorithm’s autonomous decision does it in the light of not understanding the exact way it works.

In summary, we cannot prevent the development of new technologies which challenge our ethical and social understanding, but we can make an effort to steer them in such a way that they serve the wider public.

Connections with Environmental Challenges

There is rising awareness for the limitedness of our resources, for climate change and the necessity to use less energy, for instance. This awareness and the cost of energy make energy saving a selling point. It seems to soothe our conscience to believe that by equipping our homes with sensors and gadgets we can save energy, money and the world. “Smart” devices are often advertised with the simple claim that they help in saving energy. It may be true that we can reduce the amount of energy directly required to heat our home using “smart home” devices, which detect whether or not someone is at home and starts heating again when we are on the way back home. What is usually ignored in these calculations is the energy that goes into manufacturing, shipping and installing the devices, the power consumed by the sensors and the ICT infrastructure. There is little evidence to support that “smart” gadgets generally help save energy. Instead, if there is potential, one can expect that rebound effects will nullify those savings.

Data science itself has a high energy demand that will continue to grow with the number of IoT devices. The whole infrastructure, from the smart device to the data center, consumes energy when data is gathered. The analyses, many of which simply aim at better understanding customer behavior, consume energy. Instead of creating any value, they serve only to raise hyper-consumerism to even higher levels with the associated environmental effect. Moving data into the cloud means that we are less capable of seeing the footprint of our online data consumption, as it does not appear on our electricity bill. Apart from the energy consumption, the whole life cycle of the billions of IoT devices and the whole ICT infrastructure needs to be taken into account when the environmental impact is assessed.

Conclusion

We have argued that it is not enough to push away privacy concerns assuming that Internet users have no interest in privacy because they willingly share all sorts of information with the general public. Whether or not an individual values their privacy is not overly relevant for many reasons. The average users cannot make a mature, fully informed decision, and they have little influence on which of their data are shared by others. Furthermore, since a lack of data privacy poses a threat to society and democracy, the issue is too important to leave the protection of data to the individual.

The discussion about how much and which data may be acquired and stored and in which ways it may be analyzed should put the concerns of citizens and society at large in the center of attention, not the interests of profit-hungry companies. The legal protection of our data must not be made void but should instead be expanded to meet the risks that the digital era poses. "Over-sharing" must not be interpreted as a sign that privacy is no longer valued. Instead it may indicate a lack of awareness of possible consequences. Since the definition of which data is private depends strongly on the context in which the data is used, regulations must also define the purposes data may be used for and how data may be aggregated.

Skepticism and critical thinking can mitigate some of the risks of manipulation. The awareness of the value of our data and the risks connected to our digital traces needs to be promoted to help make us mature users of our technology. Transparency is needed with respect to where data is collected, how it is analyzed and how automated decisions are made. We may assume that developers act with good intentions and that they act based on their passion for the technical possibilities and a strong belief in progress. Still, they may not be able to gauge the complex effects that their products have on society. The discussion needs to be promoted and boundaries set for all algorithms which make automated decisions, be it the personalized result of a search query, the insurance premium for a single person or the reaction to an event in traffic.

The discussion that is currently held on simple claims that smart cities, autonomous cars and the like will improve our lives tremendously needs to move to a more factual discussion about our values, rights (privacy, democracy, etc.) and our priorities. The chances and risks need to be evaluated holistically and objectively. This brings us back to the underlying motto of this book: "Exploring possibilities and limits of a sensible and responsible dealing with risks". Instead of letting technocrats decide what the future looks like, we should make an effort to design our common future sensibly and democratically, and be considerate of future generations. In particular, answers have to be found on how much freedom we are willing to give up for comfort.

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Chapter 23
Sustainable Risk Management in Business

Martin Steger

Introduction

Any innovation and any technological development bear a threat of failure, a threat not only to the acting organization, but also to a number of other persons affected. Decisions in an enterprise affect owners and shareholders. Employees rely on right decisions to keep their job. Clients rely on goods and services of a quality that suits the purpose and allows a safe handling of the product.

Risk is intrinsic to business. Business transactions and projects are carried out for profit but equally bear the risk of losses and venture. A decision is the choice between two paths, only one of which will turn out to be correct. Risks in business are caused by internal and external effects. Typical internal effects are of strategic or operational nature, human resources, data processing and financial risks. The product must meet the demands of the market (see Fig. 23.1).

In addition, there are situations that we must deal with that come from outside (external risks) and demand decisions connected with further uncertainties. Besides risks on the market, there are challenges that cannot be altered by a business company. There are political changes, environmental issues and changes in society.

Risk management has increasingly become an issue in economic leadership in bank and business matters. It is subject to legislation and normative business standards. Recent regulations demand a fundamental risk management for enterprises and processes. The basic standard on quality management in organizations (DIN ISO 9001) has turned its focus from description of processes to risk management. The European Capital Requirements Directive (CRD, Basel III) (Directive 2013/36/EU), regulating access to the activity of credit institutions and the prudential supervision of credit institutions, focuses on business risks as well and is the base of credit for investing companies.

