Gesellschaft – Technik – Umwelt, Neue Folge | 26
Society – Technology – Environment, New Series

Grunwald | Krings | Lösch | Scheer [Eds.]

Back to the Roots

The Conceptual Development of TA in Germany

Nomos

Gesellschaft – Technik – Umwelt
Neue Folge

Society – Technology – Environment
New Series

edited by the Institute for Technology Assessment and Systems Analysis (ITAS) at the Karlsruhe Institute of Technology (KIT) and by Prof. Dr. Armin Grunwald

Volume 26

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Andreas Lösch | Dirk Scheer [Eds.]

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The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at http://dnb.d-nb.de

1st Edition 2025

Published by
Nomos Verlagsgesellschaft mbH & Co. KG
Waldseestraße 3–5 | 76530 Baden-Baden
www.nomos.de

Production of the printed version:
Nomos Verlagsgesellschaft mbH & Co. KG
Waldseestraße 3–5 | 76530 Baden-Baden

ISBN 978-3-7560-3343-0 (Print)
ISBN 978-3-7489-6307-3 (ePDF)

DOI https://doi.org/10.5771/9783748963073

Online Version
Nomos eLibrary

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Introducing early conceptual development of TA in Germany

> Thus, the history of TA itself can be interpreted as a tentative experimentation and constant learning process, in which each new approach claims to avoid certain shortcomings of the known approaches, but in doing so raises new questions and produces other shortcomings (Grunwald 1998, p. 2).

Technology assessment (TA) can look back on a history of over 50 years. It owes its current form (cf. Böschen et al. 2021; Grunwald 2024) to a multitude of practical experiences and theoretical debates, spread across different industrialized countries with different focal points and at different times. The 1980s and 1990s were a time of turbulent development, with social crises, new global political constellations, and changing perceptions of problems. Examples include the growing awareness of the global environmental consequences of human civilization such as the hole in the ozone layer and climate change, the nuclear arms race during the Cold War, the accident at the Chernobyl nuclear power plant in 1996, the collapse of the communist regimes in Eastern Europe, the neoliberal conversion of most economies in the wake of Margaret Thatcher and Ronald Reagan, but also the Brundtland Report on Sustainable Development (WCED 1987). TA at that time was characterized by theoretical controversies, new conceptual developments, and diverse practical experiences, often against the background of the diagnosis of a "risk society" (Beck 1986). Examples include social constructivist technology research (Bijker et al. 1987), the development of constructive TA (Rip et al. 1995), the founding of the European Parliamentary Technology Assessment (EPTA) network in 1990, the closure of the Office of Technology Assessment (OTA) in the U.S. Congress in 1995 (Bimber 1996), the debate on the relationship between TA and ethics (Grunwald 1999), and the participatory expansion of TA (Joss/Belucci 2002). Many of these topics focused on the role of the state, the possibility of scientific but non-technocratic policy advice, precautionary issues, and the role of broader participation in view of the existential risks that were much discussed at the time (as they are today!). A wide range of analyses and perspectives on these debates were developed in Germany that can still be followed today, particularly with regard to the conceptual and theoretical development of TA.[1]

In many cases, these fundamental works are difficult to access. In line with the conventions of the time, they were usually written in German and were often published in anthologies that are rarely, if ever, available digitally. This volume in English translation aims to change this by making these contributions from the 1980s and 1990s, which are still fruitful for capacity and community building in times of global TA (Hennen et al. 2023), accessible both for the TA community and beyond. This is done in particular with a view to use in the rapidly growing field of university education in the context of TA and analogous approaches such as Responsible Research and Innovation (RRI) (von Schomberg/Hankins 2019).

In order to preserve the original character of the articles, we have deliberately refrained from using the gender-neutral language that is common today. Events and terms that not every reader may be able to understand straightaway have been explained by the editors in footnotes. To improve readability, all quotations that were originally in German have also been translated. In addition, the bibliography has been revised and updated. Some of the sources cited were still in preparation or in print at the time of the original publication and are now easier for readers to find thanks to the updated information.

The main interest of this volume lies in the fact that the level of theoretical reflection on various aspects of TA, as it was carried out in Germany decades ago, is to be made accessible for the present and preserved for the future. Looking back, it is always striking, especially in comparison with the current rather pragmatic view of TA, at what level of theory and with what social theory models TA was discussed. It was often about fundamental questions of TA, e.g., whether it could achieve anything at all as policy advice, or whether participation was an important element, whereas today, small-scale questions such as the suitability of certain formats for online participation or institutional optimizations of policy advice are often discussed. Our aim is not to play one off against the other, but to maintain a fruitful relationship between theory and practice, or practice-oriented reflections.

The debates in the 1980s and 1990s have shown that this is possible and promising. On a theoretical level, the theory of communicative reason (Habermas

1 During the period under review, the Institute for Technology Assessment and Systems Analysis (ITAS) at the Karlsruhe Institute of Technology (KIT) was founded in 1995 as the successor to the Department for Applied Systems Analysis (AFAS). It is a nice coincidence that the ITAS, where a whole series of the chapters reprinted here originated, is celebrating its 30th birthday in the year this book is published.

1981) was intensively debated vis-à-vis sociological systems theory (Luhmann 1984), the "risk society" (Beck 1986) was discussed even in the feature pages of daily newspapers, the deliberative and participatory renewal of democracy was proclaimed in terms of democratic theory (Habermas 1992; Barber 1986), there were far-reaching debates in the context of the emerging ethics of the future (Jonas 1979) and sustainable development (WCED 1987). In the discussions on TA, these major theoretical lines were taken seriously and integrated into the field.

The selection of texts for reprinting in this book was based on the main criterion of addressing conceptual and theoretical questions that are still relevant today and have left visible and relevant traces in the development of TA. In several rounds, the editors repeatedly looked through and compared countless texts from this perspective, which ultimately resulted in the spectrum realized in this volume. These texts were then translated – many thanks go to Sylke Wintzer, Miriam Miklitz, and Julie Cook, who prepared this volume in English in their usual excellent manner. Thanks also go to Gabi Petermann, who compiled and edited the literature.

In the following, the reprinted contributions are briefly presented individually according to the order they appear in the book. The editors have developed four categories to structure the collection:

- Risk as a key concept in TA – the problem-oriented dimension
- TA as advice – the consultative dimension
- TA as communication and participation – the discursive dimension
- TA as a theoretical approach – the action-theoretical and system-analytical dimension

Through this structure, we briefly describe the contents of the individual chapters with a focus on the respective theoretical and conceptual basic questions of TA, explain the authors' theses, place them in the context of the time of their creation, and ask about their relevance for TA today and in the future.

1. Overview of articles in the volume

1.1 Risk as a key concept in TA – the problem-oriented dimension

Technology assessment was established as a response to the rise of a great variety of technologies, highlighting the need for research and advice on its probable (negative) consequences. The focus of TA has always been on the trade-off between the good and the bad sides of technology impacts, and as such on risks induced by technologies. The Technology Assessment Act of 1972, which led to the establishment of the Office of Technology Assessment (OTA) in the United States, aimed "to provide early indications of the probable beneficial and adverse impacts of the applications of technology" (U.S. Congress 1972, Sec. 3c). And the establishment of the Office of Technology Assessment at the German Bundestag (TAB) was justified in the constituting decision in 1989 as follows: "The German Bundestag must help to exploit the opportunities offered by new technologies and to minimize the risks" (German Bundestag 1989). Thus, the concept of risk can be seen as the backbone of TA. Analyzing risk as probable negative consequences perfectly meets the task of TA to reflect on non-intended, negative impacts a technology might bring in the future. Therefore, it comes as no surprise that the term risk is widely addressed in early TA publications. The concepts of risk covered objective risk assessment methods, subjective risk perception research, and risk as a constituent paradigm of modern societies, synthesized in the famous "risk society" concept of Ulrich Beck (1986). It is striking to see that the concepts of risk in TA combines two research lines, where the passion for risk-oriented method pragmatism in the U.S. meets the German passion for social theorizing on risk. How is that reflected in early German TA publications?

Overview of articles:[2]

(1) Bechmann, Gotthard (1994): Early warning – the Achilles' heel of technology assessment (TA)? (*original title:* Frühwarnung – die Achillesferse der Technikfolgenabschätzung (TA)?)
(2) Renn, Ortwin (1982): Methods and procedures of technology assessment and technology evaluation (*original title*: Methoden und Verfahren der Technikfolgenabschätzung und der Technologiebewertung)
(3) Münch, Erwin & Renn, Ortwin (1981): Safety for technology and society – theory and perception of risk (*original title*: Sicherheit für Technik und Gesellschaft – Theorie und Wahrnehmung des Risikos)
(4) Bechmann, Gotthard (1993): Risk as a key category of social theory (*original title*: Risiko als Schlüsselkategorie der Gesellschaftstheorie)

The contribution by *Gotthard Bechmann* (1994) in Chapter 1 discusses the topic of early warning as a distinctive technology assessment function to address future assessment needs. The anticipatory, future-oriented focus is indeed a key characteristic of TA – back then in the early days as well as today. Early warning is

2 For full bibliographic details, see the list at the end of this chapter.

supposed to identify technology consequences as early as possible, prevent its negative impacts, and provide prospective knowledge on possible future action. Bechmann critically reflects on several dimensions of early warning, i.e., its time, objective, and social dimensions. Just like other forms of foresight, early warning shares a common dilemma: If the warning is successful, then no one can see whether what was warned against would have occurred at all. If the warning is not considered and the damage occurs, then the warning was useless. However, what is emphasized is TA's need for future assessment. The core business of TA is assessing future non-intended (and hence negative) technology consequences and impacts – and thus directly follows from the crucial term of risk, namely its future probability dimension and its emphasis on non-intended damage-oriented consequences. Foresight and prediction as key aspects of TA are then reflected from various perspectives. The role of time and temporalities of future considerations within a changing – or not changing – environment are discussed, resulting in a foresight dilemma: There are various forms of foresight to assess possible futures, and on the one hand foresight serves technology assessment as an informative decision-making tool, but on the other it stands on the shaky ground of uncertain probability statements.

Early warning is still an essential part of today's TA activities in the field of future studies, scenario development, and modeling and simulation. This includes prospective impact and ex-ante consequence analysis where the emphasis now is on developing detailed method integration techniques as in the field of scenarios and modeling, or analysis of expectations (e.g., vision assessment). In addition, early warning has benefited from progress and innovation within information and communication technologies. Here, real-time (big) data mining and analysis aim at early warning signals in technology and earth systems (e.g., cyber-attack, tsunami, volcano).

Chapter 2 by *Ortwin Renn*, originally published in 1982, discusses the methodological diversity of technology assessment and technology evaluation. The concept of risk is at the center of methodological considerations. Technological risk, understood as a probabilistic consequence of damage, is reflected in different methodological variants. The focus here is on the epistemic and methodological robustness of the risk statement in relation to important facets of technology assessment, for example, the identification of different harmful consequences, the relationship between benefit and risk, the uncertainty of statements about the future, or the role of objectivity and subjectivity in the assessment of consequences. The methods discussed are assigned to different categories such as technology-oriented methods (e.g., cost-benefit analysis, revealed/expressed preferences), economically-oriented methods (e.g., welfare theories, marginal cost analysis), politically-oriented approaches (e.g., voting and participation procedures, muddling through), and systematic weighing procedures (e.g., benefit-risk analysis, multi-attributive decision, planning models). Finally, the scenario technique, the interdependency approach, and the basic need concept are dealt with under system-analytical approaches. The concept of risk is consistently reflected in its diverse methodological implementation and methodological theorization as well as in very different methodological specifications, covering formal-mathematical calculations, subjective gains of utility for majorities, legitimacy of collective policy decisions, or a combination of quantified consequences and value preferences. Many of the risk-considering methods which are discussed are prominent in empirical pragmatically-oriented research in the US.

Today, there are two ways in which TA methods work can be done. On the one hand, the different TA methods for assessment and evaluation have been systematically compiled and classified within several TA handbooks and manuals, providing easy orientation and guidelines for TA practices. On the other hand, method development with a focus on interdisciplinary and transdisciplinary integration efforts is widespread, for example, energy scenario development or living-lab and real-world lab research.

Chapter 3 on theory and risk perception by *Erwin Münch & Ortwin Renn* (1981) addresses security considerations of technologies within societies. It introduces risk as a multidimensional concept that can mean very different things to different people: Gamblers' expectations of winning, calculations of life expectancy, the future market success of businesses, or the prospects of success or failure of medical surgery. It is obvious that risk consideration and evaluation is used in very different situations, and with a very different understanding. The occurrence of probability calculations and assessments is the common feature of these situations. However, it is clear that probability estimations have their limits, both objectively and subjectively. Objectively, they rely on the law of large numbers of events, i.e., point predictions are not possible with only a small number of events, and subjectively, they rely on individual intuitive risk perception patterns. Thus, risk is foremost a social construct between objective and rational calculation and subjective and irrational (mis)interpretation. A key element is therefore the introduction of the psychology of intuitive risk perception, which paves the way for risk sociology. This is where the US-inspired empirical psychometric risk perception research of the 1970s enters the TA debate. Intuitive risk perception is based on perceived loss expectations, qualitative risk and benefit characteristics, and perceptions and opinions with regard to the sources of risk. Societal deliberation processes on technology assessment need to take these mechanisms seriously for effective handling of risk technologies.

Subjective and individual risk perception research is still of great importance in TA. It forms the backbone of what has become technology acceptance and acceptability research within TA. The question of social resonance, risk perception, and levels of technology acceptance is one of the key research questions asked by stakeholders and decision-makers in any case of new and emerging technologies.

Chapter 4 on risk as a key category of social theory, also by *Gotthard Bechmann* (1993), combines the pragmatic method-oriented results of risk research with system-analytical social theory considerations in an excellent way. It reveals the different meanings and constructs of risk as a fundamental characteristic of what constitutes and shapes modern societies. In that sense, risk has become a functional-structural element of what defines the risk society. The concept of risk embodies the basic experiences and problems of a highly industrialized and highly scientific society as seen before the turn of the millennium. In short: Risk as a social theoretical concept. The very different roots and meanings of risk are well reflected here. Tracing the roots of risk back to the financial lending business in the Middle Ages reveals that interest reflects the risk of loss – and is no longer seen as usury. Risk is increasingly associated with different meanings and contextualizations: The universalization of risk awareness, the conceptual pairing of safety and risk, risk and decision-making, or risk in the sense of attribution are just some of the important nuances of risk discussed. Next, current social theory, focusing on systems theory and its functional differentiation of society, is reflected on the basis of risk concepts. Subsequently, both approaches are brought together, i.e., the structure of risk in modern times. The focus on technological risk reveals different forms, types, and temporal dimensions as well as their implications for and the responses of social systems and societies. And that is also where ethics, norms, and values come into play. Thus, it remains an open question whether risk and uncertainty constitute the starting point and backbone of what modern societies are experiencing.

It seems that the peak of social systems theorizing in Germany has come to an end since the turn of the millennium. Within the TA community, there currently seem to be no far-reaching ambitions to theorize on technology assessment and evaluation within the framework of long-term social systems theories. However, this reflects the fact that the passion for big theories is generally fading.

1.2 TA as advice – the consultative dimension

TA emerged as scientific policy advice in the U.S. Congress in response to demand from politicians (Bimber 1996). It builds on a long history of policy advice by scientists and experts, and in particular on the Think Tanks founded in the 1950s (e.g., RAND). The consultative dimension is deeply inscribed in TA through this history and subsequent developments: It works not only in a knowledge-based manner, but also as a knowledge-based transfer service of the scientific system to non-scientific addressees. The range of addressees has expanded considerably over time, even beyond policy advice (Grunwald 2024). The TA knowledge provided should enable informed opinion-forming and decision-making in various areas and find its way into social practices. TA should achieve "impact," as it is called today, through consultative activity (Decker/Ladikas 2004).

This expectation leads to a wealth of questions and challenges, which are primarily due to the TA constellation of consultants and consultees, in which TA as a consultant both wants to and should achieve an impact, but in which the opinion-forming and decision-making of the addressees, e.g., in parliaments, should not be technocratically predetermined or even determined. In the 1980s and 1990s, the foundations were laid for the high level of theoretical insight and practical experience that exists today.

Overview of articles:

(5) Mayntz, Renate (1986): Learning processes: Problems of acceptance of TA among political decision-makers (*original title*: Lernprozesse: Probleme der Akzeptanz von TA bei politischen Entscheidungsträgern)
(6) Bechmann, Gotthard (1992): Consequences, addressees, patterns of institutionalization and rationality: Some dilemmas of technology assessment. (*original title*: Folgen, Adressaten, Institutionalisierungs- und Rationalitätsmuster: Einige Dilemmata der Technikfolgen-Abschätzung)
(7) Petermann, Thomas (1992): Away from TA – but where to? (*original title*: Weg von TA – aber wohin?)
(8) Petermann, Thomas (1999): Technology assessment as policy advice (*original title*: Technikfolgenabschätzung als Politikberatung)

Renate Mayntz's (1986) essay (Chapter 5) on the acceptance of TA among political decision-makers is set in the context of the planning-optimistic paradigm of the 1960s and 1970s with its central assumptions of the state's high steering competence and the predictability of social developments through cybernetic models.

In her analyses of a more modern understanding of the state, the author deals with the role of TA in policy advice. She opposes TA as a scientistic-cybernetic instrument with which planning-optimistic ideas could ultimately be realized through TA. Such a rationalistic TA would not meet with acceptance in politics because political self-rationality – here one can sense the influence of systems theory (Luhmann 1984) – would not allow this. With reference to the functional differentiation of the state, Mayntz argues against under-complex ideas of TA as policy advice. Its acceptance and thus its sustainable success depend on the one hand on the presumed political implications of the results and on the other hand on adequate placement in the differentiated political system.

Today, planning optimism has been buried and TA is no longer geared toward the cybernetic support of overall state control. Nevertheless, Mayntz's analyses remain relevant. States around the world are regaining considerable control competencies, and cybernetic control optimism is returning in many areas due to digitalization and the AI euphoria. In these developments, the predictability of the world and its data- and model-based prediction have once again become an explicit goal, so to speak in a new guise, which many computer scientists in particular consider to be achievable. Mayntz's essay thus continues to encourage ongoing reflection on the relationship between the state, TA, and society and its changes.

In Chapter 6, *Gotthard Bechmann* (1992) comes to a sobering conclusion with regard to the cybernetic understanding of the consultative dimension, in which scientifically reliable knowledge of consequences is a prerequisite for effective management. After many prognostic failures, the once enthusiastically pursued futurology is no longer in vogue. With regard to the consultative dimension of TA in the political process, he refers, like Mayntz (in Chapter 5), to the structural discrepancy between the political and scientific systems (Luhmann 1984). In particular, the implementation of TA results encounters limits due to the necessity of evaluations. If TA results are politically unwelcome, they could easily be ignored with reference to the subjectivity of TA. There is a risk that decision-makers will only accept TA results if they converge with their own goals or preconceptions. TA would then be degraded to the legitimization of already existing positions. Bechmann rejects the repeatedly proposed normative abstinence that TA should withdraw to the role of a pure knowledge provider of value-neutral information with reference to the limits of instrumental reason according to critical theory. He also rejects the "elitist model" of policy advice, according to which a *Chief Science Advisor* or an academy of science, for example, could authoritatively prescribe these assessments.

According to Bechmann, the "participatory" negotiation model of TA remains closely related to the "pragmatist model" according to Jürgen Habermas (1968). In order to avoid problems caused by suspicions of subjectivity, Bechmann calls for an impact assessment that is "objectified" through transparency and criticality, similar to the concept of social epistemology (Longino 1990), which was presented at almost the same time. Overall, these analyses have triggered a wide range of debates on the values and normative dimension of TA, which are still enriching today (Nierling/Torgersen 2020).

Thomas Petermann (1992) sets a different accent in Chapter 7, "Away from TA – but where to?", originally published in the same book as Bechmann's Chapter 6. Petermann focuses on criticism from social science technology research and – to a lesser extent – from the philosophy of technology of the basic assumptions of TA, which attack the possibility of successful policy advice through TA based on the following: TA can only rationalistically feign its claimed objectivity; it is subject to a double determinism of technology; technology development is seen as an exogenous and quasi self-dynamic factor instead of considering technology genesis and technology as a social process; it has no eye for alternatives but sees technology consequences as determined by technology instead of developing a theory of technical change; and it is technocratic and affirmative instead of critical. This impressive list reflects the lively TA debate of the time.