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Fig. 23.1 Wrong business model (*Source* Photo by the author)

With this background, risk management seems to be the main issue of today´s economics. The number of books on this topic covers shelves in bookstores. Many corporations employ risk managers or have installed risk management departments.

If risk management is such a critical issue, why do companies sometimes act so hazardously? A corporation manufacturing rubber boots became one of the market leaders in mobile communication and now has turned back to rubber boots; the largest company in photographic technology almost vanished into oblivion; companies are playing with their fate using corrupt sales methods.

Tools

There are many tools for risk evaluation and risk management. Some examples:

ISO 9001 demands a general overview of risks for the processes of an organization. Table 23.1 shows an example of a risk analysis matrix. Risks must be identified beforehand. Risk evaluation serves as a type of diagnosis to make evident

- Specific issue
- Occurrence probability
- Escalation rate (grade of effect)

Table 23.1 Typical risk analysis matrix (Source: Quality Management COPLAN AG)

Risk	Exemplified issue	Parties involved	Probability of occurrence	Escalation rate	Measures	Responsibility
Strategic risks						
Operational risks						
Human resources						
Data processing						
Financial risks						
Regulative risks						
Political risks						

An instrument developed in the 1990s designated to give a fundamental approach to business decisions is the Balanced Scorecard. This instrument is intended to be a kit of different criteria to measure performance of an organization (Kaplan and Norton 1996). Balanced scorecards can also be used for specific decisions or strategies (Fig. 23.2).

This tool is characterized by the combination of hard facts and soft criteria. In order to be calculated in a scorecard, soft criteria must be turned into calculable numbers.

Single processes and decisions can furthermore be analyzed by tools such as SWOT-analysis (analysis of strengths, weaknesses, opportunities and threats). In a 2 × 2 matrix, the internal (strength, weakness) and external (opportunity, threat) effects to the decision are summarized and can be pondered.

The “Plan–Do–Check–Act (PDCA)” Cycle, according to W.A. Deming, is part of the ISO 9001 standard. This cycle indicates a permanent control of terms, processes and results to achieve a continuous improvement of the organization (Fig. 23.3).

Risk analyses, though, have limits. Economic data are hard facts that allow—almost—no interpretation. Yet, according to Albert Einstein, not everything that counts can be counted, and not everything that can be counted, counts. When soft factors come into play they are subject to interpretation. Analyses of soft factors will

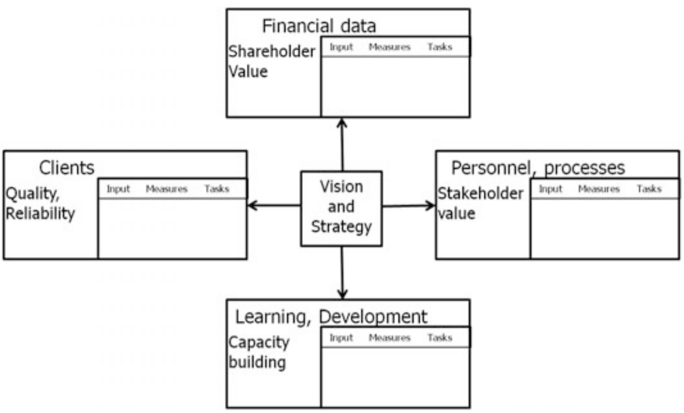

Fig. 23.2 Typical balanced scorecard according to Friedag and Schmidt (2002)

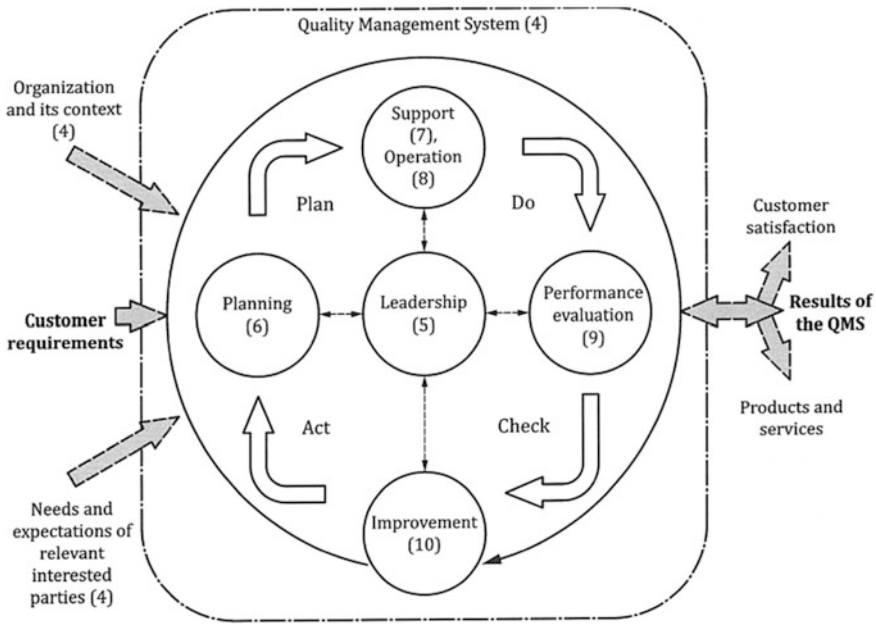

Fig. 23.3 PDCA Cycle (Plan–Do–Check–Act) (*Source* DIN ISO 9001 2015)

show different results depending on the persons carrying out the evaluation. Effects and probabilities will be considered individually. Risk analysis can thus rend a venture predictable only in a sense that we call the behavior of a person predictable.

These tools bear a risk in themselves: They mislead to the belief that we are in reliable knowledge about future developments. All the input to these tools is human made and thus influenced by human thinking. In fact, decisions are commonly based on intuition, instinct and common sense. They will be based on experience and neuronal functions.

It is an additional challenge to human thinking that risks are moving from individual threats to a superior or even global level. A travel through a continent was time consuming and a danger to life in former centuries. Today we safely cover these distances in hours. The impact of traffic is now much more related to ventures in primary (energy consumption) and secondary resources (pollution), affecting a much larger number of lives. Basic human instincts are not apt to identify these issues.

Dealing with Risks

Ways to tackle risks can be:

- Avoiding risks
- Eliminating risk sources

- Partitioning of risk
- Taking risks to gain chances and acting responsibly
- Risk transfer

Risk transfer can be a legitimate way to reduce the risk for a person or an organization. In fact, we all transfer risks via insurance to prevent us from oversize financial damage, for instance, in a car crash.

An illegitimate and unfair risk transfer takes place when large organizations might fail and the damage is transferred to society. "Too big to fail" was the keyword during the financial crisis in 2008.

Avoiding risks is frequently misinterpreted as avoiding decisions. Not to decide means a loss of action. The initiative will then be taken by other persons or institutions. This will not solve any problem nor avoid any risk. In fact, further risks of a new character can turn up possibly with even higher risk potentials.

The only way to deal with risks in business is to take ventures and act in a prudent way. A policy of eliminating or avoiding risks cannot be the basis of business decisions. Innovations go along with risks. Facing a continuously—or even disruptively—changing market, changing regulations and changing demands makes it necessary to develop and bring forward innovative products and solutions. We face new situations more and more frequently, since the speed of development seems to increase steadily. Still we tend to stick to familiar methods and familiar technologies. The more than hesitant progress towards electromobility seems to be "driven" by car manufacturers and suppliers who are anxious about how they will be able to trade their today´s products in the future. Rather proceed with familiar technology to the absolute limit than change to a new system seems to be the dictum (Fig. 23.4).

Decisions in new and unfamiliar situations demand a resilient approach and need to be cut down into several steps. Further steps will only be taken when the previous action proved successful. This is one of the ideas of the PDCA cycle. The inventor of this instrument, W.A. Deming, largely influenced Japanese economy by his principles of increasing product quality by a process of continuous improvement.

Risks can be minimized by keeping negative results transparent. This possibly is the key to deal with business risks, although it diverges from common business principles promoting the efficiency of processes. Efficiency and resilience contradict each other. The more efficient a process is established, the more it depends on fixed base conditions. Resilience is the way to deal with uncertain conditions.

Error Aspects

Errare humanum est—to err is human. We must face the fact that humans commit errors. A sustainable management of risks must take this into consideration. Tools that make effects evident are more and more common. Economic effects, as well as

Fig. 23.4 “Adventurous risk management” (*Source* Cartoonstock, Internet)

effects in processes, are presented by the simple figure of a traffic light with green showing an o.k., yellow giving a warning and red signaling danger. I personally am captivated by the way the function of a person on an American aircraft carrier can simply be identified by the color of their outfit. The more complex a process is, the simpler the signals should be.

According to Reason (1994), human errors can be distinguished into different types. We all know execution-based errors (slips and laps). Did you ever find yourself wearing socks of two different colors? Execution-based errors in most cases have manageable implications.

On a rule-based level we deal with familiar issues. Mistakes may occur when we choose a wrong or inadequate rule to solve the problem. A rule that may have been the right choice in the past can proof wrong in the current situation.

A knowledge-based level comes into play in novel situations, where actions must be planned using analytical processes and memorized knowledge. In these situations, decisions must be made to deal with an uncertain future. Risks arise from a limit of resources and incomplete or incorrect knowledge. Our knowledge is based on our experience and thus will be incomplete to deal with new situations.

Especially in these situations, fair play in the organization and a positive working climate are keynotes to a sustainable risk management. A frank and open communication inside an organization is of the essence. Errors will necessarily have to be brought up to be corrected. Hierarchy combined with communication

Fig. 23.5 Maintaining established standards (*Source* Photo by the author)

problems can lead to fatal developments once a wrong way has been chosen. It may lead to illegal actions, to a loss of clients and to expensive compensation issues. Furthermore, it is a severe obstacle to necessary progress in technology to meet altered requirements. Effects of maintaining obsolescent standards are evidently more common in organizations with a dominant leader (Fig. 23.5).