The consequences that Petermann draws from this are still groundbreaking today: TA must abandon naïve technological determinism, but without succumbing to a voluntarism of arbitrary designability, it must overcome misunderstood claims of value neutrality and its "positivist hesitancy" and must take into account the cultural interdependencies of technology debates as well as the patterns of interpretation and cultural staging of technology contained therein (here one can see an early reference to hermeneutic TA, see Mehnert/Grunwald 2024). In addition, it must take technology seriously as a social process of genesis, use, and disposal, systematically learn from historical processes of technology assessment and deal with technological change and its influencing factors. In summary, TA should be "social assessment."

In a later article published in 1999 (Chapter 8), *Thomas Petermann* no longer focused on a lost role of the state as a central steering authority as in the steering debate, but on TA in new and more complex constellations of consultation. In the framing of the text, the shock wave of the closure of the OTA in the U.S. in 1995 is clearly recognizable, which ultimately represented a failure of consultative TA in the face of hard political realities (Bimber 1996). According to Petermann, it must be taken seriously that in TA as policy advice, two professions that are profoundly alien to each other come together and that difficulties in cooperation are to be expected. It is absurd to assume that scientific knowledge can simply be transferred to politics and "applied" there. The consultative dimension of TA is not a simple transfer of knowledge, but a complex communication process consisting of the decontextualization of scientific TA results and their recontextualization in the political system. It is not simply "politics" that is the addressee of policy advice, as this does not even exist. Instead, the state itself is differentiated in many ways, both vertically and horizontally. It has also delegated many of its technology-related regulatory or promotional activities to other actors or levels, such as expert councils, commissions or authorities. With reference to Mayntz (Chapter 5), Petermann concludes that there can be no question of a resigned withdrawal of the state, but that it is not monolithic in itself, but rather highly diversified. TA is therefore still in demand as policy advice, but must be able to serve this political diversification in its consultative dimension.

Together, these four essays point out that the constellation of TA as both an advisor on the one hand and as the advisee in politics on the other is a constitutive element of TA. This is the central theme in the reflection on its consultative dimension. As part of science, TA is mandated to provide knowledge and reflections, but not to intentionally influence or technocratically determine the social or political debates and decisions based on them. The motivation to achieve an "impact" through advice, while at the same time preserving the freedom of the institutions mandated to make decisions and shape the future as "honest brokers" (Pielke 2007), is one of the balancing acts of TA (Grunwald 2019).

The transfer of scientific knowledge to non-scientific areas as well as the transfer of consulting needs to TA is not trivial in either direction. TA as an advisory practice requires a good knowledge of the working methods and world perceptions of its addressees, e.g., in parliaments, in order to make impact possible. Conversely, those being advised must be able to articulate a need for advice and be willing to be advised or, in Niklas Luhmann's language, "irritated" by TA as a science.

1.3 TA as communication and participation – the discursive dimension

Participation and discourse, the involvement of non-scientific social groups, and dialogue procedures are now standard in many TA research projects and advisory settings. Depending on the topic and objective, focus groups, dialogues, and citizens' conferences are held with stakeholders, users, affected parties, or the general public. They are intended to generate knowledge for the technology assessment that cannot be gathered through purely scientific research, such as empirical knowledge, interests, values, fears, and wishes. Conversely, they are intended to provide information and understanding between TA and society and to prepare political decisions. However, participatory processes are also criticized in the TA community today for being too cost-intensive, and because their "impact" is not verifiable, the representativeness of the participants is hardly given, and the relevance of the results for political and scientific decisions in technology promotion, regulation, and development usually remains very uncertain (Böschen et al. 2021; Hennen 2012). In general, however, the necessity of the discursive-participative dimension of TA is not called into question.

Compared to the debates in the TA community in the 1980s and 1990s, participation and discourse have become more or less "normalized" today. Back then, there was a controversial discourse about the meaning and functionality of participatory and discursive processes. The historical background was the legitimacy crisis of the state and the public loss of trust in the authority of purely scientific expertise as a result of environmental crises, chemical disasters, and the nuclear accident at Chernobyl – generally in the course of the anti-nuclear movement and the increasing protests against genetic engineering releases. The importance of participation was discussed very substantially in the TA publications of the time. Today, the discussion within TA focuses more on problems in participatory procedures and how these can be overcome (Fuchs et al. 2018). If in that earlier time the participation of the population in TA analyses was discussed as a necessity for political decision-making in view of the state's legitimacy crises and the associated technology controversies, today the emancipatory and learning potential of participation seems to be in the foreground.

Overview of articles

(9) Paschen, Herbert (1975): Technology assessment as a participatory and argumentative process (*original title*: Technology Assessment (TA) als partizipatorischer und argumentativer Prozess)

(10) Hennen, Leonhard (1994): Technology controversies. Technology assessment as a public discourse (*original title*: Technikkontroversen. Technikfolgenabschätzung als öffentlicher Diskurs)

(11) Gloede, Fritz (1994): Technology policy, technology assessment, and participation (*original title*: Technikpolitik, Technikfolgen-Abschätzung und Partizipation)

(12) Bechmann, Gotthard & Gloede, Fritz (1992): Recognition and acknowledgement: A consideration of the limits to the idea of "early warning" (*original title*: Erkennen und Anerkennen. Über die Grenzen der Idee der "Frühwarnung")

In Chapter 9, *Herbert Paschen* (1975) defines TA as a scientific and advisory practice for anticipating and assessing, as systematically and comprehensively as possible, all effects (especially subsequent and unintended secondary and tertiary effects) of new technologies on all affected areas of society and the natural environment. His ideal flow chart for TA analyses was as follows: The first step is to define the problem and determine the assessment task. This is followed by the development of a comprehensive information base, which is the prerequisite for identifying, analyzing, and evaluating potential consequences. Based on this expertise, options for action are derived and, if necessary, direct recommendations for policy are made: This basic scheme still guides TA today. Paschen responded pragmatically to the criticisms of TA which were made at the time and are still known today (e.g., no demonstrable objectivity of future knowledge, value-laden and interest-driven results, unclear future relevance of the results, neutrality of the TA institution), and which could not be resolved even by the most perfect TA practice, by demanding the greatest possible transparency, process-accompanying public information, and ensuring a maximum of active, direct participation. This chapter devotes particular attention to the latter, as affected groups with little economic- and decision-making power should also be integrated into TA analyses and evaluations. Paschen derives options for the realization of direct participation, such as telephone statements or publicly accessible information databases. He characterizes the discursive-participative dimension of TA as an argumentative, open, and not only knowledge-generating process. In doing so, he laid the foundation for further justifications and critical discussions on participation and discourse, as presented in the following articles in this part.

Chapter 10 by *Leonhard Hennen* (1994) was originally published at the height of the technology controversies, in the 1990s, particularly with regard to green genetic engineering and participation debates. Hennen takes up the topic of state control and legitimation crises and the resulting technology controversies. His thesis is that discursive procedures of TA are to be understood as a reaction to public technology controversies and that their efficiency and rationality are based on this. He addresses the discursive-participative dimension of TA by classifying procedures of "discursive TA" as a necessary attempt to organize technology controversies in public discourses. He reconstructs their necessity with reference to Ulrich Beck's social diagnosis of the self-reflection of socially generated risks and dangers in the "risk society" (1986), and Niklas Luhmann's thematization of the low resonance of ecological protest in political, scientific, and economic subsystems due to the lack of connectivity to the system-specific codes and programs in "Ecological Communication" (1990). In order to overcome the problem of resonance, Hennen justifies the necessity of organizing public discourse by providing participatory arenas on the part of TA. He sees this organization of discourse – following Jürgen Habermas' "Theory of Communicative Action" (1988) – as a necessary medium of social integration in view of the loss of public trust in scientific expert systems and the legitimation problems of state technology policy. Hennen illustrates the difficulties of successful discursive-participatory TA with the problems of the participatory TA project on the "Cultivation of crops with genetically engineered herbicide resistance" (1991–1993; Bora/van den Daele 1997) carried out at the Berlin Social Science Center (WZB). Despite all the unresolved problems of discursive TA, he emphasizes the creative potential of the discursive-participative dimension of TA, which is often underestimated. He describes expectations that participatory discourse will lead to consensus on highly controversial issues as highly unlikely. Thus, like Paschen (see Chapter 9), Hennen also justifies the discursive-participative dimension of TA, whereby the emancipatory potential that is more strongly discussed in TA today already resonates with him.

The challenges of participatory TA and the problems of the WZB procedure are also the subject of *Fritz Gloede*'s article (Chapter 11). This was also originally published in 1994, but with a focus on different expectations and often undifferentiated justification contexts for participation: Participation as a functional requirement for cognitive decision-making vs. participation as a democratic political demand vs. participation as an element of discursive mediation and social learning processes. Using the WZB procedure, Gloede shows how it was precisely the intermingled contexts of justification and conflicting expectations of industry representatives, genetic engineering critics, and the organizers that led to conflicts, and ultimately to the failure of the procedure (the withdrawal of NGOs critical of genetic engineering and genetic engineering releases by industry during the procedure). He also locates participation and discourse as a necessary, but not sufficient, condition for democratic technology control, and characterizes participatory TA as a primarily qualitative and argumentative process. For Gloede, as for Hennen (see Chapter 10), the procedural criticism of participatory TA (e.g., lack of representativeness of the participants, no quantifiable impact measurement) is not the central problem for the critical self-reflection of TA on its discursive-participative dimension. Thus, he emphasized the emancipatory potential of participation very early on.

The final contribution to this dimension by *Gotthard Bechmann & Fritz Gloede* (1992) in Chapter 12, takes up the topic of TA as early warning, which also plays a role in the part on the risk dimension of TA (Sec. 1.1), in relation to the necessity of participation. As already emphasized in the part on the consultative dimension of TA (Sec. 1.2), Bechmann & Gloede focus on early warning of technical hazards and risks as a basis for the timely recognition and assessment of future environmental problems that are not yet visible as a knowledge base for the state's duty to take precautions in accordance with the precautionary principle introduced in the 1990s. Based on Niklas Luhmann's theory of functional differentiation of subsystems of society (Luhmann 1984), the authors work through the problems of translating TA knowledge into information relevant for political decisions. According to Bechmann & Gloede, the potential dangers of new technologies that are not yet visible at the time of the assessment are not per se relevant information for the political system in terms of decision-making and regulation. These concerns could only become relevant for political precautionary decisions through public participation, organized by TA by means of discursive-participative procedures on even vague dangers (not yet calculable as regulation-relevant risks in the sense of classic risk assessment). In this way, political decisions can represent the public interest of their electorate in accordance with their system-specific selection conditions. This contribution thus brought a new aspect of the discursive-participative dimension of TA to the fore, namely that TA knowledge can only become policy-capable and preparatory for decision-making through public participation. Nowadays, this reflection can hardly be found in scientific debates on TA and related scientific practices, although the problems of translating TA research results into decision-oriented knowledge for politics have by no means disappeared.

Compared to these reflections on the discursive-participative dimension of TA, which were strongly grounded in social theory, the debate today has narrowed to questions of procedural and process optimization. But even if the points of criticism and socio-theoretical contextualizations of participation and discourse put forward at the time seem to be below the radar of TA today, this does not mean that the problems and challenges identified at the time can be considered as solved and overcome – i.e., that everything is just a question of process optimization. The influence of TA expertise on political decisions is often uncertain (despite the direct institutionalization of policy advice, e.g., by the TAB) (e.g., Grunwald 2019). In contrast to the 1980s and 1990s, however, participation and discourse are no longer much discussed as a necessity for overcoming state decision-making and legitimacy problems, but are increasingly seen as a medium for enlightening and emancipating the public – participation as a collective learning process of all social groups involved has come to the fore.

1.4 TA as a theoretical approach – the action-theoretical and system-analytical dimension

Looking at the wealth of literature that has considered TA as "a specifically different form of science" (Böschen et al. 2021, p. 15) in recent decades, it is admittedly difficult to discover a common thread with regard to a coherent theory development within the framework of TA. However, such a development was not planned in the genesis of TA. The history of TA shows, as all authors in the "history of theory" agree, that since the 1960s there has been an increasing need for critical reflection to advise politics and society in order to avoid negative consequences for society. The role, functions, and position(s) of TA in the context of societal debates subsequently became complex and influenced the design of innovative scientific directions (Böschen et al. 2021). Nevertheless, or perhaps precisely for this reason, a process of self-reflection in TA began in the 1990s, which describes central positions, but also areas of tension, both externally and internally, which have hardly lost their topicality to this day. What is more, it seems that these reflections on TA's own work in those years were driven by a certain urgency, not least because TA was confronted with various kinds of causes and resistance from both science and politics. This style characterizes the seven selected contributions in this final part of the volume: Here, a search movement is indicated which, in view of the technically-induced problem situations in society, formulates possible certainties, but also the contradictions of TA and puts them up for discussion. This reveals a view of theoretical-conceptual premises that was to become constitutive for TA in its further course. Against this backdrop, it still seems incredibly inspiring to devote oneself to these contributions from the 1990s, given the current state of debates in TA.

Overview of articles:

(13) Paschen, Herbert & Petermann, Thomas (1992): Technology assessment: A strategic framework for the analysis and evaluation of technologies (*original title*: Technikfolgen-Abschätzung: Ein strategisches Rahmenkonzept für die Analyse und Bewertung von Techniken)

(14) Dierkes, Meinolf & Hähner, Katrin (1999): Concept development of technology assessment: Review and outlook (*original title*: Konzeptentwicklung von Technikfolgenabschätzung: Rückblick und Ausblick)
(15) Gethmann, Carl Friedrich (1999): Rational technology assessment (*original title*: Rationale Technikfolgenbeurteilung)
(16) Grunwald, Armin (1998): Technology assessment – between sociological systems theory and philosophical ethics (*original title*: Technikfolgenabschätzung zwischen soziologischer Systemtheorie und philosophischer Ethik)
(17) Grunwald, Armin (1996): The epistemological status and cognitive limits of technology assessment (*original title*: Erkenntnistheoretischer Status und kognitive Grenzen der Technikfolgenabschätzung)
(18) Bechmann, Gotthard & Frederichs, Günter (1996): Problem-oriented research: Between politics and science (*original title*: Problemorientierte Forschung: Zwischen Politik und Wissenschaft)
(19) Gloede, Fritz (1992): Rationalization or reflexive scientification? On the debate about the functions of technology assessment for technology policy (*original title*: Rationalisierung oder reflexive Verwissenschaftlichung? Zur Debatte um die Funktionen von Technikfolgen-Abschätzung für Technikpolitik)

The history of the emergence of TA is constitutive for the methodological design of TA and still ensures that TA has a firm place at the interface between society (politics) and science. The first three articles in this part, all describe the "concept development" of TA, which goes back to the 1960s. During this period, people in the U.S. became increasingly aware of the consequences of technical and scientific progress in the form of catastrophes and undesirable consequences and thus became the subject of public debate. U.S. politicians reacted with a report which, among other things, called for the establishment of an "early warning system" to identify the negative and positive consequences of technological applications. The term technology assessment was officially used for the first time in this report. There were similar developments in many European countries, which are considered by Paschen & Petermann and Dierkes & Hähner. As a policy-related information instrument, TA was institutionalized in many European countries in the subsequent decades. According to *Meinolf Dierkes & Katrin Hähner* (1999) in Chapter 14, the social consensus on technological progress became fragile during these years, as described in almost all the articles in this part, that the assumption that technical and social progress are in a linear, directly proportional relationship to each other has lost much of its trust. Due to this situation, institutional

forms had to be found that could provide a systematic assessment of technologies with regard to social developments. Dierkes & Hähner formulate relevant proposals such as iterative analysis circles in the assessment of socio-technical problems or technology genesis motivated by social science, which is beneficial from today's perspective, as many of these aspects were pursued further in TA.
Against a similar background, but already with some initial experience of TA as an advisory institution at the German Bundestag, in Chapter 13 *Herbert Paschen & Thomas Petermann* (1992) proposed strategic instruments quite early on that should be implemented as part of a reflexive design of socio-technical systems. As important ideal premises of this design, they mention, among other things, the claim of "early warning" of technology impacts, the decision orientation of TA, and the inclusion of problem-oriented knowledge with regard to technical programs. These topics are still being discussed intensively today as part of the epistemic knowledge canon of TA (Böschen et al. 2021).

The contribution by *Carl Friedrich Gethmann* (1999) in Chapter 15 is somewhat different, recognizing that TA should be regarded as an interdisciplinary cross-sectional task of the science system, but that TA is largely integrated into the political system and thus its scientific nature suffers considerably. Against this background, he opposes TA with the concept of "rational technology assessment" and argues primarily for a rational obligation to justify statements and the need to justify actions. He develops his remarks with the statement that technology assessment must be measured not by factual acceptance, but by the normative acceptability of decisions, which itself can only be (laboriously) determined in social processes. In the end, however, Gethmann concedes that it is not demarcation, but rather a fruitful dialogue between the two approaches that is crucial in order to work out the complementarity of both concepts. Interestingly, the description of rational technology assessment corresponds exactly to what is often carried out today with the inclusion of applied ethics in TA studies, be it in the field of energy transition, robotics, or other topics (Grunwald/Hillerbrand 2021).

The next two contributions follow on from Gethmann in disciplinary terms, but open up the space to explore the conceptual framework of TA. In Chapter 16, *Armin Grunwald* (1998) responds to the theoretical approaches of systems theory, which, based on the work of the sociologist Niklas Luhmann, reached a high point in social science debates in the 1990s (Luhmann 1984, 1990). The difference between system and environment introduced by Luhmann as well as the paradigm of closed self-referential systems, which no longer allows control of the overall system, affects the scope of action of TA to a large extent. Prior to this interpretation, ethics was also declared largely obsolete for technology issues, whose system-analytical argumentation logic Grunwald vehemently contradicted in this article. He calls for the practical relevance of technology ethics to be understood in concrete cases by (also) incorporating the system-theoretical diagnosis of current societies. For example, the scientific treatment of concrete social consequences of technology from the point of view of knowledge and advice is necessary in order to clarify the relationship to ethics in individual cases and to offer solutions. In the end, however, it is not the determination of a blockade to action that is functional, but rather the question of whether society can decide whether and how it considers drawing technical boundaries. The challenging answers to many open questions in the relationship between society and technology lead to the constitutive characteristics of the self-description and self-understanding of modern societies, which an epistemologically committed TA must face up to. In view of this expectation, Grunwald argues that ethics should be integrated more than ever into existing or newly established practices of technology design. It is important not to start from a control center of society, but to use ethical reflections where conflict situations (can) arise. Chapter 17, the second contribution by *Armin Grunwald* (1996), also touches on the debates mentioned above. Before the assumption of closed social systems, each with their own functional logic, human actions were explained in system-theoretical approaches as operations that take place solely via "acts of communication" (Luhmann 1986, p. 269). This led to the assumption that in TA too, the relevance of cognitive problems is increasingly devalued in favor of communication problems in the TA process or the implementation problem (Luhmann 1986), which would be tantamount to an enormous loss of significance of TA. Grunwald counters this thesis by proposing a distinction between the scientific study of cognitive problems of technology assessment *and* the communication of these results. Only when scientific results, i.e., scientifically reliable results of TA, are available would their communication to the outside world and the implementation of these results become relevant. Against this background, the epistemological status of TA must be brought into focus, struggled for, and ultimately developed. As an example, he then discusses topics that are still relevant today, such as the justification of TA statements from an epistemological perspective.

The final two articles in this part (critically) reflect on specific aspects of TA that have become constitutive for TA theory formation. Chapter 18, "Problem-oriented research: Between politics and science" by *Gotthard Bechmann & Günther Frederichs* (1996) is now considered a "classic" of TA. The authors agree with the diagnosis of intensive debates in the 1990s, which were conducted under the concept of "post-normal science" (Funtowicz/Ravetz 1993). This diagnosis states that a functional change is taking place in the relationship between science and politics, which began with the Manhattan Project[3] in the U.S. during World War II, but only came to fruition in the 1990s in view of complex social problems such as environmental pollution and the (controversial) organization of the welfare state. A new type of problem-oriented research emerged, which developed new research structures in the face of complex social problems. However, Bechmann & Frederichs concede that the old impetus of wanting to achieve better policy with the means of science remains. In light of these developments, new expectations were placed on science not only to provide specialist knowledge, but also to make predictions about future events that needed to be prevented. The authors identified TA as a prototype of this form of knowledge and thus moved TA close to the field of science, without neglecting the advisory role of TA. On the contrary, they defined the framework of TA as "problem-oriented research" and defined framework conditions including differentiation parameters from basic research and the necessity of inter- and transdisciplinarity. These aspects as developed and critically discussed in this article are still part of the theoretical dimensions of TA today.