Fig. 23.6 Ianus, Roman God of changes (*Source* Internet en.wikipedia.org)

Conclusion

Decisions afford courage, one of the Aristotelian virtues. In Aristotelian ethics virtues are defined as a median between two extremes. Courage is the right measure between cowardice and folly. The right way to deal with risks is based on the ethos of the stakeholders. Persons active in business should take personal responsibility and lead developments forward rationally and with emotion.

Our thinking and our background to take decisions is based on experience. All our knowledge has its source in the past. This leads us to carry on in trodden paths instead of accepting changes. The correct way to prepare for decisions would be an Ianus-headed approach looking backward at experiences and at the same time contemplating consequences and outcomes for future actions. Ianus is the Roman god of change and of transitions (Fig. 23.6). He symbolizes beginning and end, light and darkness and the transition from past to future.

Let us transfer our experiences into future action—digested by brain.

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Part V
Memorandum

Chapter 24
General Recommendations

Peter A. Wilderer

For Decision Makers in Governmental, Economic, and Societal Institutions

Risks are taken in order to seize new opportunities and profits. At the same time, actions associated with potential negative side effects may lead to inacceptable negative consequences. When placing emphasis on the potential negative consequences, the term "risk" points to the possibility of the occurrence of harm, including disasters. However, risks also provide chances for important innovations and create momentum for sustainable development. In the case of risks with global effects (above all, environmental and social degradation, water and soil deterioration, and further spread of poverty, thirst, and hunger), governments are encouraged to act in the long-term interests of society and not in short-term economic interests. Otherwise, such risks will be further intensified through secondary consequences that build on them (e.g., health, social, and political risks).

Reflecting on such concerns, the participants of the workshop recommended to consider the following aspects in the process of decision making (Figs. 24.1 and 24.2):

a. Customized strategies are needed for the various types of risks (risk categories).
b. Every decision includes some degree of risk. What is essential is whether the level of the remaining risk is acceptable to society.
c. Decision making should not rely solely on feelings or perceptions, particularly when the decision has binding effects about whether a whole society or community should or should not accept or tolerate a given risk. Rather, the discussion on the emotional level has to be supported by rational argumentation and considerations.

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d. A solution-based management of risks should not be compromised by unilateral interests and exertion of power.
e. The probability of failure is inherent in every technical system. The decision whether in any particular case the likelihood of failure is tolerable requires a participatory discourse.
f. Prior to decision making it is important to reach a consensus on the criteria and the relative weights for each benefit and risk. Important in this process is the acquisition of the best available knowledge regarding the consequences, but also the inclusion of uncertainties and knowledge gaps.
g. Politics must strive on the one hand for an evidence-based approach when it comes to weighing opportunities and risks, yet on the other hand, promote a safety culture favoring error-friendliness and resilience due to the remaining uncertainties.
h. Strategies for managing risks requires the readiness of taking responsibility. Those who are making final decisions have to take into account the likely consequences of their decisions. Only by responsible risk management and governance can trust in risk management institutions be created.
i. Analysis and evaluation are both necessary elements of risk management. The analysis comprises the best available assessment methods for characterizing probability and extent of the consequences. In addition, risk management needs to set standards of what remaining risk is deemed tolerable for society and its constituents. This value judgment should include a variety of societal viewpoints.
j. Risk assessments have to be continuously scrutinized and, when necessary, corrected and updated. The limits and possibilities of a risk assessment are to be communicated openly in order to contribute to the risk awareness of those responsible and those affected.
k. A democratic culture of sustainable risk management is an important instrument to assign the adequate trade-offs between efficiency, effectiveness, resilience, and fairness of decisions.

Explanation

a. Customized strategies are needed for the various types of risks (risk categories). The term “risk” means in general the possibility of the occurrence of negative or unwanted consequences of an action or an event, such as death, illness, and ecological or monetary damage. The risk is calculated according to the probability of the occurrence and the extent of damage. Sustainable management of each type of risks requires specific interventions. There is no universally applicable method of dealing wisely with risks.
b. Every decision includes some degree of risk. What is essential is whether the level of the remaining risk is acceptable to society.

Even when all measures available to limit the product of probability of occurrence and even when the extent of damage have been exhausted, it is de facto impossible to lower this result to "zero". A residual amount of risk always remains, as low as it may be.

c. Decision making should not rely solely on feelings or perceptions, particularly when the decision has binding effects about whether a whole society or community should or should not accept or tolerate a given risk. Rather, the discussion on the emotional level must be supported by rational argumentation and considerations.

Fears borne out of emotions are usually not a good guide for action when it comes to complex threats. On the contrary, a rational, science-based approach is required. Proposed solutions should be communicated in an easily understandable manner and continuously reviewed against current scientific knowledge.

In case of conflicts between a solution determined by technical algorithms and a similarly effective solution focusing on judgments of people, the latter solution should have precedence in principle.

d. A solution-based management of risks should not be compromised by unilateral interests and exertion of power.

In the case of societal relevant risks, beneficiaries of technical changes and those who are likely to bear the risks often do not coincide. This is why it is particularly important that the allocation of risk and benefit to target individuals and groups is determined in a just and fair manner. Beyond that, it has to be ensured that knowledge of risks is generated and applied independently and without privileging one-sided interests.

e. The probability of failure is inherent in every technical system. The decision whether in any particular case the likelihood of failure is tolerable requires a participatory discourse.

Living a culture of failure is to be understood as part of innovation. To achieve societal acceptability that technical systems may fail requires information and justification on both the probability of harm and the extent of harm (guiding principle: as low as reasonably possible). In this context, it has to be understood that any strict minimization of the likelihood of failure (i.e., the maximization of reliability) may cause a significant increase of costs. General experience shows that the same effort is required for the final 5% to gain a "100% result" as for reaching the initial 95% (marginal costing).

f. Prior to decision making it is important to reach a consensus on the criteria and the relative weights for each benefit and risk. Important in this process is the acquisition of the best available knowledge regarding the consequences, but also the inclusion of uncertainties and knowledge gaps.

Every decision made under conditions of uncertainty includes three components of action:

- The assessment of the consequences of each option.
- The uncertainties connected to this assessment.

- The desirability of each option based on the assessment of the respective consequences and the utility it provides for society.

Each strategy for managing risks requires knowledge, classification of uncertainties, and risk assessment. However, it is not possible to adequately judge the acceptability of risks based on knowledge alone; both knowledge and values are required in order to evaluate and manage risks responsibly.

g. Politics must strive on the one hand for an evidence-based approach when it comes to weighing opportunities and risks, yet on the other hand, promote a safety culture favoring error-friendliness and resilience due to the remaining uncertainties.

Science and politics should strive towards a contribution to public risk awareness. Transparency of the available information, as well as the communication of limits and prospects of the risk assessment are crucial components of a responsible outreach program.

In order to be successful in this context, the following steps are necessary:

- Setting up a knowledge base while observing scientific standards, data protection regulations, and quality standards.
- Promoting and emphasizing goal-oriented and result-oriented research.
- Maintaining fact-based knowledge transfer, improving educational efforts with respect to probability and risk knowledge, and creating awareness so that critical decision-making processes will not be distorted by subjective perceptions.

A sensitivity for responsible strategies of risk management should be promoted already in school and during professional training. An introduction to risk awareness should be part of education in all school subjects, but particularly in the STEM subjects (science, technology, engineering, and mathematics)

h. Strategies for managing risks requires the readiness of taking responsibility. Those who are making final decisions have to take into account the likely consequences of their decisions. Only by responsible risk management and governance can trust in risk management institutions be created.

Risk management is to be guided by a sensitive balance of knowledge and ignorance, trust and responsibility.

As our world becomes increasingly complex, it is essential to assign the responsibility for risk management to persons or institutions possessing not only the necessary knowledge but also the ethical background needed to make decisions that are sound both factually and morally. Only once these conditions are met society's willingness to trust "service providers" can grow. Irresponsible actions lead to loss of trust and thus to secondary risks. As a consequence, supervisory bodies and liability regulations have to be instituted and governed to focus on responsibility and trust.

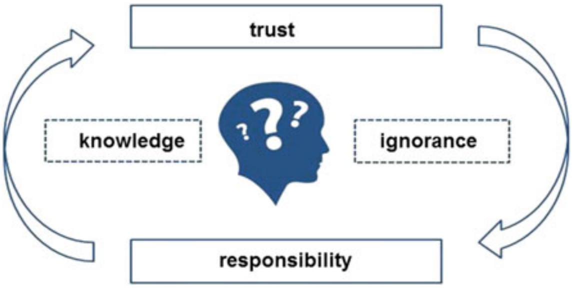

Fig. 24.1 Risk management requires a balance between trust and responsibility, knowledge and ignorance