Chapter 19 by *Fritz Gloede* (1992) theoretically refers to the debates on a "reflexive modernity," which were particularly characterized by the sociologist Ulrich Beck in the 1990s (Beck/Bonß 1998). Gloede addresses technically-induced social problems that – despite great political and scientific efforts – cannot be solved. The ambivalent structural dynamics of technological developments (Grunwald 2019) persist, and the problems that continuously arise from them (temporal, factual, social) cannot be solved even by TA. Gloede therefore argues that TA should be recognized as both subject and object within the framework of a "reflexive scientification" (Beck/Bonß 1989, p. 29). At the level of problem situations *and* at the level of social and societal problem perceptions, a self-enlightened TA concept should refer to itself in a doubly reflexive way. This means that TA is both an observer and a participant and should always reflect this dual role in its work. This is an assessment that has already been formulated by Grunwald (see Chapter 16) and to a large extent contains the expectation of developing theoretical-conceptual frameworks for TA. Gloede goes on to discuss aspects that describe TA as problem-oriented research with which TA must deal reflexively

3 The Manhattan Project was a U.S. research and development program during World War II to produce the first nuclear weapons. It was carried out in collaboration with the United Kingdom and Canada.

and continuously: The concept of technology, the concept of consequences, and the advisory concept in which TA operates. He summarizes that a reflexive and self-reflective view of TA brings forth various problems of the concept of consequences that need to be taken into account. In principle, however, technology development as social mechanization must always be understood as a social strategy whose normative and factual implications must be taken into account.

The articles selected for this book show that already in the 1990s, premises, basic requirements, but also many methodological uncertainties were placed on TA, which are still highly topical today – despite changing framework conditions. Moreover, these basic requirements have shaped TA in the further development of its theoretical foundation. A look at these debates today shows that the topics dealt with in these articles have become anchored and further developed as theoretical premises of TA.

2. Conclusion and outlook

In 2022, the "Limits to Growth" study (Meadows et al. 1972) reached its fiftieth birthday. From today's perspective in particular, the study is considered a milestone in the awareness of the economic, technical, and ecological consequences of the future, which were caused in particular by Western industrialized countries. Other technically-induced events followed, such as the poisoning accident in Bhopal, India, in 1984 and the reactor accident in Chernobyl, Ukraine, in 1986, which became engraved in people's collective memory. For the first time, these events caused deep cracks in the belief in scientific and technological progress, which stood as a guarantee for social prosperity. As the selected articles in this volume show, TA emerged precisely in this social and political environment. First in the U.S., and shortly afterwards in Europe, there was a call for institutions to analyze and evaluate the far-reaching problems of the relationship between society and technology and to make this orientation knowledge available to political decision-makers. Technically-induced crisis phenomena, i.e., the "risks" of technological progress, can therefore be seen as the birth of TA. From the very beginning, the challenges facing TA were enormous. The articles in this volume point this out. TA, which was located at the interface between politics and science, had to quickly develop a profile. This was achieved by developing the strategic framework conditions for its advisory role, but also by successively developing methodological framework conditions for generating scientific expertise in many technical fields and, based on this, advising initially political and later also other stakeholders. Against this background, the 1990s can certainly be seen as a decade of the TA search movement, a search movement in which TA often had to defend itself against external "hostility." The selected articles tell of this search movement, of tentative experimentation, and of a constant learning process, in which TA certainties emerged that are still valid today, but at the same time new questions were raised that TA is still dealing with now.

The selection of articles was made jointly by the editors, and provided much cause for discussion and – in retrospect – for renewed appreciation of the contributing authors. Firstly, many topics that are now part of the TA canon were substantiated and passionately demanded and defended by the contributing authors during this period. Secondly, topics were discussed that were subsequently conceived as theoretical contributions to TA, but are still being negotiated today as open and methodologically relevant questions. Thirdly, the articles are characterized by an intensive culture of debate in which the topics are presented with professional expertise and personal commitment. Prominent scientific debates of the 1990s are incorporated into the articles and form the blueprint for the respective argumentation logics. From today's perspective, this is very enlightening and makes it clear how and in what way conceptual ideas in TA have evolved.

We, the editors, wish that the interested readers of this volume also experience these moments of amazement, of remembering, of learning and, above all, the desire to participate in the future field of TA.

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1.
Risk as a key concept in TA – the problem-oriented dimension

Gotthard Bechmann

Early warning – the Achilles' heel of technology assessment (TA)?

The early warning function of technology assessment (TA) is seen as an essential service (Komwachs 1991; Paschen/Petermann 1992; Roßnagel 1993). It should help to recognize future technological consequences in good time, prevent negative consequences, and extend our foresight for the consequences of our actions as a whole in terms of time. Viewed as a whole, it is hoped that this will lead to more comprehensive and more preconditioned planning of technical developments, which should find expression in a higher degree of rationality in decisions.

So much for the promises, which sound plausible at first glance. Only when this program is implemented does it become clear that early warning is not an easy business in many respects; it is usually met with ingratitude and little recognition. There are several reasons for this. The error rates can be high, in which case you are sure to be ridiculed by those who follow you. But even if the person giving the warning later remains right and is able to provide solid reasons for his warning, it is the rule that his predictions are not heeded and he is hardly listened to. The fate of the Jewish prophets of the Old Testament should serve as a lesson here. Although they proclaimed God's word, who never made a secret of his intentions and his will, who never deviated from his words, who wanted nothing more than for the contract between him and his people to be kept, i.e., conditions that were clear and understandable and for which the consequences could easily be foreseen in the event of a breach (Weber 1980), even these unconditional predictions were rarely believed, and even less so the corresponding conclusions for action.

Even back then, dealing with the future seemed to be difficult. Perhaps this is the reason why the ancient wisdom teachings always linked the brightening of the future with a reintroduction of darkness in the Oracle's saying; otherwise their foresight would not have been accepted (Luhmann 1992). One need only recall King Croesus, who was threatened by the young, militarily successful Cyrus and prepared a pre-emptive strike. To back up this decision, he sought advice from the most renowned TA institution of the time: The Oracle of Delphi. This spoke clearly and unambiguously: If Croesus crossed the river Halys, he would destroy a great empire. Croesus felt vindicated, marched off and lost his empire. He had forgotten to ask whose empire.

But all this belongs to a sunken world. Thales of Miletus, who not only predicted a solar eclipse based on an in-depth study of the movements of the stars, but also bought up all the oil presses when he expected a rich oil harvest and thus cleverly increased his wealth, comes closer to how we deal with the future. So it is no wonder that people have always been fascinated by prediction and forecasting. Reinhard Koselleck even sees this as an anthropological determinant of human action, which can be seen in the ability to distinguish between possibility and reality that is typical of humans (Koselleck 1976).

Since we have neither an Oracle of Delphi nor a genuine belief in prophets in our scientific and technological world today, we must try to grasp the future on the basis of methodical instruments. We know that early warning as a scientific and political task is recognized today as legitimate scientific business, despite the countless false predictions that have not come true (Swiss Science Council 1986).

1. The concept of early warning

Early warning has so far remained an unanalyzed term, which is essentially considered to be good because of its appeal function (Bechmann/Gloede 1991). Who would not want to be warned of possible damage in good time? In the context of technology planning and technology policy, early warning combines at least three aspects:

Time dimension

In terms of time, anticipations are made. One must be able to distinguish between past, present, and future, whereby the present is only the point from which the difference between past and future can be determined and their difference marked at all. But that is not all. We also know that much of what will be the case in future presents depends on decisions we have to make now. But since we can only make decisions when it is not yet clear what will happen, there is also a gap between the present and the future. Less and less can the past be used as a basis for orientation in the future. We must therefore perceive the future from two perspectives: As the future present, which will be as it is now, and as the present future, which is as we imagine it to be. Rationalizing this difference is the task of scientific anticipation.

Factual dimension

From a factual point of view, early warning is about determining and assessing the unintended consequences of a technology. The unsuccessful formula, or rather the political compromise formula, which is that TA has the task of assessing the opportunities and risks of a new technology, obscures the actual core of TA. The opportunities, objectives, or intended consequences of a technology have not actually been a problem up to now. They are always provided free of charge by the inventors and promoters – their effects are only seen in a positive light and underpinned by reliable data. The real problem with technology development today is the unintended side effects, which can have a counterproductive effect in relation to the desired goals. Unintended consequences can be described as a class of phenomena that are "the results of human action, but not of human design" (von Hayek 1964, p. 243). Unintended consequences are not deficient means-ends relations that could be remedied by rationalizing the use of ends and means, but are the necessary consequences of means-end rational patterns of action – according to the more recent rationality debate (Spaemann 1980). It is therefore about the non-rational preconditions of purposeful rationality. To put it bluntly, the side-effects make us aware of the fade-outs on which purposive rationality is based and relativize it to a form pattern alongside several other types of rationality.

Social dimension

From a social point of view, early recognition is about the acceptability and acceptance of knowledge. If one analyzes the term "early recognition," it has two components of meaning: A cognitive one (early recognition of problems) and a normative one (timely recognition of the developing problem situation, which calls for political action). Although mixed up in the specific case, the analytical distinction between these two functions is helpful. On the one hand, it is a problem of knowledge, the stimulation of research, more precise or even sensitive observation and the understanding of contexts. On the other hand, it is a problem of recognizing risky problem situations that are not clearly given, i.e., accepting that action must be taken without undeniably certain knowledge.

The early warning is based on a paradox that is almost impossible to resolve and repeatedly leads to heated debate. If the warning is successful, it is no longer possible to determine retrospectively whether what was warned against would have happened at all. If it is not heeded and the damage occurs, it was useless because it did not prevent anything (Clausen/Dombrowsky 1984). Recently, another problem of early warning has been pointed out. Volker von Prittwitz has called this the disaster paradox. Using many examples, he develops the thesis that ecological and civilizational dangers and risks are often perceived politically in the opposite direction to their dangerousness. One could almost say that political action is only taken when the actual danger has passed (von Prittwitz 1993). In the following, only the anticipatory aspect of early warning will be examined.

2. The need to consider the future

There is no question that early warning is the anticipation of future events and, in the case of TA, the anticipation of unintended consequences. In general, it can be said about the structure of all attitudes toward the future that, in thinking ahead to the future, they also include visualization of the current state of affairs. Anticipation thus means the structural unity of anticipation and visualization. Georg Picht distinguished between three forms of contemplating the future, and in this way drew attention to how scientific-technical cultures visualize the future. He distinguishes between prognosis, utopia, and planning (Picht 1971, p. 13–19).

Scientific forecasts or other predictions attempt to predict what will presumably or probably occur in the future and which events seem foreseeable. Picht aptly describes forecasting as a "diagnosis of the future." Utopia, on the other hand, is the entire blueprint of the future that precedes all purposeful action. It is both an anticipation of possible alternatives to the existing situation and a critique of what has been achieved so far. These are possible overall developments in society that can and should be realized. The close interlocking of normativity and factuality distinguishes utopia from mere fiction, just as it keeps its distance from the purely empirical description of society.

Planning, in turn, is the elaborated draft for shaping the future. Planning selects one of the recognized possibilities and begins to implement the possibilities determined by utopia and prognosis into a program of action. It is analytical insofar as it uses the means-ends scheme to develop a strategy for implementing and realizing the utopia. These three basic forms in which human action can relate to the future are in turn interrelated:

> There is no prognosis without utopia; there is no utopia without prognosis. Planning mediates between utopia and prognosis; but there is neither prognosis nor utopia without planning, because every theoretical design is itself necessarily subject to planning, which presupposes its own utopia and prognosis (Picht 1971, p. 17).

This reciprocal entanglement of prognosis, utopia, and planning implies several things.

- Forecasts, utopias, but also planning are related to a context of action. They are not objective predictions of what will happen, but only of what could happen if the identified trends continue.
- Forecasts, utopias, and planning are strongly determined by expectations. They intend and articulate the desired and expected future. The future is imagined from relatively certain points of reference as a process predetermined within certain limits by the dynamic factors of the present, i.e., the future is projected and anticipated as the probable product of already existing conditions and ongoing developments in terms of their process stages.
- Forecasts and utopias, but not planning, have a warning function. A large proportion of forecasts are not expected to come true, as they only have the one purpose of pointing out undesirable developments. The analyses of the Club of Rome or the current forecasts of the population explosion essentially point to trends that need to be changed *now* or stopped in their tracks. Incidentally, this is probably also the reason for the often lamented misuse of forecasts. Because forecasts are intended as warnings, they generate appealing pressure on decision-makers, which they interpret as encouragement or as an imposition, depending on their coloration, but they always feel restricted in their freedom of choice. Forecasts create pressure to act, which is their real social secret.

In addition to the points mentioned above, the connection between forecasting, utopia, and planning also points to another fundamental aspect. From an anthropological point of view, Immanuel Kant pointed out that considering the future is a constitutive feature of human and social action. Although the future fundamentally eludes our experience, there are nevertheless predictions that can be transposed from experience into expectation with greater or lesser plausibility. This is the ability to predict, the *praevisio*.

> "To possess this faculty," says Kant, "is of more interest than any other: because it is the condition of all possible practice and ends to which man relates the use of his powers. All desire contains a (doubtful or certain) foresight of what is possible through it. Looking back on the past (remembering) only happens with the intention of making the foreseeing of the future possible: by looking around us from the standpoint of the present in general – in order to decide something or to be prepared for something" (quoted from Koselleck 1985, p. 46).

Kant points to a dilemma here. As a biologically undetermined, cosmopolitan being, man is compelled to always plan for the future for his actions in order to be able to exist. However, since the future will always remain empirically unknowable, he must anticipate it, whether accurately or not.

3. Forecast dilemma

If it is true that people are dependent on anticipating the future to the extent that they realize that their future could look very different from what they have planned, then a forecasting dilemma arises.

Hermann Lübbe (1987) has observed a loss of certainty about the future in modern society. This means that the time horizon of modern societies has shifted from the past to the future (Koselleck 1976, p. 17ff.). Not only has society's range of possibilities increased immensely, but the fact that the past no longer forms the standard of orientation for action, but rather an uncertain future, is probably of equal importance for modernity. More and more decisions in the life of the individual are taking the form of a risk calculation. In other words, decisions where it will only become clear in the future whether they were right or wrong. *Social contingency is becoming the dominant life experience* of modern man. Every action can also be carried out differently. Every social situation is constituted by a decision and is therefore, in principle, also conceivably different. The pressure to make decisions has therefore increased immensely. Even living conservatively is based on a decision, and preservation (conservare) becomes a selection process.

The divergence of experiences and expectations as a fundamental experience of modernity creates a pressure on science to alleviate precisely this discrepancy through scientifically guided analysis and forecasting. The loss of certainty of expectation with regard to the future creates a need for compensation. In the field of estimating and evaluating new technologies, this problem is further exacerbated by two factors.

Especially in areas where purposeful rational action and planning is practiced in its purest form – in science and technology – one becomes aware that every action has its side effects and, far more importantly, begins to counteract the effect of the intended action.

Karl Popper emphatically pointed out that motives and purposes of action on the one hand and structures and institutions on the other must be strictly distinguished. This is because the intention and results of an action rarely coincide, as only a minority of social institutions are consciously planned, while the vast majority of institutions simply grow as an unintended result of human action (Popper 1972).

Side effects occur all the more frequently the more long-term and holistic the planning of action is, as it becomes difficult or impossible to disentangle causes and effects with the increase in complexity in factual, temporal, and social terms. Long-term projects in particular are subject to the constantly accompanying phenomenon of unplanned planning, which constantly forces revisions and improvisation due to unexpected and unintended repercussions.

The innovation cycle in the field of technology development has accelerated, with the speed of development and innovation values increasing. More and more new products and technical systems are being created or improved. Systems are becoming more complex and their diverse effects more complicated. Both of these factors mean that surprises are inevitable and there is a compulsion to constantly adapt to new developments.

Borchardt (1979) has derived a forecasting dilemma from this, in which he shows that the demand for forecasts increases in turbulent times, while at the same time the conditions for a reliable forecast deteriorate, as new experiences and old expectations fall apart.

> Forecasting is relatively easy when nothing changes and there is therefore little demand for forecasts, because the constancy of the course of events does not remain hidden. When forecasts are in great demand, the forecasters usually have no strong certainty either (Borchardt 1979, p. 8).

What are the consequences of this dilemma for the validity of the forecast?

The philosophy of science attempts to counter this problem with a restrictive concept of prediction: Predictions are scientifically substantiated statements about previously unknown, real, or possible facts that can be derived within the framework of a scientific theory from known statements of law and statements about initial and boundary conditions of the process to be predicted with the help of a logical conclusion (Stegmüller 1966). This structural identity of explanation and prediction is only plausible if prediction is used to verify statements of law (Lenk 1972). However, since this is already hardly possible in the natural sciences, it is probably even less possible to make exact forecasts in the field of technology assessment. On the contrary, forecasts are not aimed at explanation, but are a call to action. Their need arises from the political and social utilization contexts. They should be action-oriented. However, a different concept of prognosis must then be found.

4. Forms of prognosis

Assuming that forecasts are *not* a prediction of future developments, but an analysis of *possible* futures from the point of view of the present, they provide us with information about what developments could be expected if the changes in the influence variable structure observed in the past continue with the same consistency.

According to Knapp (1978), explanatory forecasts should be distinguished from so-called “inexact” forecasts. Explanatory forecasts have long been the subject of scientific-theoretical discussions, whereby forecasts in this context are understood as statements that can be derived from laws and boundary conditions in a purely logical manner. In the case of TA, this type of forecast is likely to play a minor role, as the necessary legal knowledge will rarely be available. Forecasts are characterized by two features: Their statements are statements of expectation, and the expectation preferences expressed in them must be justified. If this justification cannot be made on the basis of legal knowledge, one will have to fall back on trend forecasts and expert forecasts (Helmer/Rescher 1959). In both cases, an attempt is made to describe the basic structure of a change, and the direction and the speed of changes as tendencies and inherent possibilities. In addition, a well-founded assessment of a particular development is required, which then results in the preference of one future extrapolation over possible other extrapolations.

Empirically meaningful statements can only be made if the most important parameters are fixed over a defined period of time. A special form of this so-called coordinated forecast is the action-dependent or action-related forecast. Here, the occurrence of the predicted states and events is made dependent on particular actions of the forecaster or other persons, so that the actor has defined possibilities to influence the realization of the prediction, i.e., to bring about the conditions. The decisive question and thus the central problem of prognostics is how probable a given prognosis – wherever it may come from – is in absolute terms or in comparison to alternative prognoses, and whether the empirical basis presented for its empirical-inductive justification can be regarded as sufficient according to intersubjective criteria and requirements. Additional difficulties arise in the field of social sciences and in particular in the area of the interdependencies between technological development and social change, as there is only a limited amount of theoretical knowledge and well-founded empirical data available. In contrast to the economic sciences, where there is agreement on the concept of national accounts, no valid measurement and classification system for technological progress has yet been developed. Each analysis works with its own concept and definitions.

Furthermore, it has not yet been possible to isolate the effects of technological developments – e.g., on labor market conditions, qualification, and economic structures – from other influences such as economic cycles or the influence of global economic development. So far, only relatively arbitrary attributions exist. The development of early indicators for impact chains that can indicate the diffusion of technical development with a certain degree of reliability is encountering great difficulties.

The issue here is the link with innovation research, which describes what is technically possible or has already been developed, but cannot indicate which innovations will spread in what way, at what speed, and in what space. It is even more difficult when it comes to forecasting changes in values or organizational changes: Futurology, which used to be conducted with great enthusiasm, no longer seems to be in vogue.

So if it is not possible to make precise statements about possible consequences or side effects of technical innovations, TA analysts should commit themselves to developing structural analyses and theoretical knowledge that can then guide the impact analysis, whereby it is initially important to identify bottlenecks, important development trends, or contradictory patterns of action. An important task thus arises in the continuous observation and analysis of technical and social change, whereby an attempt should be made to link explorative forecasts with empirically sound assumptions.

Kern and Schumann (1985) have introduced the term "bandwidth determination" for this purpose:

> We can thus characterize our method of prediction in summary as theoretically guided and empirically supported bandwidth determination. "Theoretically guided" because we refer to a theory of capitalist development that is based on the distinction between logic and forms of rationalization and contains certain assumptions about the change of form [...]. "Empirically supported" because we use empirical means to prove that the old forms are beginning to be replaced by new concepts of production. The concept of "bandwidth" is intended to define fields and boundaries within which the development can be expected (Kern/Schumann 1985, p. 378).