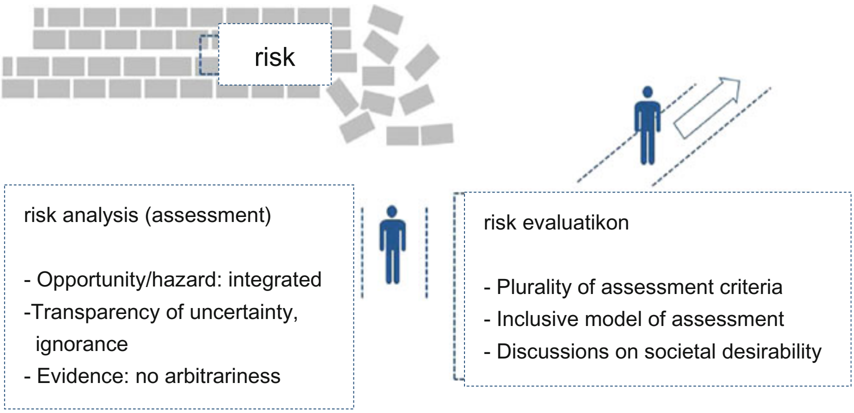

Fig. 24.2 Crucial components of an effective risk management process

i. Analysis and evaluation are both necessary elements of risk management. The analysis comprises the best available assessment methods for characterizing probability and extent of the consequences In addition, risk management needs to set standards of what remaining risk is deemed tolerable for society and its constituents. This value judgment should include a variety of societal viewpoints
Analysis and evaluation are crucial components of an effective and responsible risk management. The following graphic illustrates this process:
j. Risk assessments must be continuously scrutinized and, when necessary, corrected and updated. The limits and possibilities of a risk assessment are to be communicated openly in order to contribute to the risk awareness of those responsible and those affected.

The evaluation of risks results from current scientific insights and societal framework conditions (legal standards and ethical values). Since either of these factors is continuously changing, risk assessment must be continuously and dynamically adjusted.

It is the principle goal of increased safety to reduce the risk inherent in the use of a technical system (e.g., the stability of a dam, or the reliability of the steering function in a vehicle). The aim is to limit risks to a degree that deems acceptable to the affected publics. In this process, the assessment of how large inherent risks actually are and how effective strategies for risk reduction are designed is to a large degree relying on sound methodologies based on experiences with existing technical systems and their management (e.g., possibilities of improper use, sources of technical failure). Especially when new technology is introduced, standardized approaches may reach their limits (e.g., unknown mechanisms of action) and are thus subject to failure themselves. This is where new adaptive management approaches are needed.

It is the task of science and politics to ensure transparency with respect to all assumptions that underlie all risk assessment methods and protocols, particularly for innovative technology. It is important to communicate the assumptions clearly in order to make the limits and prospects of the assessment understood by those affected and those responsible, thus providing a sound and useful basis for a decision. Deliberately taken "blind spots" in the process of risk evaluation counteracts the development of public resentments that may impede innovations if an unexpected risk occurs.

k. A democratic culture of sustainable risk management is an important instrument to assign the adequate trade-offs between efficiency, effectiveness, resilience, and fairness of decisions.

Assigning trade-offs for the purpose of risk management requires a participatory and deliberative process in a democratic society. Uncertainties must be taken into consideration when making acceptability judgments. Of course, in addition to the factors of efficiency, effectiveness, resilience, and fairness, the benefit needs to be considered, too. Focusing on benefits only is not expedient.

Chapter 25
Specific Recommendations

Peter A. Wilderer

1. Responsible management of systemic risks requires the willingness to continuously learn even from weak signals of the environment. Moreover, far-reaching decisions regarding risk management need to be examined through independent democratic bodies and balanced by multiple safeguards.
2. Systemic risks often occur as a result of implementing or governing complex systems characterized by a high degree of interdependencies (e.g., Internet of Things). Dealing with systemic risks requires suitable strategies that are designed to cope with the systemic character of these risks. Successful strategies for managing conventional risks are only to a limited extent applicable to handle systemic risks.
3. For ensuring a sustainable use of the opportunities of digitalization (e.g., autonomous driving, robotics, Industry 4.0), a sustainable labor market policy is required that meets the human need for a life in dignity.
4. For a systematic overview of environmental risks (e.g., climate change, water and soil degradation, loss of bio-diversity, engineering landscapes) a dynamic risk inventory is necessary according to causes and sectors.
5. Global goals, such as the Sustainable Development Goals of the United Nations or the Paris Agreement, must be taken into consideration at all subsidiary levels of political decision making when risks are governed. Such considerations must also be part of any risk communication.
6. For the sake of minimizing risks in (oncological) medicine, health policy has to ensure an ethically substantiated and knowledge based training and education of physicians.

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7. Politics are urged to base any communication strategy on mammography screening on medical competence.
8. Powerful governmental registers are needed in order to enable optimal long-term care of patients in radiation medicine.
9. Within the mandate of risk regulation to minimize risks to patients, health policy should conduct constant and regular reviews of the approval requirements for new drugs.

Explanation

1. Responsible management of systemic risks requires the willingness to continuously learn even from weak signals of the environment. Moreover, far-reaching decisions regarding risk management needs to be examined through independent democratic bodies and checked/balanced by multiple safeguards.

Systemic risks have four characteristics:

1. They occur across systems (often globally).
2. They are complex and interlinked.
3. The effects are not linear.
4. The cause-effect chains follow stochastic patterns.

This oftentimes makes these risks hard to detect and easy to underestimate since the dominant learning strategy to advance by trial and error does not apply here. In non-linear systems, the error only becomes apparent when it is already too late, and there is no second chance.