Thus, in a purely logical sense, forecasts of the indicative type are dispensed with, and one restricts oneself to naming danger points and limits of development. However, this is an opportunity to obtain empirically sound statements without having to submit to the constraints of a deductive forecast.

The model forecast can be distinguished from the trend forecast. In a model forecast, several mutually influencing variables are examined simultaneously with the relationships between them. The compilation of the relevant variables that can be found by a theoretical concept and the relationship between them is called a model. With the help of this model, which can be made increasingly complex as long as enough data and theoretical assumptions are fed in, an attempt is made to simulate possible consequences of complex relationships, possible bottleneck developments, and perhaps also possible consequences of human intervention.

> In this context, the scenario technique is also used more frequently. A scenario encompasses a qualitative (verbal) representation of a future situation and the development path that leads to this situation, and in this respect can be regarded as the qualitative counterpart to the quantitative model (Steinmüller 1993, p. 21).

5. The importance of prognosis in TA investigations

In the context of TA studies, the forecast has different tasks. On the one hand, it can serve to make explicit the prerequisites for decisions where there is no shared consensus. Every decision about technologies has a future reference. A decision for or against a technology is at the same time always an examination of alternative possibilities in the future. With the help of forecasts, the premises on which the decision-making process is based can be made clear and an objective discourse can be conducted on the basis of the predicted developments. Particularly in decision-making situations where the traditional consensus on the essential goals and values has been broken, legitimacy can only be generated through the persuasive power of a systematic approach. However, we must not ignore the fact that any gains in greater transparency achieved must come at the price of increased social complexity. Forecasts and their comparisons can increase the potential for conflict due to the pluralistic diversity of opinions and interests, and the decision alternatives can quickly grow into an immense number (Frederichs/Hartmann 1992).

Secondly, forecasts are not statements of fact, but statements of probability, which means that the basis for decision-making is partly fictitious. Niklas Luhmann (1992) pointed out this aspect:

> Under modern conditions, it is practically only possible to talk about the future in the mode of the probable or improbable, i.e., in the mode of a fictitiously secured reality (duplicated by fictions). We therefore know that the future present will be different from what the present future expresses, and it is precisely this discrepancy that is expressed by only discussing probabilities or improbabilities when it comes to the future. Whoever claims to be certain exposes himself to deconstruction in any case and can only expect support from fellow believers (Luhmann 1992, p. 187).

Luhmann thus alludes to one of the main problems of the discourse on new technologies and their effects. It is always about assessing future conditions and developments. However, even with a high level of scientific expertise, there is no a priori certain basis for this on which a broad and future-proof consensus can be reached. Agreement can only be reached on a situational basis on the assumption that the preconditions for agreement can be revised at any time. This could be called the probabilistic aspect of prognosis.

Thirdly, forecasts can be used to learn how the time horizon of action itself changes. In TA studies in particular, we often find that the further into the future the study extends, the more likely it is that unforeseen consequences will outweigh the recognizable ones. And there is something else. The unpredictability threshold of the future is now moving closer to the present. Known ignorance, i.e., the knowledge of gaps in knowledge, is increasing to the extent that it is already appearing on the horizon of decision-making. This can be visualized using the example of the current energy-environment problem. It is a decision-making problem with different time horizons in three phases.

Firstly, it concerns our direct dependence on oil, which we must reduce in order to avoid political blackmail and to bring about an international balance of payments. This is likely to take a period of ten years. Secondly, the prospect of depleting gas and oil reserves, a problem that will have to be solved within a generation or so. Thirdly, the combined problem of the depletion of fossil fuels in general and the impact of their combustion on the climate. The time span of this third problem is about a century. In terms of knowledge, different degrees of certainty are evident here with regard to the facts and possible connections. The horizon for action has increased immensely, which no longer corresponds to certain knowledge at the level of action. As a paradoxical effect, this dilemma is exacerbated by the increased ability of science to generate an almost infinite amount of perception and knowledge. The expansion of new laboratory technologies and measurement methods increases our ability to detect and assess even the smallest direct and indirect effects of our actions.

Fourthly, however, it can be said that forecasting is a scientific and not a political instrument. Although forecasts are repeatedly used in political disputes, they are a neutral procedure. They are characterized by a methodical approach and the explication of their assumptions. They are hypothetical and undogmatic. They can be revised at any time and are argumentative, provided their conditional form is not concealed.

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Ortwin Renn

Methods and procedures of technology assessment and technology evaluation

Introduction

The consequences and effects of new technologies are increasingly being discussed today. Market-oriented economists attribute the selection of productive technologies and the regulation of the speed of their diffusion to the guiding forces of the market. In contrast, non-economists or critics of the market economy call for a political evaluation of innovations. The traditional cost-benefit analysis, originally intended as a substitute for market selection for public goods, is thus gaining a new significance: It should no longer scrutinize the economic profitability of an innovation, but should also take into account the negative side effects for the environment, the economy and society. What is required is a comprehensive analysis of the advantages and disadvantages of an innovation, which should encompass several dimensions simultaneously. The ideal model for such a cost-benefit analysis is a procedure in which the decision-maker is presented with the expected future benefits and the risks to be accepted in quantified form and he (or the democratically legitimized bodies) weights these positive and negative consequences of an innovation on the basis of his value systems. Ultimately, only the technology that promises the highest net benefit will prevail. Without anticipating the results of the further discussion of individual technology assessment procedures, it should be clearly stated here that there can be no objective measure for the future consequences of a technology. In principle, the ideal described here can never be realized, even with refined and improved models in the following two problem areas:

- Uncertainties and margins of discretion will occur in any calculation of future consequences, no matter how complex and comprehensive a calculation may be.
- Although assessments and identifications are theoretically separable, in practice they are interwoven areas of impact analysis, which means that although the separation into “objective scientific impact analysis” and “subjective, political assessment” is feasible in principle, it can only be realized in a constant process of dialogue between these two decision-makers.

In addition to these two fundamental objections, the following problems are considered unresolved in the literature:

- the recording of consequences from the infinite variety of possibilities,
- the lack of knowledge of interdependencies in the course of the consequences,
- the aggregation of different types of consequences,
- the lack of an objective measure to obtain criteria for systematizing (and possibly evaluating) the consequences and weighting different dimensions,
- the assignment of probabilities for the sequence chain.

The particular problem with all methods is the question of how different impact dimensions should be recorded and processed. Attempts are made either to select one dimension as a representative criterion (e.g., deaths per year as an indicator of risk), or to combine several dimensions in one index, or, in the case of process-related selection procedures, to leave the aggregation to the groups involved in the decision-making process. The following discussion therefore serves the purpose of explaining the procedure and the significance of the various methods with regard to their approach to solving the general problems outlined here, and of explaining their possibilities and limitations. Of course, not all methods can be dealt with within the scope of this article, but it is important to provide a representative picture of the variety of methods.

1. Technologically-oriented processes

(1) Risk assessment with threshold value setting (targets)

The aim of this procedure is to estimate the risks from an installation or project as accurately as possible using probabilistic or deterministic analyses and to set specific limits for a damage consequence that should not be exceeded. The individual damage possibilities and their effects on health and life are recorded with the help of theoretical emission dispersion models, methods of average expected damage consequences, or damage indices on the basis of collective consequence exposures, and multidimensional aggregation procedures are calculated to determine the total exposure. At the same time, emission limit values are defined taking into account the pollutant distribution and the dose-response relationship, which is usually investigated experimentally (Rowe 1977). These are determined either intrinsically from the possibilities for the respective installation (criterion of the best possible or the most affordable technology), or in reference to other technical, civilizational or natural sources of risk. As a rule, the boundary is drawn in such a way that the negative expected value of a risk source may not be higher than the corresponding reference case (e.g., natural radiation risk, risk from other civilizational pressures, etc.). More complicated probabilistic models take the dispersion of the reference cases as a way to estimate the range within the probability distribution for all negative consequences and to prescribe standards (e.g., 1–2 standard deviations). The advantage of setting threshold values lies in the relative ease of use, the good institutional control options and the intuitive comprehension of the threshold values (Lowrance/Klerer 1976). In terms of methodological stringency, however, this type of acceptance specification is problematic for the following reasons:

- The determination of the consequences of damage is susceptible to strategy because the different procedures lead to different results.
- The aggregation of different types of pollutant effects always remains a question of subjective weighting.
- The theory of risk thresholds assumes that the benefit of the respective system plays no role in the acceptance of the risk. This assumption cannot be upheld either empirically or normatively. (This point of criticism does not apply if the comparison involves alternatives with equivalent benefits.)
- Even low threshold values are unacceptable if these values can be undercut with little effort through appropriate safety requirements.
- Threshold estimates based on negative expected values are implicitly based on the assumption that all sources of risk should be assessed equally. Intuitively, such equal treatment is rejected by the public.
- The interaction between different sources of risk and their harmful side effects is often given too little consideration when setting uniform threshold values and synergistic effects are therefore underestimated.
- Threshold values based on comparisons with other civilizational or technical reference cases can at best serve the purpose of clarifying the range of acceptable and unacceptable risks. Without taking the benefits into account, however, such comparisons are irrelevant.
- Threshold values based on comparisons with natural risks are certainly not suitable as normative parameters for assessing risks. It is precisely the purpose of many technical facilities to mitigate the risks of nature for humans. It would be like turning the gardener into the goat if the dangers to which mankind is exposed through nature were to be used as a measure for the acceptance of non-natural sources of risk.

These statements make it clear that the definition of threshold values cannot be derived from inherent valuation patterns, whether determined by nature or technical progress. The establishment of threshold values is of course institutionally necessary, but their justification cannot be derived from the type of risk source or the comparison of expected values.

In reality, the acceptance of risks cannot be explained by the expected value of losses. Figure 1 provides an overview of the expected values of various sources of risk. It can be clearly seen that a number of acceptable sources of risk – measured against the expected value – are not accepted and, conversely, a number of unacceptable sources of risk – again measured against the expected value – are readily accepted by the population. The expected value of possible damage cannot be regarded either normatively or empirically as a threshold value for evaluating technology. Of course, the expected damage must be included as a criterion in any technology assessment, but the calculation of the numerical risk is neither sufficient for evaluation alone, nor can a threshold value of acceptance be derived from its level.

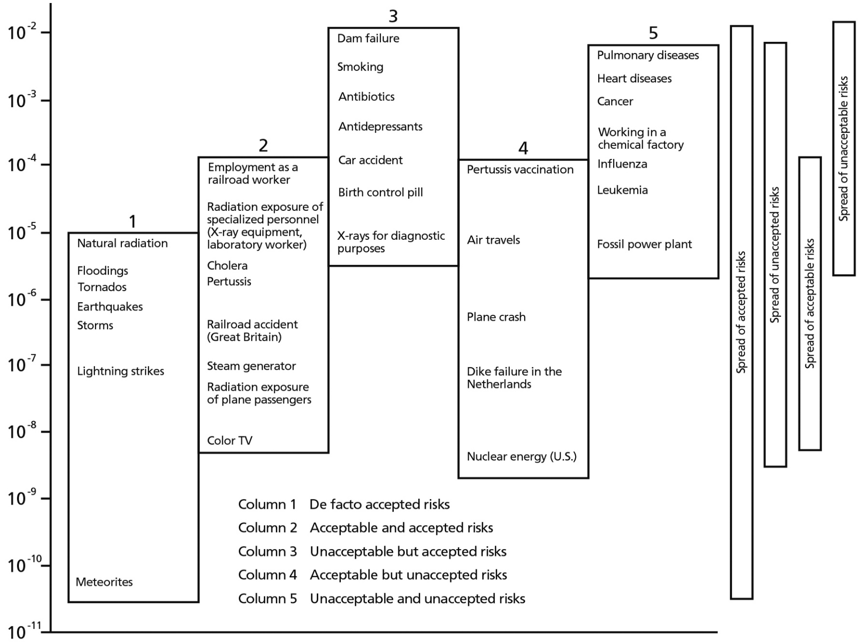


Figure 1: The spread of accepted (unaccepted) and acceptable (unacceptable) risks Histogram of individual risks of death for various risk sources

Source: Based on Nuclear News, Sept. 1980.

(2) Revealed preference approach

In this method, the acceptance of risks is assessed according to the extent to which the expected value of a risk does not exceed the magnitude of previously accepted risks. In addition to the expected value, the founder of this approach (Chauncey Starr) also includes the voluntariness of risk acceptance as a determinant of historical acceptance (Figure 2). Based on his analysis, Starr arrives at the following quantitative statements:

- Historically, a source of risk is accepted if the benefit increases by at least the third power of the risk.
- Voluntarily accepted risks are three orders of magnitude more likely to be accepted than imposed risks (Starr 1969).

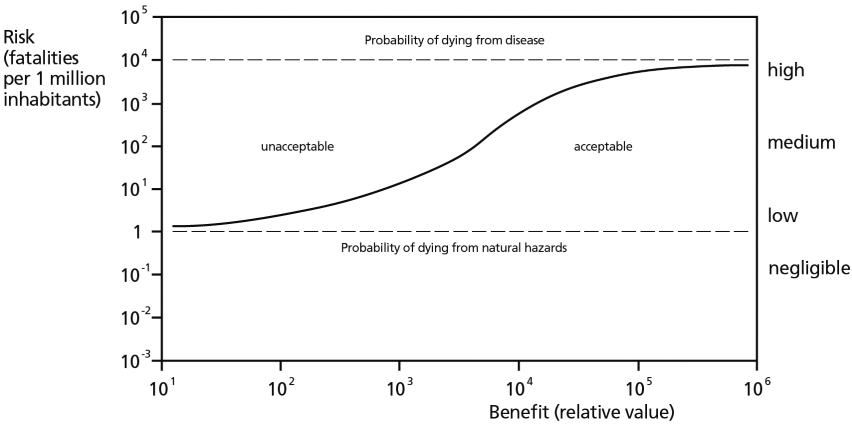


Figure 2: Revealed preference approach for technologies

Source: Based on Starr 1969.

A number of objections have been raised in the literature against the revealed preference approach, questioning the calculation method for quantifying benefit and risk on the one hand and doubting the validity of the entire method on the other. The comparison of new risks with historically accepted risks can certainly illustrate the situation of a society with regard to risk acceptance, but it is unsuitable for demonstrating quality criteria for the assessment of risks. Not only is it unrealistic because it assumes that there was complete transparency about the consequences before a decision was made about sources of risk and that a rational decision was made in the knowledge of these consequences; as we have already shown in the previous point, it also fails to take into account the real risks, because risks with the same expected values can be assessed differently.

(3) Expressed preference approach

With the help of this procedure, evaluation criteria for risks are determined on the basis of survey results in the population. Suitable questionnaires and experiments are used to determine the intuitive dimensions of the assessment of risk sources, and these inherent assessment patterns are consistently and systematically applied to the assessment of new risk sources (Fischhoff et al. 1978). This method requires a high degree of transparency of the risk consequences in the population and is basically only feasible if established viewpoints and assessment criteria already exist. It must also be assumed that these dimensions can be applied to all possible sources of risk. These prerequisites are currently controversial.

2. Economically-oriented processes

(1) Welfare theories

The optimal combination of goods in an economy is determined in such a way that, starting from a utility possibility curve defined as the geometric location of all Pareto-optimal solutions, a tangential point P is selected at which the social welfare function (aggregate utility function for society) touches the utility possibility curve. Although marginal welfare theory represents an elegant and conceivably optimal solution from a theoretical point of view, it is impractical for practical economic policy, namely:

- because cardinal utility functions can hardly be determined, even for individuals,
- because ordinal utility functions can contain logical contradictions when aggregated,
- because an aggregation of individual utility functions is not an adequate representation of collective preferences,
- because public goods can hardly be recorded with it (problems of the "free rider"),
- because inconsistencies and paradoxes can occur with more than two goods in this model, and
- because goods are not arbitrarily divisible and substitutable.

As a rule, welfare effects are measured using the share of gross national product or social indicators. For example, projects can be assessed according to the extent to which they increase per capita income or have a positive impact on other variables of the gross national product. However, this evaluation method does not take into account the effects of projects on non-monetary external variables (such as the environment and social security) or the question of the cost-minimizing efficiency of measures.

In addition, this method is very susceptible to strategy because various evaluation criteria (income increases, national product per hour worked, net production values, etc.) can be selected from the composition of the national accounts. As a rule, there are also long-term consequences where estimates of real costs and profits for the coming years have to be made (problem of return on capital and discounting). Ultimately, the measurement of economic projects using the parameters of the national accounts is identical to the monetary methods of cost-benefit analysis.

(2) Marginal cost analysis

The starting point of the cost-efficiency analysis is not the evaluation of a technology, but the optimization of safety. When is the point reached at which the costs of minimizing external effects (risk, environmental impact) are no longer worthwhile? Assuming that the cost dimensions can be quantified, it is economically worthwhile to spend money on safety measures until the last Deutsche Mark (DM) invested corresponds exactly to 1 DM of safety gained (Starr 1971). Figure 3a shows this optimization process in graphical form. In addition to the two types of costs – expected damage versus safety costs – Starr has also suggested including the conflict resolution costs in the calculation. This takes account of the fact that the subjective benefit allocation for 1 DM of damage suffered and 1 DM of safety gained can be different. According to Starr, these non-monetary benefit considerations are proportional to the conflict resolution costs that arise, i.e., as people value the security gained more highly than the resources to be spent on it, the more conflicts will arise if the decision-maker aligns his security measures with the marginal point. The inclusion of social reactions can also be transferred to the diagram. Figure 3b shows this optimization process, whereby the new equilibrium always contains a higher risk minimization than the optimum point of the pure cost-efficiency method.

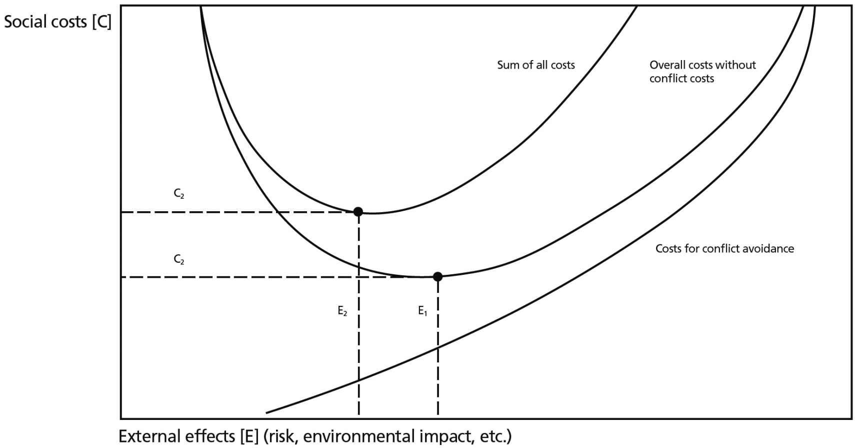


Figure 3a: Cost efficiency according to Starr for typical technologies including social costs

Source: Based on Starr 1979.

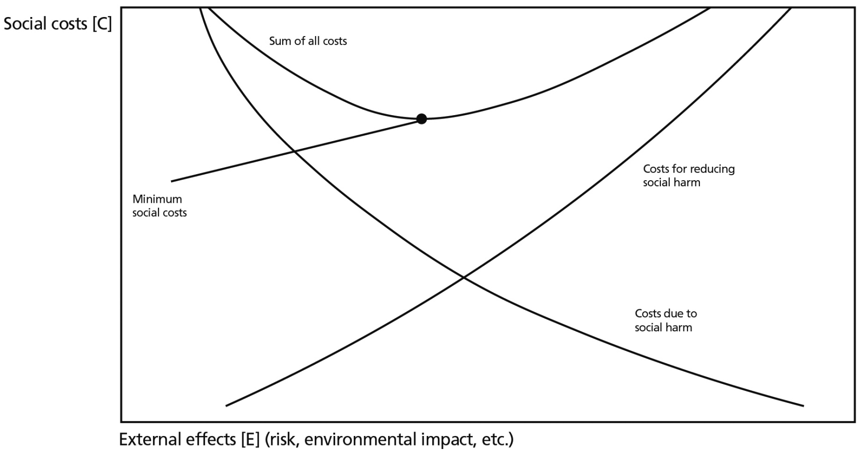


Figure 3b: Cost efficiency according to Starr including costs for conflict avoidance

Source: Based on Starr 1979.

A modified method of marginal cost analysis comes from Steiger (1979). In the external effects, he distinguishes between the cost curves for the elimination and avoidance of risks and for damage that can no longer be remedied. He also attempts to include a synthetic quantification of non-material costs (such as aesthetics) in the analysis. When these cost functions are added together, a minimum point can be specified at which the lowest total costs are incurred. The corresponding value on the abscissa indicates the percentage of conceivable risk-minimizing measures that make sense in terms of costs (Figure 4).