Therefore, it is imperative to create institutions and regulations that on the one hand systematically pick up and evaluate weak signals for systemic risks and on the other hand simulate possible consequences in a virtual space in order to be able to intervene already at a point in time when the negative consequences have not yet become substantial. This requires a close interaction of science and politics.

2. Systemic risks often occur as a result of implementing or governing complex systems characterized by a high degree of interdependencies (e.g., Internet of Things). Dealing with systemic risks requires suitable strategies that are designed to cope with the systemic character of these risks. Successful strategies for managing conventional risks are only to a limited extent applicable to handle systemic risks.

Mankind must remain an integral part especially of highly automated systems (e.g., robotics) with regard to responsibility for and trust in the control of such system and of the associated know-how. Liability and responsibilities must be decided upon before control is passed on.

3. For ensuring a sustainable use of the opportunities of digitalization (e.g., autonomous driving, robotics, Industry 4.0), a sustainable labor market policy is required that meets the human need for a life in dignity.

Digitalization is a key innovative development in all industrialized countries. If a country such as Germany, which is characterized by industry, misses this development, it faces being degraded to the status of a supplier country: the big IT groups (especially in the US) will then dominate for example the automotive sector, the–motor and plant engineering—but also the agricultural sector.

On the other hand, digitalization will go hand in hand with a dramatic change of the labor market. Politics should realize that digitalization is more than a matter of technical and economic success. It is a social challenge. In the next 10 years, many industrial sectors and branches of profession and trade will become obsolete if they continue to be based on traditional methods. They will be replaced by artificial intelligence. The question, "When will machines take over?" illustrates the fear of imminent job loss due to automation.

Until now, one of Germany's locational advantage has been its traditionally highly developed vocational training (e.g., dual-training system). School, university, and vocational training have to make sure that they prepare people for new innovation boosts ahead of time. This requires lifelong learning, the framework conditions for which must be set to education, business, and economic policies.

So far, little attention has been paid to the fact that the global digitalization of infrastructures (e.g., mobility) is highly dependent on energy. The increase in efficiency through digitalization has an energy price that is reflected in the environmental balance. Digitalization is therefore a challenge for the entire society consisting of opportunities and risks for which politics must consider the technical, economic, social, and ecological aspects (i.e., across the competent government departments).

4. For a systematic overview of environmental risks (e.g., climate change, water and soil degradation, loss of bio-diversity, engineering landscapes) a dynamic risk inventory is necessary according to causes and sectors.

Environmental risks have a collective effect. Mankind only reacts when motivated to minimize risks. In order to gain a comprehensive overview of the environmental risks, we suggest a dynamic risk inventory. The inventory should be organized by causes and effects and by types of risk. The following table is a first attempt to demonstrate the inventory outlined above. We chose agricultural production of protein as an example (Table 25.1):

It should also include the definition of the risk and the necessary steps to minimize them. The goal hereby is to sufficiently motivate those acting to overcome taboos (unquestioned self-evident truths) and to question risk-promoting justifications.

In addition, specific remedies should be explained and the institutions responsible explicitly named.

The perception of risks and the options to manage them are continuously developing further. Environmental risks and remedies must be regularly questioned and re-evaluated in keeping with scientific and technical changes.

Table 25.1 Risk inventory: agricultural production as an example

Risk type	Examples of risks	Motivation for risk management	Arguments for negating a risk	Institutions for remedies
Normative	• Violation of • Good practice • Water framework directive • Current standards	• Transparency • Knowledge transfer • Changes in consumer behavior • Public disapproval	• Short-term advantages • Lack of acceptance • Lack of knowledge	• Strengthen execution • Strengthen awareness of standards • Sanctions
Technical	• Drying of wetlands • Reduction of capacity to bind $C0_2$	• Technically evident events • Gaining insight	• Additional costs for existing systems	• Create standards • Benchmarking • Governmental warranty
Suppressed	• Multi-resistant germs from animal husbandry • Health effects of unbalanced consumption • Consumption of terrain • Secondary effects in developing countries	• Visualization • Create concern • Public discussion, among other things as "scandal"	• Resistance to change • Negation of opportunities	• Science • Civil society • Medicine • The media • Education system • Authorities
Hypothetical	• Effect of novel chemicals • Spreading of resistant germs • Spreading of nano-particles • Scarcity of food	• Precautionary principle • Analysis of scenarios	• Violation of the "codes" of science • Bias of the large financial bankers • Ideologies • Resistance to insights	• Fantasies, fears, hopes • Think tanks such as IESP • Governmental bodies • Environmental associates • Research

5. Global goals, such as the Sustainable Development Goals of the United Nations or the Paris Agreement, must be taken into consideration at all subsidiary levels of political decision making regarding the limitation of risks. Such considerations must be part of any risk communication.

Considerable systemic risks result particularly from alarming developments with global effects. For example, the environmental crisis as a whole is to be classified as an overwhelming threat to our global civilization. It is the task of the United Nations and its agencies to agree on global approaches to global risks. Such agreements serve as positive signals that give rise to hope. Current examples are the COP 21 agreements made at the climate summit in Paris and the Sustainable Development Goals succeeding the Millennium Development Goals of the United Nations.

To begin with, it is the duty of the signing states to implement these regulations in their respective legislations. It would be helpful for several reasons if in addition to this hierarchical implementation there would also be a more intense subsidiary perception and take-over responsibility for these goals by each individual on Earth. The broad identification with global ethical assumptions would make it easier for politicians to act responsibly in favor of the whole (e.g., when it comes to investments in development aid and other expressions of solidarity among the members). Moreover, such successful joint initiatives and agreements counteract the fatalistic collective paralysis resulting from the feeling of being powerless as an individual, despite recognizing the global risks.

This positive perception should also apply to our relationship to the EU. The role of the EU as a strong collective immunization system, especially against environmental risks, is much too rarely recognized and often purposefully defamed as being "dirigistic". As experience shows, internationally binding programs such as the water framework directive and the Natura 2000 network represent highly effective strategies for minimizing risks.

6. For the sake of minimizing risks in (oncological) medicine, health policy has to ensure an ethically substantiated and knowledge based training and education of physicians.

Each individual patient must be advised and treated in his or her existential uncertainty by a responsible physician in a professionally funded and empathic manner. This goes beyond medicine that is based purely on guidelines and algorithms and requires corresponding political framework conditions and acceptance by society.

Risk communication must take place in a space that to the greatest extent possible is free of economic (pharma industry), systemic (bureaucratic health care systems), and egotistical influences. It must be ensured that patients are informed about alternatives/risks. Risk consideration (and risk communication) has to refer to the life time and not only to a few years.

7. Politics are urged to base any communication strategy on mammography screening on medical competence.

The current communication strategy concerning mammography leads to an over-emphasis of risks and to an underestimation of advantages when comparing it with the alternatives of in part extremely stressful therapies of tumors developing later on. Politics are urged to correct this by including medical competence.

8. Powerful governmental registers are needed in order to enable optimal long-term care of patients in radiation medicine.

In radiation medicine, optimal patient care includes long-term support in order to be able to quantify risks such as late sequela, interactions of different therapies, and secondary tumors. This requires the application of new and different methods in order to collect and evaluate long-term data and depict the quality of results. This only works using powerful, governmental registers.

Creating, scientifically supporting, and financing is a task for the government and is to be carried out by a governmental institution according to methods that are uniform in all federal states regarding the data on diagnostics, therapies, and life-long aftercare that are to be documented.

9. Within the mandate of risk regulation to minimize risks to patients, health policy should conduct constant and regular reviews of the approval requirements for new drugs.

No more deaths because of therapy combinations that are necessary in principle, yet have not been researched!

When ethics committees evaluate multi-modal therapies, they should pay special attention to the problems that can occur due to possible interactions of radiation and drugs (chemotherapeutics, biologics, etc.). The results of the pre-clinical testing of

Fig. 25.1 Signatories in alphabetical order: Klaus Arzet, Werner Bauer, Michael Belau, Werner Buchberger, Wolfgang Bonß, Patrick Dewilde, Markus Disse, Teresa Wildemann, Michael Flentje, Anton Frank, Daphne Gondhalekar, Franz-Theo Gottwald, Konstantin Grambow, Martin Grambow, Tobias Hafner, Thomas Herrmann, Sylvia Heywang-Köbrunner, Ulrich Hildebrandt, Georg Iliakis, Julia Jost, Michael Kellnberger, Willi Kiefel, Andreas Klinke, Claudia Klüppelberg, Jane Korck, Daniela Korhammer, Peter Lukas, Klaus Mainzer, Wolfram Mauser, Daniel Mendéz, Michael Molls, Ursula Nestle, Elke Oettinger, Claudia Peter, Ortwin Renn, Max Rossmann, Bernhard Schätz, Gernot Spiegelberg, Franziska Steger, Martin Steger, Adrian Straub, Theodor Strobl, Gabi Toepsch, Klaus Rüdiger Trott, Markus Vogt, Raoul Weiler, Peter A. Wilderer

new drugs that are potentially to be administered at the same time as or sequentially with the radiation treatment are to be evaluated by scientists with experience in radiation biology using adequate in vivo models.

The Signatories

See (Fig. 25.1).

Erratum to: Sustainable Risk Management

Peter A. Wilderer, Ortwin Renn, Martin Grambow, Michael Molls and Klaus Mainzer

Erratum to:
P. A. Wilderer et al. (eds.), *Sustainable Risk Management*, Strategies for Sustainability, https://doi.org/10.1007/978-3-319-66233-6

The original version of the book was inadvertently published with incorrect location "Vatican City, Italy" in Foreword (page (vi)), which has been now corrected as "Munich, Germany". The erratum book has been updated with the change.

The updated online version of the book frontmatter can be found at https://doi.org/10.1007/978-3-319-66233-6

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Strategies for Sustainability, https://doi.org/10.1007/978-3-319-66233-6_26