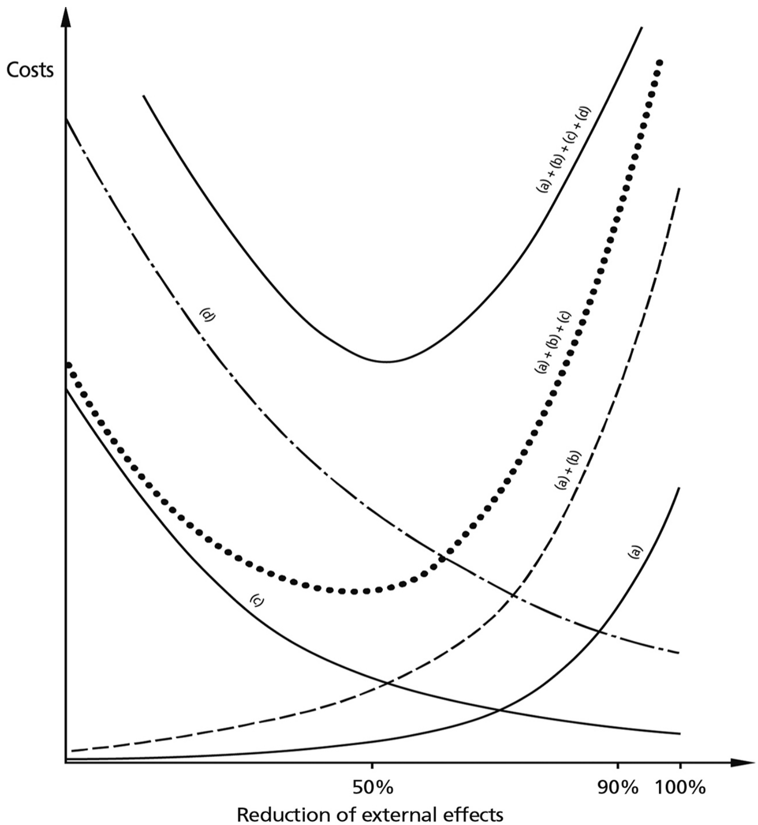


Figure 4: Cost efficiency according to Steiger Cost trends of the individual social cost components and total social costs

Source: Based on Steiger 1979.

The total social costs result from the addition of the curves belonging to the individual social cost components. Here, (a) represents the course of the avoidance costs and (b) the course of the repair costs of both material and immaterial damage. (c) shows the costs of material damage that has occurred but has not been remedied. These decrease with increasing measures to prevent or remedy damage. The addition of these three curves (a) + (b) + (c) expresses the total material social costs. (d) shows the cost trend for the non-material damage that has occurred and has not been remedied. It is typical for these to be considerable even with a very high degree of avoidance or elimination. Furthermore, a degree of elimination of 100 % is not achievable for this social cost component because the part of the immaterial damage that consists of the loss of irreplaceable assets cannot be remedied with any measures.

Cost-efficiency methods all suffer from the difficulty of converting different scale dimensions into cost units. The question of how to translate a lost human life into cost units alone has led to thousands of different attempts at solutions, none of which are satisfactory. In addition, economists are repeatedly – and wrongly – accused of trying to equate human lives with monetary units. An original solution to establish comparability comes from Black et al. (1975). The authors do not convert the damage losses into monetary units, but work with current loss units. They compare the expected losses from a risk source with the losses that would be expected if risk-minimizing measures were implemented. If, for example, the implementation of risk-minimizing measures for a major technology would lead to more accidents at work than would result in active safety for the population, then the limit point of rational safety improvement has already been exceeded. This process can also be illustrated graphically (Figure 5).

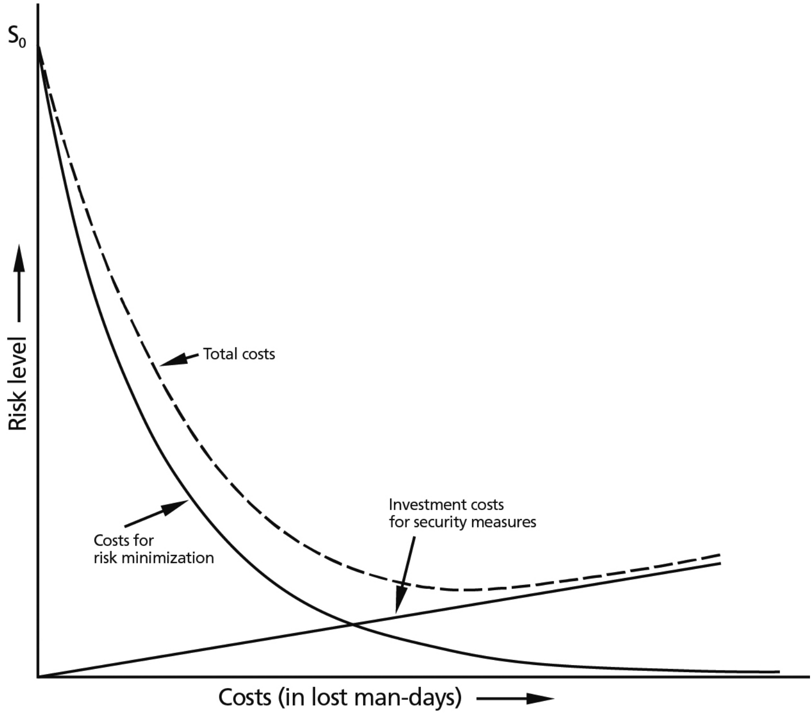


Figure 5: The marginal cost model of Black, Niehaus, and Simpson

Source:Based on Black et al. 1975.

Cost-effectiveness analyses are in principle suitable instruments for determining threshold values for the cost of safety and environmental measures. However, they do not provide an indication of whether a technology is acceptable as such, or how to select the best one from a range of alternative technologies.

(3) Social indicator solution

The social indicators establish certain quality criteria that serve as a multidimensional measure for the evaluation of projects. Social indicators were primarily developed to enable comparisons of welfare between different countries (OECD). However, their range of application is broader: Among other things, they make it possible to examine the benefits of certain projects within an economy with the help of an operationalized set of quality criteria (Zapf 1977).

The following objections can be raised against the social indicator concept:

- The selection of indicators is difficult to justify intersubjectively (susceptible to strategy).
- The operationalization of indicators is often arbitrary and ambiguous.
- Comparative benchmarks between several dimensions of a project cannot be derived objectively.
- Linking the indicators to form an index leads to considerable weighting problems.

3. Politically-oriented selection procedures (election theories)

(1) Voting procedure

Voting procedures are process-related evaluation programs that focus less on the question of economic rationality and more on the legitimacy of decisions. This is based on the idea that the cost-benefit balance is best reflected by the fact that as many of those affected as possible perceive a subjective gain in benefits. There are various methods to choose from: The unanimity rule (Wicksell), majority voting, plurality voting, point voting. All of these procedures have their specific problems (Mackscheidt/Steinhausen 1977). They are often susceptible to strategy and lead to paradoxical results (Condorcet). The biggest problem, however, is that for the people who vote, the transparency of the benefit-gain does not play a role in the vote (at most in the case of point voting). This means, for example, that projects in which a large majority would only achieve minor benefit gains, but a small minority would have considerable losses, would be accepted, while other projects with considerable benefit gains for a small minority, but insignificant losses for the majority, would hardly be enforceable (problems of relative distribution).

(2) Participation procedure

In this procedure, not only institutionally appointed bodies but also ad hoc groups drawn from the public are involved in decisions on upcoming projects. Citizens' forums, planning cells, citizens' councils, citizens' initiatives, etc., can be used for this purpose. Compared to simple election procedures, participation models offer the advantage that the participation groups are largely informed in advance and can reach a balanced judgment in discussions and hearings. However, this procedure leads to a double conflict: On the one hand, the participation body must legitimize itself in the view of the institutional decision-maker and, at the same time, in the view of the non-participative public. As sensible and recommendable as public participation in decision-making may be, it should not be overlooked that participatory bodies are not a "black box," but must in turn make their internal assessment according to some kind of criteria. The method of participation cannot avoid a procedure for measuring projects. Participatory forms of decision-making can only be applied once a transparent cost-benefit structure has been presented.

(3) Muddling Through

This procedure is not based on specific threshold values, but instead evaluates the process of enforceability of innovations as a benchmark for the selection of new projects. Technologies are evaluated by the groups in a society according to the maxim of asserting their own interests, and the interplay of forces results in a compromise that offers maximum benefit for all those involved (Lindblom 1959). This model is based on the economic theory of politics, which views political decision-making as analogous to the market process. Each group maximizes its benefit and minimizes the risk. When these interests clash in the political debate, a compromise solution is found that is just acceptable to each group.

The following objections can be raised against this model:

- The influence of organized social groups is not proportional to their number of members, nor does it depend on the degree of conformity with social welfare. On the contrary: The more exclusively the benefit can be limited to a group, the greater the chance that it will develop a powerful interest group (Olson criterion).
- The model of welfare-optimal representation of interests ignores the fact that public opinion selectively chooses certain areas of interest and neglects others. This inevitably results from the need to reduce the flood of information about aspects of our environment. As a result, it cannot be ruled out that technologies with little publicity and very high negative impacts are overlooked because another source of risk is dominating the public debate.
- Many projects and technologies are so complex that the extent of the benefits and risks for individual social groups is not clear. This results in a distorted perception of risk, which is not due to people's inability to assess risks, but

is caused by the fact that basic information is required for the assessment, which must first be collected, transmitted and processed.

One variant of "muddling through" is the "mixed scanning" proposed by Amitai Etzioni (1967). According to this, new projects should first be evaluated and assessed by the relevant institutions and only after this internal consolidation process should the public be involved in the discussion. This proposal corresponds roughly to today's approval procedures for large-scale installations. In terms of economic theory, this proposal is based on the idea that a series of Pareto-optimal solutions are initially proposed as alternatives through market processes or welfare strategies, with the specific selection from the set of optimal points being left to the interplay of political forces.

4. Systematic weighting procedures

(1) Cost-benefit analysis

Cost-benefit analysis is the most common method for comparing the costs and benefits of projects with external effects. Despite all criticism of the conversion of various cost-benefit dimensions into monetary units, it should not be overlooked that only a multidimensional aggregation procedure enables a meaningful comparison of the advantages and disadvantages of a project. Strictly speaking, the cost-benefit analysis is also not based on the assumption that the costs of a project (in particular the indirect effects such as damage to health or environmental pollution) can be covered by the benefits of the project, but on the assumption that either a new project makes some people better off without disadvantaging others (Pareto optimality), or – more realistically – that new objects should only be introduced if the beneficiaries can compensate those harmed in such a way that there is still a net surplus for the beneficiaries (Kaldor-Hicks criterion). The intention of the cost analysis is therefore not to offset damage to health or even deaths in monetary terms, but to compensate all injured parties according to their subjective loss of benefit as if the damage had not occurred in the first place (Niskanen et al. 1973; Mishan 1975; Engelmann/Renn 1980). As economically elegant as the cost-benefit analysis method is, the problems with its practical application are obvious.

The following problems should be mentioned in particular:

- A number of harmful effects (such as death) are not compensable under any circumstances.
- A number of benefit and harm dimensions are not commensurable with one another.
- A number of dimensions of benefit and harm cannot be quantified.
- The problem of relative income distribution is largely excluded.
- A standard of comparison between different dimensions cannot be derived objectively.
- The distributional effects of benefit and harm are not taken into account.
- The individual damage or benefit dimensions are not independent of one another, but are usually in a substitutive relationship with one another.

The last point is particularly important. In practice, cost-benefit analyses have excluded those dimensions for which quantification or a common standard of comparison with other dimensions is hardly possible. This reduction is considered sensible in order to avoid diluting the precisely determinable data with value judgments about qualitative characteristics. It is assumed that the decision-maker considers the monetary cost-benefit analysis to be only part of the basis for his decision and includes the other evaluation dimensions in qualitative terms. However, due to the substitutive effect of these dimensions, even this reasonable procedure is problematic, as it is easily possible to reduce the costs of a project by increasing the dimensions of damage effects that are not included.

(2) Risk-benefit analysis (risk-benefit balancing)

This is a new form of cost-benefit analysis in which the risks are considered instead of the costs and assessed in relation to the benefits. Here, too, the same problems arise as with cost-benefit analysis. There is no rule for how to translate benefits into monetary units and which unit of comparison is used to relate the risk to the benefit. All these comparisons presuppose some form of universal measure for assessing benefit and risk that cannot be derived from the scientific-objective data situation. One example is the evaluation of human life. Not only are the procedures for obtaining such a market value of human life problematic, but also the specification of a constant value for different situations and risks (e.g., voluntary versus involuntary risk-taking).

(3) Multi-attributive decision procedures

Multi-attributive decision-making methods are an attempt to first quantitatively represent the individual benefit and risk dimensions as probabilistic functions of possible losses and then to establish preference functions for the different variants based on the decision-makers' values. The combination of quantified consequences and value preferences is achieved by assigning utility values to each dimension and weighting factors for risk appetite (e.g., risk-taking, risk-averse, etc.). A decision process in which the decision-makers input the evaluative information while the decision theorists adequately and logically translate these values into the variant selection is considered ideal (Keeny et al. 1976). This process is understood as an ongoing dialogue.

The following objections can be raised against these decision-making procedures:

- It is often difficult to distinguish between value and factual statements (assessment and its weighting).
- Preference functions presuppose certain mathematically predetermined properties of the preference structure of decision-makers (such as transitivity). This is likely to be unrealistic in many cases.
- The aggregation of multidimensional sequences into an index is always determined by mathematical-formal models (such as questions of additive, multiplicative and logarithmic linking), even when preference and utility functions are included.
- Multi-attributive decision models require a single decision-maker who is free of contradictions. If there are value conflicts between the decision-makers, it is almost impossible to set up a preference function.
- Aligning the preference function with a decision-maker is often seen as undemocratic and authoritarian; however, it cannot be ruled out that preferences are only established after a democratic or participatory dialogue (quasi as a compromise).

Despite the existing criticisms, multi-attribute decision-making procedures have the advantage that the impact assessment is seen as a continuous accompaniment to the decision-making process, and that the non-scientific input of preferences and risk appetite comes from the legitimized decision-makers.

(4) Planning models

In addition to the individual procedures described so far, a number of multiple, procedural decision-making models have been proposed in the literature, which are usually subsumed under the generic term "planning procedure." The PPBS process (Planning, Programming, Budgeting System) became particularly well known in the 1960s. The process runs according to the following functional steps (Hansmeyer/Rürup 1975):

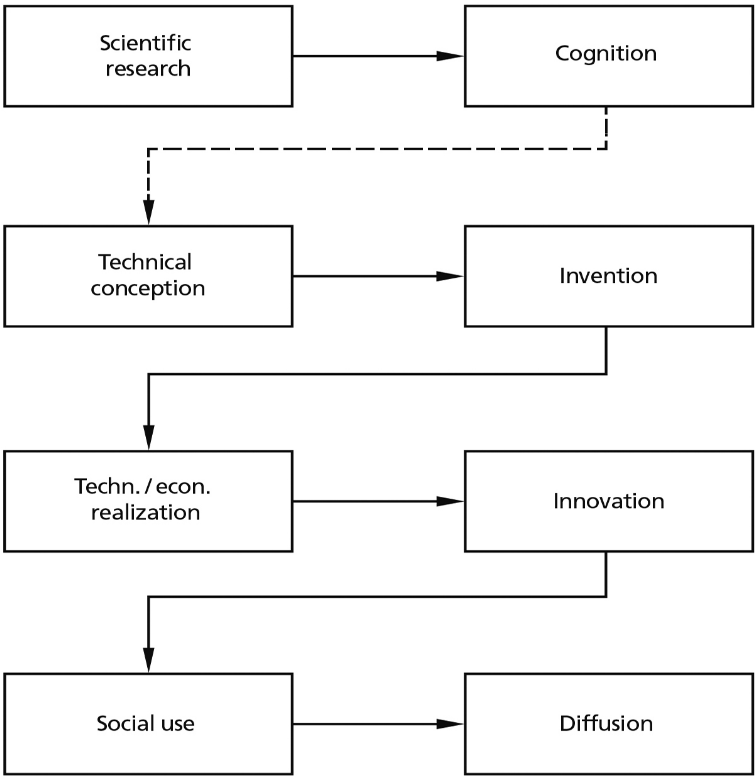
- Planning (definition of project objectives, operationalization of sub-steps)
- Program development (development of feasible alternative programs)
- Budget preparation (cost estimate, financing, etc.)
- Performance review (comparison of actual values with target values)

The PPBS method has basically proven itself as a systematic method for achieving objectives, but its numerical application soon encountered major difficulties. The same problems arise in program evaluation as in cost-benefit analysis. These are exacerbated by the fact that political programs have no market value, which means that the conversion into monetary units has to be even more arbitrary. Similarly, the question of aggregating dimensions and the weighting of damage or benefit aspects remains unanswered. In practice, this deficit has led to a concentration of power on the part of the planning authorities, which have introduced their own value judgments into the analyses under the guise of economic rationality. Similar points of criticism also apply to most of the other planning procedures, which are more or less a combination of the individual procedures already described. Exceptions are relevance tree analysis and the utility method, which are based on multi-attributive models and at least take into account the preferences of the decision-makers. Unlike these, however, they are not defined as dialogue-capable systems.

5. Systems theory approaches

(1) The scenario technique

Systems theory approaches are intended as a counterpoint to the more static methods of cost-benefit analysis and other related methods. The intention is to analyze innovations in the context of the surrounding social and economic systems and to examine the feedback of the innovation on the elements of limiting systems. A key feature of systems analysis work is the tracking of projects over a longer period of time within the framework of a model of system interrelationships, so that when changes are predicted in one system, the associated consequences for the other affected areas are also recorded. A simple example of a system-analytical consideration is shown in Figure 6. Here, Günter Ropohl traces the diffusion of a technology from its discovery to its implementation within the framework of a two-field system: Economic/technical feasibility and social perception (Ropohl 1979).



Phases of technical ontogenesis

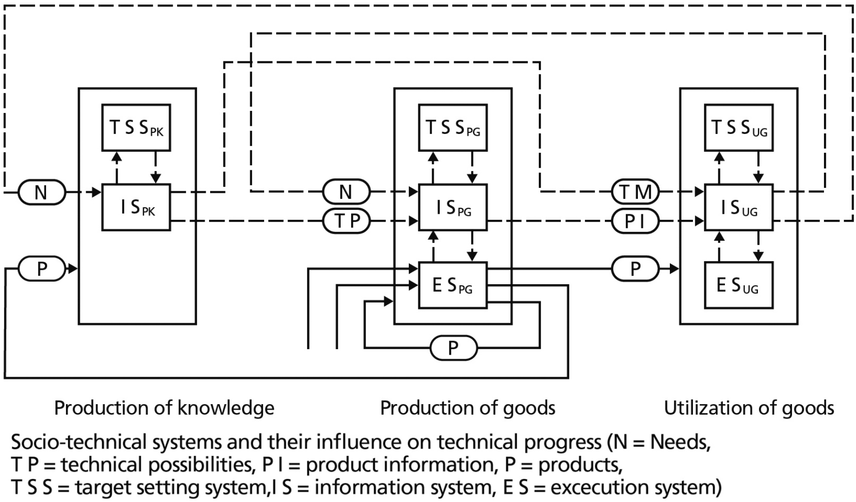


Figure 6: Simple diagram of a system-theoretical model of technology assessment

Source: Based on Ropohl 1979.

Obviously, reality is far too complex to include all the dependencies of systems in a theoretical model. In addition, there are always events outside the model framework whose developments cannot be determined by other system specifications. For this reason, a selection must be made, whereby the most important parameters and their scope of influence must be defined in advance. One of the most important methods in the context of system analysis is the scenario technique. A scenario describes a model in which variables are run under defined conditions to identify a change in the "if-then relationships." Such free variables are, for example, relative prices, political measures or the introduction of new technologies. The effects that the innovation is likely to have on other systems within society and the economy are examined in detail. The result of such analyses is a collection of information on the probable reactions of the systems over time, for example on the unforeseeable side effects of a new technology. In order to uncover such system correlations, so-called input-output tables are mainly used, in which the variables are entered as input and the resulting output data are fed-in as new input for the dependent systems. If the processing of the input variables is correctly reproduced for each system, then reliable forecasts can be made about the effects of changes in one system on neighboring systems that are not directly affected. For example, a scenario can be played out in which a new technology offers a new service in the investment area at half the price. As a result, the selling price of products that require this service in order to be manufactured will adjust depending on the input processing model (e.g., competitive situation). This in turn has an influence on the prices and quantities of possible substitute goods. Finally, if the innovation in question has far-reaching consequences, possible employment effects and other economically relevant aspects can be included in the chain of effects.

As elegant and effective as technology assessment scenarios may be, they are also fraught with many problems and extremely susceptible to strategy, because:

- The interdependence of the systems in question is difficult to deduce from empirical data and often has to be replaced by rough estimates,
- The freedom to choose assumptions harbors the danger of building models in such a way that desired results are supposedly scientifically confirmed,
- Subjective factors such as consumer behavior or political reactions can hardly be adequately taken into account in such models,
- Interdependencies and relationships in systems that are subject to rapid change are almost impossible to grasp,
- The selection of the systems under consideration and the relevant parameters is difficult to carry out using objective criteria, but usually only according to subjective preferences, whereby the possibility of conscious or unconscious manipulation is high.

All in all, the scenario technique appears to be a useful tool for investigating the impact of new technologies on economic and social areas, albeit with the caveat that the models used often abstract very far from real conditions and are therefore suitable for the political rationalization of preconceived opinions.

(2) Interdependency analysis

Interdependency analysis can be seen as an excerpt from the scenario technique. This method focuses on the question of how changes in one system affect elements of another system. The method is often used to analyze the effects of a technology on the natural environment. One example is the Strategic Environmental Assessment System (SEAS), which is used in the U.S. for legally prescribed impact analyses for the environment and nature. Figure 7 shows an overview of this procedure. In contrast to cost-benefit analysis or risk assessments, the individual dimensions are not aggregated but treated separately as individual systems. All effects associated with the introduction of the technology are fed into the model as input variables in order to be able to take into account feedback from production to demand and other relevant variables. This is to ensure that the dynamics of the sequence of consequences, i.e., the interplay of action and reaction, are adequately captured (House/McLeod 1977). The interdependency analysis is based more directly on the object than the scenario technique and therefore does not require a dataset that includes the entire economy. However, this also limits the validity of such analyses and all systems not taken into account are treated as constants. Otherwise, the same points of criticism apply as for the scenario technique.

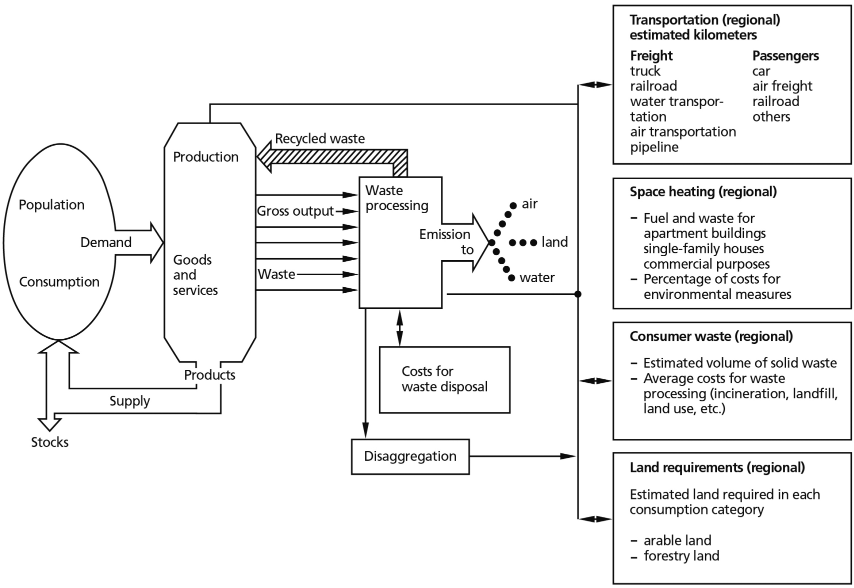


Figure 7: Diagram of the "Strategic Environmental Assessment System" (SEAS)

Source: Based on House/McLeod 1977.

(3) The basic needs concept

Recently, Cole et al. introduced a new concept that makes human needs the central focus of consideration. If the need is taken as the starting point, there is no necessity to quantify the benefit (Cole/Lucas 1979; Meyer-Abich 1978). The analysis according to this model is divided into two procedural steps:

- A comparison of use-equivalent demand coverage variants with regard to possible external effects (risks, economic benefits, social consequences) and their distribution effects;
- A comparison of the best alternative with the opportunity costs if the need remained unsatisfied or only partially satisfied.

The basic needs concept therefore does not start with a technology and attempt to systematically record the consequences of this innovation. Instead, it takes the needs of the individual or the collective as the starting point for consideration and attempts to assess alternative technologies according to how well those needs can be satisfied and what side effects are to be expected. Figure 8 provides an overview of this model variant. A positive aspect of this method is the link between need satisfaction and technology, i.e., the purpose of the technology introduction is also included in the analysis. However, the questions of how needs are measured and how the degree of need fulfillment is determined are problematic. The social impact analysis proposed by Meyer-Abich and others pursued a similar approach. Here, too, the energy supply is not based on the demand for energy sources, but on energy services. This includes people's needs for heat, light and power. The side effects of the individual strategies for satisfying needs are recorded and compared using selected criteria within a systems analysis framework. This is often followed by an evaluation of the alternatives, but in some cases this evaluation is left to the decision-makers or participatory bodies.

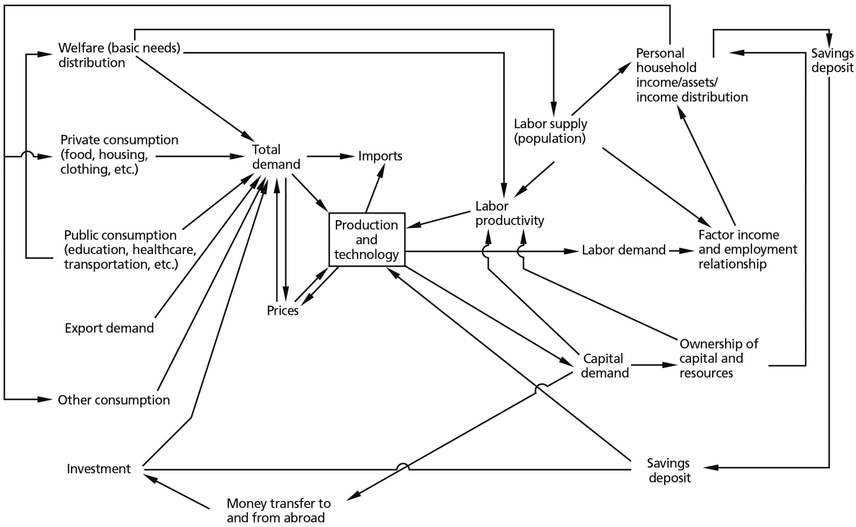


Figure 8: Basic elements of the basic needs concept

Source: Based on Cole/Lucas 1979.

6. Summarized criticism of the techniques and methods of technology assessment

What general conclusions can be drawn from this presentation and assessment of decision-making procedures and how can they be implemented for a meaningful collection of criteria (cf. Conrad/Paschen 1980)?

- Risk theory approaches are unsuitable for objectively determining acceptance thresholds or establishing sole criteria for evaluating technologies and projects.
- The economic methods of market selection, welfare theories and marginal utility theories are either based on too narrow a scope of application (economic efficiency) or can only be used for certain purposes (risk minimization) or under conditions that are very remote from practice (e.g., creation of welfare functions).
- Political procedures focus on the decision-making process and the selection of decision-making bodies. The way in which decisions are prepared and their content weighed up is either not considered at all (a black box) or is understood as a result of the interaction between individuals and institutions

maximizing their interests (political economy approach). These procedures cannot be regarded as a normative basis for rational impact assessment.

- Although cost-benefit analyses or other balances of advantages and disadvantages represent more comprehensive ways of comparing benefits and risks, they lead to the problem of universal comparability, the incommensurability of the various dimensions and the questionability of objectifying comparative standards. The functional dependence of the different impact dimensions also leads to serious methodological difficulties.
- Although multi-attributive decision-making processes solve the problem of value assignments and benefit perceptions of different consequences by developing dialogue-capable models between decision-makers and scientists, they require consistent and unanimous objectives and are susceptible to strategy, depending on the aggregation model.
- Systems analysis methods express the interdependencies between technologies and the fields in the economy and society that affect them and can therefore also follow the dynamic processes of innovation reactions. As a rule, system-analytical studies only provide catalogs of consequences; the evaluation must be carried out by the decision-makers themselves. The selection of the individual systems is subject to a certain fictitious arbitrariness and the linking rules for the elements of each system are difficult to derive from reality. As a result, systems analysis work is usually very strategy-sensitive.

What general conclusion can be drawn from the presentation of the methods and procedures for technology assessment? Many methods, such as cost-efficiency analysis, are important and meaningful decision criteria within their narrow scope, provided the results are only related to this area of application. Although far-reaching methods, such as cost-benefit analysis or system-analytical studies, cover a large number of dimensions, they must be interpreted with particular caution due to the need for subjective input and modeling conventions. A technology assessment process appears to be optimal in which strategies for meeting needs are first developed based on the basic needs concept, the individual variants are examined for their social and economic consequences and effects using social indicators, feedback and unexpected effects on neighboring systems are detected using interdependency models, and finally the data thus determined is evaluated in a participation process. Each variant can then be optimized again in terms of safety based on a cost efficiency analysis. How exactly such a combined technology assessment might look is described in detail elsewhere (Renn 1981). The conclusion to be drawn from the above considerations is that there is no such thing *as a* technology assessment procedure. Each procedure has strengths and weaknesses that make universal application inadvisable. Similarly, one should beware of the illusion of wanting to realize a completely neutral impact assessment without subjective guidelines. As important as technology assessment and technology evaluation may be today, science cannot meet the demand for objective data collection.

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Erwin Münch, Ortwin Renn

Safety for technology and society – theory and perception of risk

Risk – a colorful term! The gambler who hopes to win, the actuary who calculates life expectancy, the entrepreneur who assesses their market opportunities, the family who evaluates the future benefits of a consumer good, the patient who considers the success or failure of an operation, the technician who investigates the possibilities of accidents and mishaps – they all start from a common concept: the concept of risk. But do they always mean the same thing?

In the insurance industry and in the natural sciences, risks are defined as the expected extent of damage per unit of time, i.e., risks are determined by specifying empirical values as to how many people on average suffer damage per year or decade. In the humanities, risk is understood as the epitome of the unforeseeable consequences of an event or action, or even as the sum of the threats to our lives and our environment. In addition to the exact scientific definition and the more philosophical approach, the intuitive view of risk is of course also of interest: what do people consider to be risky, how do they assess risks and how do they cope with risky situations? Exploring the tensions between scientific and intuitive risk perception and developing political recommendations for decision-makers from this comparison is a key task of interdisciplinary research.

Scientific risk analysis attempts to use mathematical methods to introduce systematic regularity into the wide range of possible event sequences. But how can events that may or may not occur in the future be brought into a regularity? Can science provide an answer as to whether you win or lose at roulette?

If that were the case, all risk researchers would be millionaires. Unfortunately, they are not! Because the winning numbers in the lottery, the sequence of numbers in roulette, or the outcome of a raffle can no more be predicted than the occurrence of a single accident in a nuclear power plant. What science can do is to indicate the probability of someone winning the lottery or of an accident occurring in a nuclear power plant.

The concept of probability is intuitively difficult to understand. A typical example is the toss of a coin. Even the knowledge that heads or tails each occur with a probability of 50 % (1 : 1) does not improve the chances of winning in the slightest; it may well happen that the coin falls on heads ten times in a row.

However, if a player and a teammate perform many thousands of tosses in a row, you can be almost certain that the player and teammate will have about as much money left after the game as they originally bet, i.e., everyone has lost as often as they have won. This is the statistical law of "large numbers." The more cases you consider (number of coin tosses), the more likely it is that the calculable probability distribution of events (50 % heads, 50 % tails) will be reached.

However, the coin toss is about probabilities that experience has shown to occur repeatedly within a certain number of cases or within a limited period of time, such as lottery wins, fires or traffic accidents. A whole series of events are so rare that they cannot be estimated by experiment or experience. For example, the probability that the coin will stop exactly on the edge when it is tossed. Even if this special case occurs once in a game with 50 rounds, it is not possible to derive a regularity from it, and it is not possible to draw conclusions about the probability of how often this event can be expected per toss. Only if you toss coins for years, and the rare event occurs more often, can the chance be determined when, on average, an upright coin can be expected.

The statement that an event occurs once every ten thousand throws, or, in the case of continuously acting risk sources, once in ten thousand years, therefore says nothing other than that the frequencies of the rare events are collected in relation to the normal events and used to form an average value with the specification of a confidence interval. A probability of occurrence of once in a million years gives no indication of the exact time of the event, nor can one be certain that this event really occurs once in a million years. All we know is that on average there is a single possibility that the event will occur in a given year, but 999,999 possibilities that it will not occure.

In the absence of sufficient empirical values for the occurrence of rare events, it is not possible to specify a probability in purely statistical terms. Instead, simulation models are used in such cases. Here, the probabilities of rare events are determined indirectly through experimental studies, by transferring empirical values from related areas and through system-analytical models. Such simulated procedures are particularly important today, as the development of modern technology is often accompanied by an increase in the potential for damage, in the technical language of risk theory, and the "hazard potential" increases. The greater the "hazard potential," the less acceptable it is to use "trial and error," i.e., through operation and accidents, or to gather empirical values about the probability of damage over a long period of time. Instead, the possibilities and dangers of the relevant risk sources must be assessed in a forward-looking analysis, and the extent of the risk must be clarified in advance.

1. Methods and results of forward-looking risk calculations

With today's technology, a forward-looking risk analysis is therefore necessary. But how can incident sequences be investigated in advance, their probability of occurrence determined, and the extent of damage associated with these incidents determined?

Incidents arise from a triggering event, a breakdown or operating error, which can never be ruled out. Large-scale facilities – and nuclear power plants in particular – have extensive safety systems in place to limit the effects of such incidents.

In an event sequence diagram – as it is called by the technicians – the chain of individual events is simulated, from the triggering breakdown to all conceivable incident sequences. At each stage of the incident sequence, the respective safety system is asked whether it will successfully fulfill its tasks or whether it will fail. If the system works, then the incident is under control and there are no serious consequences. However, if it fails, then the next stage of the incident progression occurs and damage may be caused. Failure probabilities can be specified for each system switching point or branch in such an event sequence diagram, which are determined using the so-called fault tree analysis. In this type of analysis, a failure is assumed and the possible causes are determined. The causes are traced backwards until individual components are found whose failure rates, i.e., the probability of failure, are either known from experience or can be determined experimentally with reasonable effort. Inaccuracies in the calculations are compensated for by increased safety margins in the probability data. Multiplying the probability of occurrence of the triggering events by the probabilities for the functioning and non-functioning of the respective subsystems in the course of the accident results in the probability for the accident sequence under consideration. As an example, Figure 1 shows the event sequence diagram for a large leak in the main cooling circuit of a nuclear power plant, which can also be used for the design basis accident (maximum credible accident, MCA).

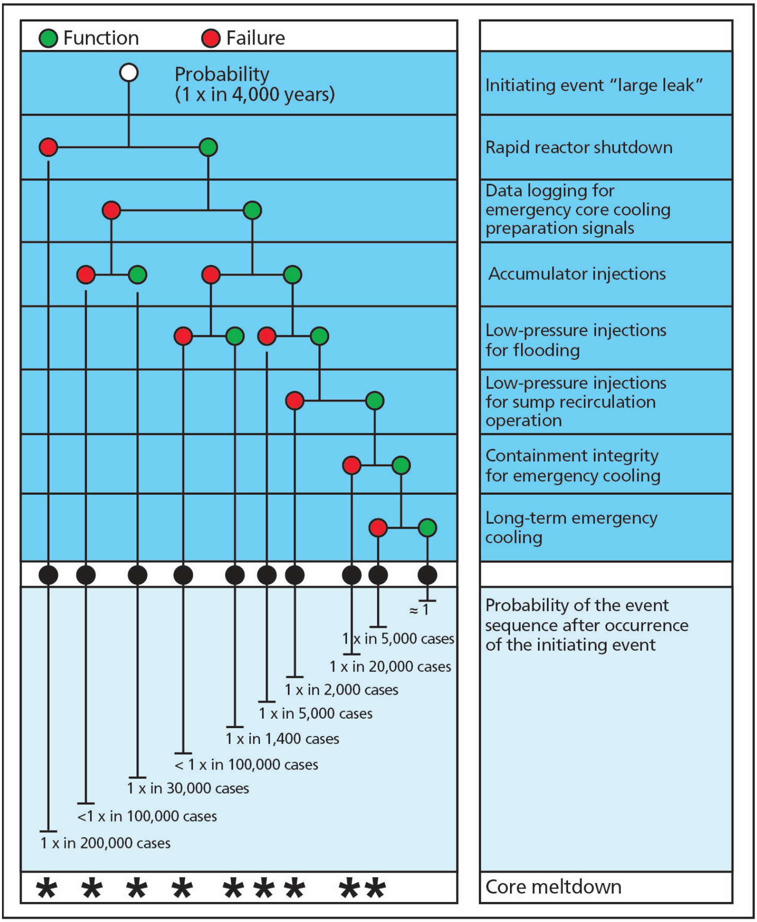

*Figure 1: Event sequence diagram for a "major leak" incident at a nuclear power plant. The probabilities for an assumed event sequence, multiplied by the frequency of the triggering event (2.7 x 10–4 per year), result in the frequency of the individual event sequences. The symbol * indicates whether the event sequence leads to a [reactor; the editors] core meltdown.*[1]

1 No sources were cited for any of the images in the original publication.

The probabilities for a given sequence of events can therefore be determined in the manner described. Depending on the course of the incident, there are possible effects on the environment (such as the release of radioactive substances), which lead to specific levels of damage based on known or calculable dispersion models and weather conditions. This includes short-term fatalities, injuries, genetic damage, long-term effects or damage to property. Multiplying the probabilities of a possible incident sequence by the extent of personal injury or property damage gives the risk of harm from a specific incident by definition. Provided that all conceivable accident sequences are examined, the total risk can be determined from the sum of the partial risks.

An example of such a comprehensive risk analysis is the German Risk Study for Nuclear Power Plants in the Federal Republic of Germany (Figure 2). The figure shows the expected probability per year of incidents leading to a certain number of early fatalities for the operation of 25 nuclear power plants. Due to the existing data uncertainties, the curve is provided with relatively large error ranges in which the relevant value is valid with 90 % certainty.

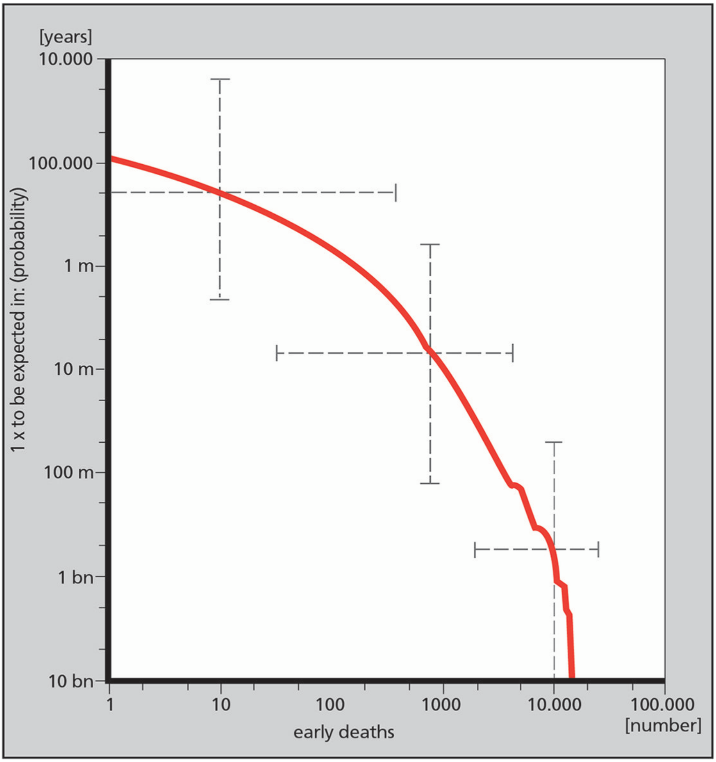

Figure 2: Complementary frequency distribution of early deaths, determined according to the expected values. The error bars indicate the 90 % confidence intervals, i.e., the correct value lies within these intervals with 90 % confidence. The plot applies to 25 nuclear power plants in the Federal Republic of Germany.

A comparison of the risk curve of nuclear power plants with the risk values determined for other technical facilities shows that nuclear power plants pose a relatively low risk to the population. To date, such careful and comprehensive risk studies have almost exclusively been carried out in the field of nuclear technology, risk assessments for large-scale petrochemical plants, such as those on Canvey Island (UK), result in much higher risk values.

Overall, the results of risk analyses show that the dangers associated with the use of nuclear energy are of the same order of magnitude or considerably smaller than those associated with other technical systems that people have known about for a long time. Based on this, one would have to assume that nuclear energy is a perfectly acceptable method of energy generation due to its calculated risk and as such is also acceptable to the population. Since this is obviously not the case, the concept of risk must be understood differently by the population. The understanding of intuitive risk perception can no longer be derived from considerations of the technical concept of risk. Psychological and social science theories and models can help here.

2. The intuitive perception of risks

If citizens assess the risk of nuclear energy differently from risk theorists, who take the scientific definition of risk as their starting point, then there may be three reasons for this:

- People do not know the results of the risk analysis, but make their own intuitive risk assessments,
- People know the results of the risk analysis but do not believe them, preferring instead to trust their intuitive convictions.
- People know the results and also believe the expert assessments, but they do not use this information as decisive criteria for their risk assessment.

Which of the three explanations is correct? Figure 3 provides an answer to this question. This chart shows the results of a survey in the U.S. and the Federal Republic of Germany. Several hundred people were asked to estimate the risks of various sources of danger, from tobacco smoking to nuclear power plants, in terms of losses per year. The estimated values are plotted on the y-axis, the actual statistical figures are shown on the x-axis. As can be seen at first glance, the estimated values for losses and the statistically determined "true values" are relatively close. However, the general trend for both the U.S. and the Federal Republic of Germany is that very high-loss risks are slightly underestimated, and very low-loss risks are slightly overestimated, meaning that people's perception of the extreme values is more in line with the midfield. Nevertheless, the correlation between the estimated and actual values is surprisingly good. Accordingly, thesis 1, according to which people are simply misguided in their estimates, cannot be correct. Since the trustworthiness of scientific risk analyses is hardly ever questioned in surveys, thesis 2 cannot be true either. This leaves only the third explanation.

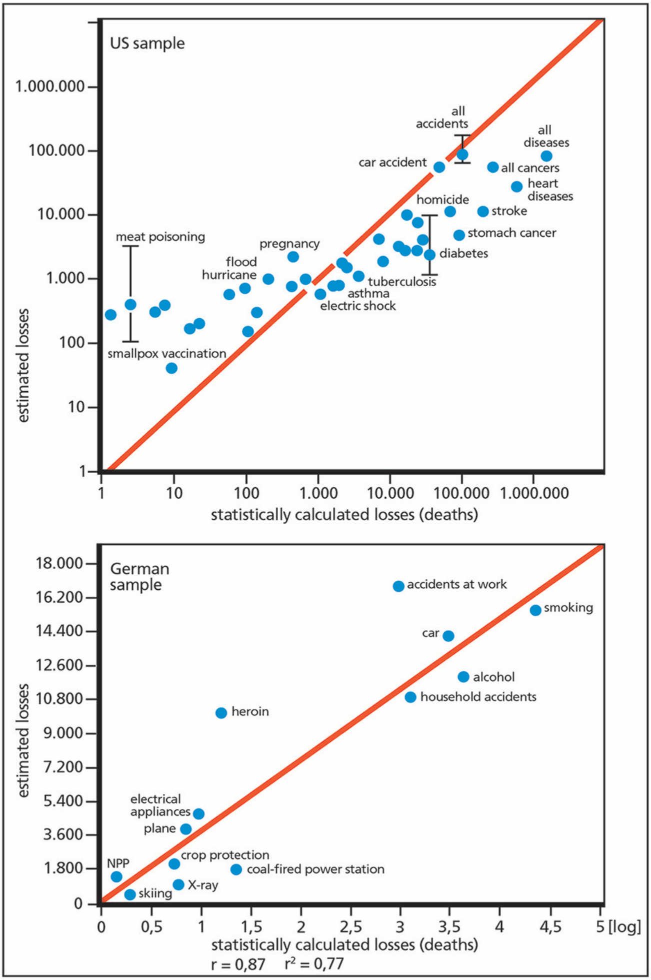

Figure 3: The population's estimate of the level of loss rates for various sources of risk compared with the statistically calculated values. The upper graph shows the results of a U.S. survey, the lower graph the results of a German survey. It can be clearly concluded from both surveys that intuitive loss estimates (here expected deaths per year) are relatively close to the true statistical values, but that very high-loss risks are underestimated and very low-loss risks are overestimated.

3. Imagined complaints – a guide to the psychology of risk perception

Before the question of the type and quality of the loss-independent risk assessment is addressed, a further survey result must be described, which was again implemented graphically (Figure 4). The mean values of the risk assessment of three independent samples from several areas of the Federal Republic of Germany are plotted in a coordinate system. There are only 100 or 500 interviewees in each case, so one would expect a wide spread of results, however, the risk estimates for all three groups are almost identical (the closer the points are to the diagonal line, the more similar the results). This is astonishing, especially as the dispersion within the individual groups is also low, i.e., most people answer in an almost identical way when assessing risks. Obviously, there are evaluation criteria that lead to a similar form of risk assessment for most citizens. It has already been explained that this homogeneous response behavior cannot be attributed to the perceived or real average loss rate. This makes it all the more urgent to ask which factors of intuitive risk assessment can give rise to such a similar view of risk.

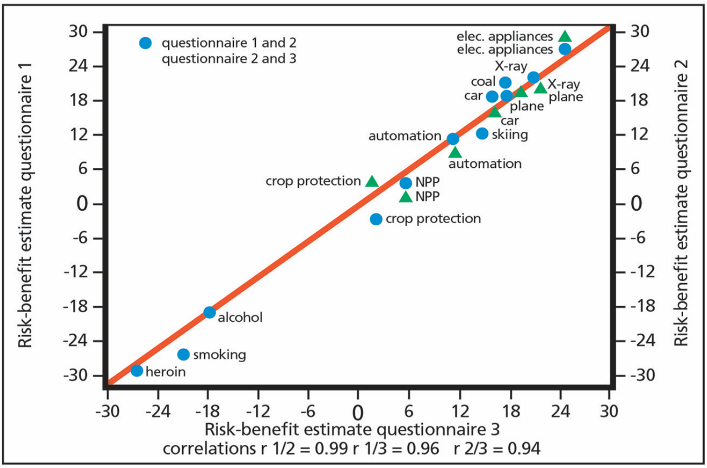

Figure 4: The assessment of various sources of risk according to the degree of their risk-benefit ratio. Three groups of people were given the task of estimating the net benefit of risk sources using a scale from -3 to +3. The surprising result of these surveys was an almost homogeneous response behavior among all three groups of people. This means that people assess risks in a similar way.

To gain an insight into how risks are perceived, a small socio-psychological experiment conducted at the Jülich nuclear research facility is described below. Two randomly selected groups of test subjects were asked by the experimenter to take part in a pharmaceutical trial test. Ostensibly, the aim was to test three different capsule coatings for possible unpleasant side effects. The test director explained to the test subjects that the first capsule contained a radioactive coating, the second a bacterial coating and the third an acid coating, with all three capsules dissolving more quickly in the stomach than conventional materials. There was in fact no health risk with any of the three capsules. In reality, the capsules were three identical commercially available vitamin tablets. The first test group was allowed to make a free choice from three options, the second test group was assigned one capsule each by the experimenter. After taking the capsule, the test subjects completed a questionnaire in which they were asked to provide information about any symptoms (stomach pressure, discomfort, etc.).

The result of this experiment is shown in Figure 5. Although all test subjects had swallowed an identical harmless capsule, the test subjects in the second group, who had not been allowed to make a choice, stated on average twice as often that they felt unwell than those who had been allowed to choose a capsule. This result was completely independent of which capsule coating was chosen or imposed. An interesting side note is that the supposedly radioactive capsule caused the most discomfort in both groups.

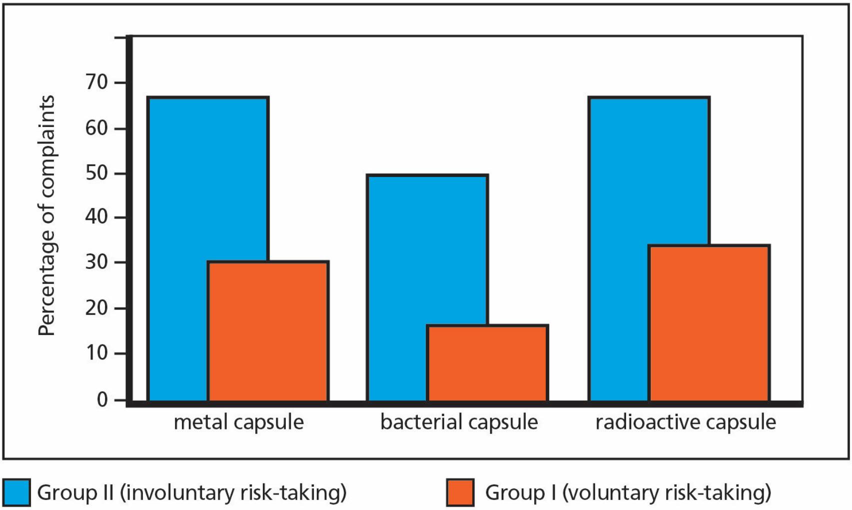

Figure 5: The results of the capsule experiment. Two test groups were given identical vitamin capsules with supposedly different coatings consisting of heavy metal, bacteria or radioactive substances. The members of group I were allowed to choose a capsule, while the members of group II had a capsule allocated by the experimenter. After the experiment, the test subjects were asked about their subjective complaints, such as stomach pressure. This clearly showed that voluntary risk-taking led to significantly lower rates of discomfort.

The fact that voluntariness is a key factor in risk perception has long been an important component of psychological risk and decision theory. However, it was not until this capsule experiment that empirical proof of this relationship was provided. Chauncey Starr has emphasized the importance of these variables in a completely different way. A comparison of statistical loss rates of different sources of risk showed that socially accepted risks taken voluntarily have a 1000-fold higher loss rate than risks that are considered involuntary.

Voluntariness is just one example of a whole chain of loss-independent variables that are referred to as "qualitative risk or benefit characteristics." Other characteristics of this type are: "personal control possible," "extreme consequences conceivable," "danger not perceptible to the senses," and "accustomed to source of danger." Surveys can be used to estimate roughly how important these characteristics are for the perception and evaluation of the source of risk. Figure 6 shows the extent to which individual qualitative characteristics are involved in explaining the risk assessment. The y-axis shows the respective correlation coefficient, i.e., the strength of the correlation, while the x-axis shows the boxes with the individual characteristic classes for nine different sources of risk.

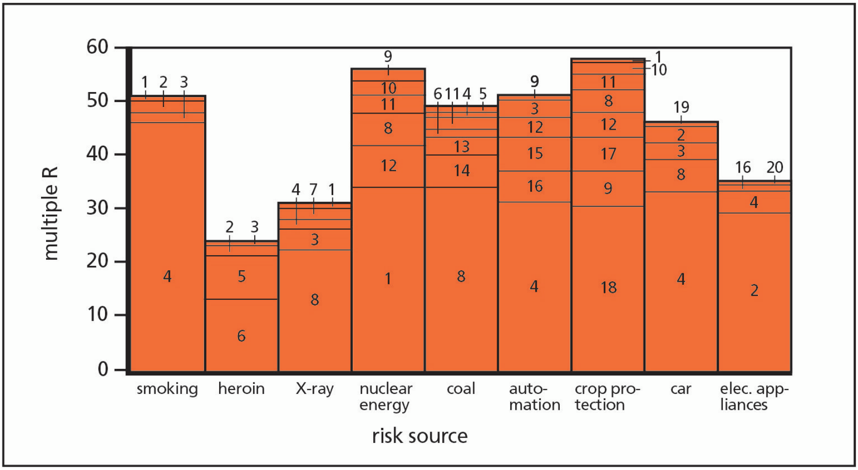

Figure 6: The influence of so-called "qualitative risk or benefit characteristics" on the level of the risk-benefit estimate. The individual bars show the multiple correlation coefficient, i.e., the strength of the correlation between the respective characteristics and the risk-benefit estimate. For most risk sources, benefit-related characteristics play the most important role, but for nuclear energy, crop protection and electrical appliances, risk-related characteristics play the most important role.

1 Catastrophic consequences, 2 Voluntary risk-taking, 3 Personal control possible, 4 Personal benefit/harm, 5 Effects known, 6 Benefit-equivalent alternatives available, 7 Everyday risk, 8 Benefit for all, 9 Safety monitored, 10 Imperceptible risk, 11 Personal control not possible, 12 Unusual risk, 13 Risk imposed, 14 Short-term harm, 15 Unknown risk, 16 Minor consequences, 17 No benefit-equivalent alternatives, 18 Long-term harm, 19 Safety monitored, 20 Scientifically researched.

If we first consider only the primary explanatory factors, i.e., the characteristics that have the greatest influence on risk assessment, it is clear that benefit-related aspects are far more important. People initially evaluate risks according to the possibilities and circumstances surrounding their use, such as whether they themselves can benefit from them, whether the benefit is for everyone or just a minority, and whether there are other alternatives that provide the same benefit with less risk. In the case of nuclear energy, crop protection and electrical appliances, on the other hand, the focus is on the risk characteristics. While the voluntary nature of the use of electrical appliances means that the associated risk is positively weighted, the dominance of the factor "catastrophic consequences possible" in the case of nuclear energy, and "long-term potential for damage" in the case of crop protection has a negative impact on risk perception. This clearly shows that the statistical loss rates are not the decisive motives for skepticism toward nuclear energy and crop protection.

Four risk characteristics that were included in the German survey described above are also recorded in the U.S. The German and U.S. values are shown in Figure 7 for comparison. As can be clearly seen, similar to the intuitive risk assessment, there is a similarity in the response behavior of German and U.S. respondents. With the exception of the ratings for car driving and X-ray diagnostics, the mean values for both countries lie within a narrow band of ± 1 around the diagonal (here the bisector = theoretical uniform distribution). This surprising agreement strengthens the assumption that qualitative risk characteristics are to be regarded as psychological weighting criteria that claim universal validity.

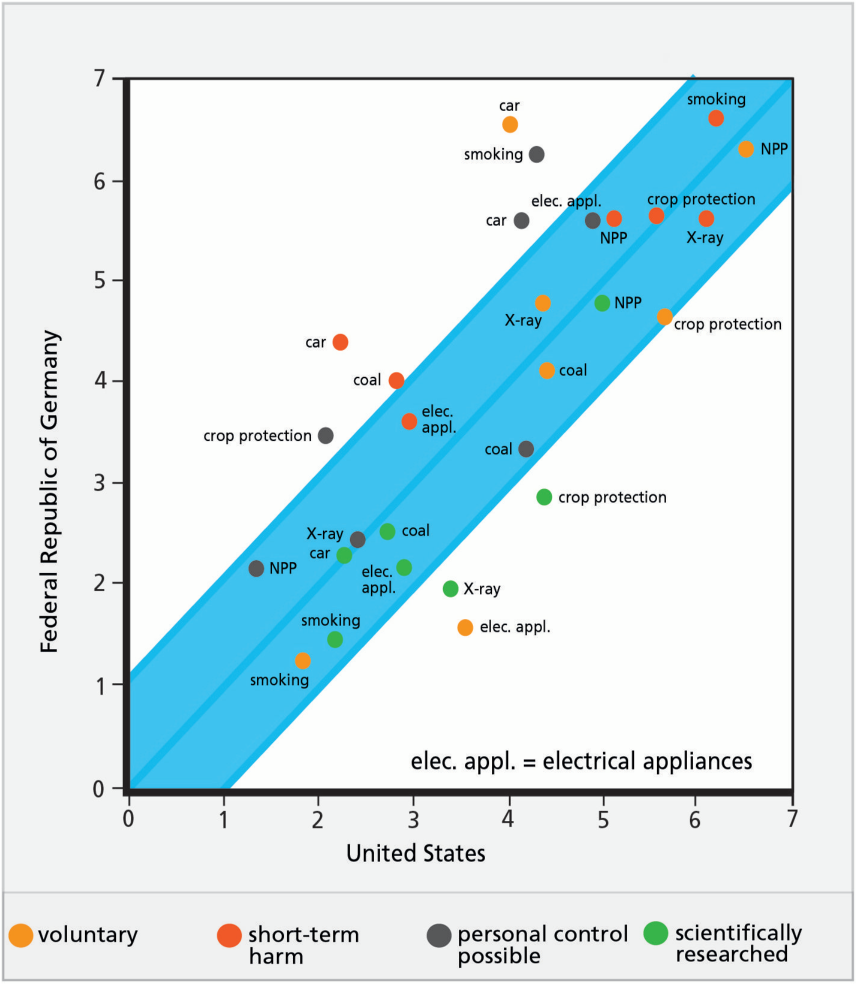

Figure 7: A comparison of the assessments of qualitative risk characteristics between a German and a U.S. survey. Respondents were asked to mark on a scale from 0 to 7 the extent to which the respective qualitative characteristic is typical for the sources of risk examined. This task also showed a clear correlation between the estimated values of the German and U.S. samples.

However, this should not lead to the conclusion that the qualitative characteristics are the decisive factors for risk assessment. The level of the correlation coefficients (Figure 6), which reflect the strength of the relationship between two variables, shows that the risk and benefit characteristics, like the loss expectations, only partially influence the perception of risk.

4. Risk sources more important than risk size

Expected loss rates and qualitative risk or benefit characteristics are two important categories by which people judge risks. However, the capsule experiment already made it clear that not only the abstract risk information (test subjects were told the risk was the same for all capsules) is seen as a decision criterion, but even more so the ideas and opinions relating to the source of the risk. Thus, the "radioactive" capsule triggered the most negative associations and accordingly caused the most frequent "imaginary" complaints. When perceiving risks, people do not separate the extent of the risk from the object from which the risk emanates. The observer is not indifferent to whether the identical risk emanates from a nuclear power plant or from a ski slope: on the contrary, the risk is only vividly thought through in its assessment when the individual can establish a connection with their ideas and opinions about the object from which the risk emanates.

It is very problematic for empirical research to measure people's perceptions of each risk source and to identify typical patterns of perception. Elaborate experiments conducted by the Risk Assessment Group of the International Atomic Energy Agency (IAEA) in Vienna have come to the conclusion that people classify their perceptions according to the criteria of "indirect effects of the risk source" (e.g., damage to health), "economic benefits" (e.g., increase in national income), "environmental risks" (e.g., pollution), "psychological and physical implications" (e.g., environmental impact) and "environmental risks" (e.g., pollution), "psychological and physical implications" (e.g., controllability of risks, artificiality of risk sources), and "impact on social and technical progress" (e.g., security of supply, social balance). These five dimensions of perceptions were obtained on the basis of survey results for the assessment of various energy systems. As this only covers part of the possible sources of risk, an intensive survey of 12 different sources of risk was carried out in a further study by Jülich in order to identify the most important ideas about the consequences of these sources of risk. With the help of a series of statistical procedures, the ideas surveyed were traced back to their central basic patterns (factor analysis) and made comparable by aggregation. The result of this evaluation was a classification and ultimately an evaluation of risk sources according to the following five aspects:

- Effects on the individual and the social environment (health, level of care, safety, etc.).
- Directly affected (personal benefit, harm, comfort, personal well-being, personal freedom, etc.).
- Impact on economic and social welfare (labor market, social balance, general standard of living, quality of life, etc.).
- Socio-political and social values (social justice, democratic rights, equal distribution of benefits and harms, etc.).
- Effects on the conditions for coping with the future (maintaining the level of performance, defending the scope for freedom, securing the level of care, etc.).

Not all of these five criteria apply to all risk sources, and the importance of the individual factors also varies considerably. To provide an overview of the strength and composition of the five criteria for different risk sources, the total values of the individual factors for six risk sources have been summarized in Figure 8. The bars below the zero line show negative assessments with regard to the risk source in question, while the bars above the zero line show the corresponding positive assessments.

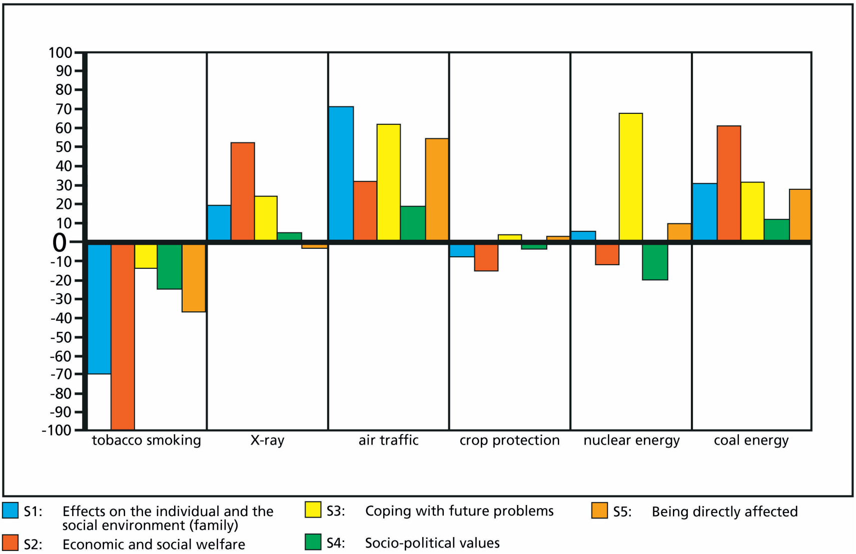

Figure 8: The importance of perceptions and associations about the risk source for assessment of the overall risk. For each risk source, the bars show the extent to which the five factors, which collectively cover the spectrum of the perception system, are used as essential assessment criteria for intuitive risk perception. The ambivalent assessment of nuclear energy and crop protection can be seen particularly vividly in the image.

A comparison of the bar charts for coal and nuclear energy clearly shows why nuclear energy suffers so much more from acceptance problems than coal energy. On average, the population associates the use of nuclear energy with a negative impact on social welfare and the realization of social values. In contrast, the direct and indirect benefits of nuclear power for their own lifestyle are perceived to a lesser extent. This negative preponderance can only be compensated for by the belief in the future role of nuclear energy in solving outstanding energy problems. The hope in the future necessity of nuclear energy prevents a consistently negative attitude toward nuclear energy. In contrast, only positive responses are found for coal, with the criterion of general welfare achieving the highest numerical value. Acceptance problems are therefore not to be expected with coal as an energy source, at least not for the majority of the population.

The assessment of pesticides is particularly ambivalent. While very negative aspects compete with some positive aspects in the case of nuclear energy, the values for crop protection scatter to a small extent around the zero value. This preference for the zero category is due less to an undecided assessment of the risk by the individuals than to extreme differences between individuals, some of whom gave very positive and some very negative gradations. The mean values around zero thus reflect a strongly polarized field of opinion. This reveals a process of perception of chemical interventions in the food chain that roughly reflects the situation regarding nuclear energy at the beginning of the public controversy in 1974.[2] For those responsible in politics and industry, these studies provide an opportunity to anticipate and avoid an escalation of the controversy and to get the problem of chemical additives in the food cycle under control at an early stage.

As a contrast to the perception profiles described above, Figure 8 also shows the perceptions for cars, tobacco smoking and X-ray diagnostics.

5. Rational versus irrational risk perception – a false starting point

If we take another look at the determinants of intuitive risk perception, three levels of influencing factors emerge that essentially reflect the population's assessment of risks. These are:

- The perceived expectations of loss,
- The qualitative risk and benefit characteristics,
- The ideas and opinions relating to the source of risk.

Some personality traits, such as a willingness to take risks and related attitudes, for example toward technological progress per se, should also be added, which will not be discussed further in this context. The level of intuitive risk assessment, which leads to relatively similar results between individuals and within the various social classes, only emerges from the interplay of these influencing factors. When weighing up risks, people generally perceive the statistically determined loss probabilities quite accurately, even if they lack direct insight into the significance of synthetic probability models. However, the statistically determined

2 *Editors' note:* The anti-nuclear movement in Germany dates back to the late 1960s and reached its first peak in the early 1970s, when large demonstrations prevented the construction of a nuclear plant in Wyhl in south-west Germany near the border with France.

measures of risk are not the sole criterion for assessing risk. This is where the scientific definition of risk and its intuitive implementation differ. While experts, for well-considered reasons, limit their risk calculation to the aspects of expected loss per time, laypersons process this information together with considerations of risk-specific circumstances (such as voluntariness) and with ideas about the corresponding source of risk. The layperson's perception is therefore more comprehensive, but less precise.

What can we learn from this juxtaposition? The artificial contrast between a rational expert assessment and an allegedly irrational lay assessment has not only obscured the true situation in today's discussion about risks, but has also made dialogue considerably more difficult. The technical calculation of risk levels is undoubtedly an important part of any decision on sources of risk and at the same time is an ideal tool for constantly improving the safety of the population. This is not at all controversial among the general public! However, making such calculations the sole criterion for the "acceptability" or "desirability" of technologies or other non-natural sources of risk contradicts the intuitive view of risk acceptance and is also unreasonable from a political and social point of view. Rather, it is precisely the accompanying circumstances that must be analyzed, and the consequences for people and society assessed, in order to compare people's fears and ideas about the effects of the observed sources with the real situation, and to correct any undesirable developments, or to avert them with foresight, and ultimately to make comprehensible decisions that reflect all levels of intuitive perception. It will only be possible to initiate a fruitful dialogue between scientists, decision-makers and citizens if we learn to take the structure and characteristics of the general view of risks seriously, and to specifically address and tackle the factors that flow into intuitive perception. If this is not achieved and people talk past each other, then the next acceptance crisis is not far away. Natural scientists, social scientists and politicians are called upon to work together to analyze the risks of modern civilization and to explore them in all their nuances so that humans, technology and nature can continue to live together in harmony.

Gotthard Bechmann

Risk as a key category of social theory[1]

1. Preliminary remarks

The workshops of social theorists are once again bustling with activity. After having spent the last decade clearing out their classical concepts, safely depositing old theoretical burdens or simply retreating into the labyrinthine building of the history of dogma, they have *discovered risk as a social-theoretical issue* (Beck 1986, 1989; Halfmann/Japp 1990).

As a special type of theory formation, social theory reflects on the defining structural features of existing society, which determine its forms of communication, its self-interpretation (ideology), and its conflicts. Social theory also constitutes itself as an analysis of the present. It asks about the present conditions of action, the evolutionary/revolutionary possibilities, and the self-interpretations and visions of the future of the members of society, which are expressed in communicative relationships. The double reference in its reflection on the functional structures and the possible development conditions of society forces it to search for the representation of the general in the particular and brings it close to metaphysics, as whose heir it presents itself – of course under different conditions and with different means – for both opponents and proponents (Heidegger 1972; Habermas 1988).

Social theory concepts are not only scientific constructs, they are also an expression of a factual awareness of problems in and of society. They are forms of reflection and embody recognized solutions to problems that have found their institutional expression in society (Luhmann 1971).

In the 17th and 18th centuries, it was the contract, subjective law and the category of the individual that inspired the theory of Hobbes, Locke, or Smith in order to make comprehensible the transition from a medieval hierarchy of laws to a simple commodity and market economy, and to reflect this development in its totality. In the 19th century, Marx, Durkheim and Weber focused on the concepts of labor, capital, class, division of labor, integration, and rationalization in order to be able to comprehensively analyze the emergence of a capitalist social

1 First published in: Kritische Vierteljahresschrift für Gesetzgebung und Rechtswissenschaft 74 (1991), pp. 212–240.

formation and its subsequent problems such as class struggle, bureaucratization and the differentiation of society. The classical concepts such as labor/capital, contract/action or state/society are still traded, but have lost both their connection to a stringent social theory for modernity and their explanatory power for the interpretation of current social reality (Offe 1982; Luhmann 1984).

Today, the *concept of risk* seems to be embarking on a career in social theory. It crystallizes the basic experiences and problems of a highly industrialized and, in many areas, scientified society. It has become the symbol of the present per se. For some, risk is directly associated with the *dangers of modern technologies* that threaten planetary civilization (Beck 1986, p. 254ff; Meyer-Abich 1990). They see risk as a danger that could escalate into an all-encompassing catastrophe. This is certainly not wrong, but it is one-sided. Even if some technologies were banned, the riskiness of life in a technical civilization would not disappear. Others associate the term risk with the *chance of extended control over nature* and celebrate the achievements of modern technology for this very reason (Heilmann 1986). From their point of view, the destructive forces thus released disappear or shrink to residual risks that can be tolerated as socially acceptable due to the immense benefits. A third group place the *emphasis on security* and see risk as a challenge to prove that security is feasible and producible (Krüger 1986), without, however, accepting that complete security has been unattainable since the Fall of Man at the latest, as since then it has at least been possible to choose between good and evil, apart from the difficulties of recognizing what is right in each case.

Our society seems to be paradoxically constituted. It can rightly be described as a society of danger and catastrophe, as Ulrich Beck does with emphatic pathos and good evidence. It is just as true when Francois Ewald speaks of the same society as an insurance company that has elevated security to a central value (Ewald 1989; Kaufmann 1973). Modern societies apparently increase security and insecurity at the same time. The concept of risk gives expression to this contradictory development and thus gains its significance for social theory.

Risk thus initially means nothing more than the *relationship between opportunities and losses in relation to a decision,* with the help of which one wants to make an unknown future predictable. The fact that this type of action has become an essential element of modernity must be understood in terms of social theory. My thesis, which I would like to make somewhat plausible, is that modern societies visualize their future as a risk and have thus found their own specific way of dealing with uncertainty, which distinguishes them from all previous societies.

2. Risk as a socio-theoretical concept

But what is risk? In recent decades, the literature on risk has exploded. Until then, the concept of risk had essentially only been of interest to a mathematically inspired decision theory, which had found its field of application in the insurance industry, but now economists, engineers, lawyers and psychologists are increasingly turning their attention to the subject. Even sociologists discovered it – albeit relatively late – as an attractive subject for their research. This intense preoccupation with risk across the various scientific disciplines suggests that an important problem of society has been addressed here. Nevertheless, *these studies lack a uniform concept of risk*. Although we now know something about how risks are perceived, how they are selected, how they can or cannot be calculated, compared or not compared, there is a lack of conceptual clarification of the underlying social problem.

Risk is often equated with danger, and risk is defined as a measure of danger. Risk is then the product of the extent of the expected damage and the presumed probability of occurrence, in short R = S x W. This formula has also been adopted by lawyers and has led them into extreme definitional and decision-making problems, as they only see a quantitative transition in probability in the distinction between danger and risk, and are unable to make the exact transition from danger to risk plausible on the basis of this conceptual construction (Kloepfer 1988). To switch from risk to social adequacy or to invoke practical reason, which then reveals itself as the reason of technical experts, indicates more of a failure to work through the problem situation than a satisfactory solution to the problem thus indicated.

The failure of "risk assessment" also shows that the risk problem must be about more than just solving a conventional measurement question (Krüger 1986). Here too, it has not been possible to develop a uniform standard. When calculating risks with a high hazard potential but a low probability of occurrence, it has been found that there is neither a binding measure for the dimension of damage nor a generally valid determination of the degree of probability (Binswanger 1990). Neither can be determined without social negotiation processes. The examples of Harrisburg[2] and Chernobyl[3] have made it emphatically clear

2 *Editors' note*: On 28 March 1979, the so-called Three Mile Island accident happened in Harrisburg (Pennsylvania, US), a partial nuclear meltdown of the Unit 2 reactor (TMI-2) of the Harrisburg nuclear power plant.

3 *Editors' note*: On 26 April 1986, during a routine power outage test, the No. 4 reactor of the Chernobyl Nuclear Power Plant, located near Pripyat in the Soviet Union (now

that the residual risk, calculated by experts to be almost zero, has become the actual social reality. Here, too, attempts were made to redefine the mathematically uncontrollable reality as a social problem. They switched from risk to acceptance and saw the real difficulty in the experts' loss of confidence (Wynne 1983).

If risk is not just a quantification of danger and at the same time risk has become a dominant topic of public discussion in society, then what is the meaning of risk?

The historical origin of the word risk provides a first clue (Priddat 1990). Uncertainty and risk appeared [in Europe] in the Middle Ages in connection with the [Christian] doctrine of usury. Interest no longer always meant [the sin of] usury, and interest taken as compensation for the risk of not recovering the money lent was seen as justified (LeGoff 1988). Nevertheless, interest takers still ran the risk of ending up in purgatory if they took unjustified interest. However, this would only become apparent in the future. Pascal's well-known [17th century] calculation of faith was also still based on religious considerations (Pascal 1980). The doubts about the existence of God that arose as a result of the confessional war[4] were to be transformed into subjective certainty of faith through rational reasoning. The risk of unbelief was simply too high, as the entire salvation of the future was at stake. Toward the end of the 16th century, the concept of risk was removed from its religious context and subjected to economic considerations. Seafaring and long-distance trade were the social contexts in which risk calculations became established. Risk (Italian riscare = to dare) here refers to a way of dealing with a future perceived as uncertain and dangerous (Bonß 1990). By insuring valuable goods, the aim was to make it possible to calculate the possible loss that could arise from lengthy transportation and the many unforeseeable dangers on the roads or sea. And not in the sense of creating security by combating or eliminating the dangers – that would have cost too much time and money and would probably not have been possible – but by taking a risk, and at the same time insuring against the possible loss, at least in part, so that if the loss event occurred, the loss itself remained limited and bearable.

If risk initially means opening up an unknown future for decisions, then riskiness from a quality of actions becomes the unavoidable form of existence

Ukraine) exploded. The Chernobyl accident is considered to be one of the most severe nuclear disasters so far.

4 *Editors' note*: Confessional wars are related to the European Wars of Religion that began after the Protestant Reformation in 1517. They were fought during the 16th, 17th, and 18th centuries. One of the most destructive conflicts in European history was the Thirty Years' War, which took place from 1618 to 1648.

of action per se. The greater the uncertainty with regard to the temporal connections between events, actions and decisions, the more it becomes possible and necessary to bring risk into play. Avoiding risky actions with the help of precautionary strategies is also perceived as risky, because it involves incurring costs and sacrifices that may prove to be unnecessary.

With the *universalization of risk awareness*, the issue of security also becomes relevant in society. In this context, risk is used as a complementary term to security. To an extent, risk is the soft form of uncertainty. Where there is uncertainty, security should be created through risk calculations. Evers/Nowotny even see this as the core of the concept of risk (Evers/Nowotny 1987). Elsewhere, Evers writes in deliberate contrast to Beck:

> Risk is a certain form of the practice of dealing with dangers, namely that which attempts to make dangers definable, calculable or even attributable by means of action techniques, methods and institutions (Evers 1989, p. 34).

This may be correct, but it does not capture the entire meaning (complexity) of the concept of risk. Any security gained in this way is, on the one hand, second-hand security: it is no longer the security of a world without alternatives; on the other hand, it is the security of a calculation that could have been calculated differently and that may prove to be correct in the future, but may also prove to be wrong. This contingency of the decision cannot be eliminated. Precisely because safety becomes conscious of being produced by decision, it loses its innocence and objectivity. In the language of safety engineers, this means that there is no absolute safety; from the decision-maker's point of view, this means: When you decide, you cannot decide without risk.

In the *term pair safety/risk*, risk is only a measure of the uncertainty that can be tolerated or of the safety that can reasonably be achieved. In addition, the concept of risk has a warning function in relation to the idea of uncertainty. It signals that more can be done about the danger: more information can be obtained, more money should be invested, more laws could be enacted. On the basis of strict calculation, the concept of risk offers a gateway for social, political and legal claims. The question that "risk assessment" has just elevated to a leading research question: "How safe is safe enough?" (Fischhoff et al. 1981), cannot be answered by this research, because then we would have to know the future.

If the concept of risk in relation to the concept of security has its function in the rationalization and regulation of claims, then in relation to the concept of danger it reflects society's historical approach to uncertainty. Luhmann has proposed an instructive distinction between danger and risk that illustrates this:

> Dangers, like risks, are about possible future damage whose occurrence is currently uncertain and more or less unlikely. In the case of hazards, the occurrence of damage is attributed to the environment; in the case of risks, it is seen as a consequence of one's own actions or omissions. The difference therefore boils down to a question of attribution. The assumption of risk is therefore based on a realization of danger. It is always possible if there are technologies that provide alternatives so that the possible damage can be attributed to the choice of action or omission. Then, however, decisions can and must also be made in uncertainty (Luhmann 1988, p. 269).

The first thing that is noticeable about this distinction is how closely the *concept of risk* is *associated with decision*. Risk presupposes a decision-making situation. The possibility of a natural disaster does not yet result in a risk, at most a threat. Risk only comes into play when you decide whether you want to do something about it.

However, the *concept of attribution* is decisive. It expresses the historical and social relationship between risk and danger. Depending on the degree of plausibility, risk and danger can be attributed to uncertain damages. If these damages are accounted for as dangers, they are externalized by society, regarded as coincidences; if they are classified as risks, they are generated by decisions and are accordingly responsible and also possible differently. If we now speak of the risk society, this term takes on a different meaning. Beck essentially used it to distinguish our society of high-risk technology from other societies. He defined the difference in terms of the new and qualitatively different hazard potential created by modern technologies (Beck 1986, 1989, 1990). In our context, we can say that modern society is a risk society insofar as it interprets all dangers as risks and thus produces an immense need and compulsion to make decisions. We no longer need to speculate as to whether the dangers of the scientific and technological age are greater or lesser than the dangers of the Middle Ages. One thing is certain: today, dangers are attributed to actions and decisions and are thus given the form of risks. Two to three centuries ago, much could still be attributed to nature, its willfulness, or even just fate, but with a few exceptions – in this case meteorite impacts or an invasion from an alien star – there is a consensus in our society that all dangers that threaten us are in principle based on decisions.

Even these brief considerations contain the essential elements of the concept of risk, which make it a fundamental concept of modernity, *in nuce*.

- First of all, it is about *uncertainty and the future,* about decision and attitude. We are uncertain about the consequences associated with a decision. It can have good or bad consequences. In any case, profit and loss lie in the future, a future that is unknown and harbors dangers, but which also opens up opportunities and promises profits. No one can take the decision to influence the future away from you. In this sense, the future is truly bleak and hopeless. Risk as a decision leads to an inconsistent attitude in time. By calculating risk, two things are attempted simultaneously: to take advantage of what the future offers and to limit the damage that may result from this action. Risk is therefore a form of decision that becomes self-reflective. It wants to be able to correct itself (Baecker 1989; Japp 1990b).

- A second moment stands out. By making risky decisions, one wants to tie up time and *make* the *future controllable from the present,* a future that one does not know, but which nevertheless determines the horizon of the action. Here we can already see that risk is a legitimate child of modern rationality, which has its credo in the feasibility of things and has found its form of action in the means-ends relationship (Weber 1971).
- A third characteristic of risky decisions is their *dependence on knowledge.* Although decisions can be made with intuition, the form of calculation forces us to collect data and information about possible events, to check their repeatability, in other words, to make them calculable.
- The fourth striking aspect is that this introduces a *subjectivization of danger.* Dangers are events that occur independently of human action. If you are aware of them, you can try to avoid them: leave the earthquake zone, don't build your house near a river, or avoid getting married. Threats can only be accepted as fate, as they come from outside and may create and uncertainties that can hardly be influenced. Risks, on the other hand, are consciously taken, their consequences must be accounted for and can be attributed to the individual as a decision that could have turned out one way or another. In the case of danger, causality prevails, albeit sometimes the causality of fate; in the case of risk, the experience of contingency dominates.
- Fifth, it becomes apparent that risky decisions are *self-referential and paradoxical at the same time*. The difference between risk and non-risk disappears, since a non-decision is also a decision. Risks are paradoxical; insofar as the option is realized, uncertainty increases with regard to the consequences that arise; if it is not realized, uncertainty arises about the associated consequences (loss of possible benefits). If you have not built a nuclear power plant, then you cannot talk about its benefits and dangers.

What is actually new, as we can now see, is not so much the feasibility of things and the ability to shape social conditions according to plan (Evers/Nowotny 1987), but rather that the concept of risk heralds a *change in human understanding of nature and itself*, which can be seen in the immense increase in human decision-making potential and in the primacy of the future over the past in society. It is obvious that all this is linked to structural changes in society itself.

3. Functional differentiation of society, future orientation and scientification

Modern societies, whereby the beginning of modernity is estimated to be in the middle of the 18th century, are incomparably more complex than previous societies. The increase in complexity not only concerns the increase in the possibilities for human action – a popular topic in the philosophy of technology – but the overall structure of society as a whole has changed. This will be outlined in a few points.

3.1 Differentiation into functional subsystems

Modern society is developing from a primarily stratified differentiation to a differentiation into functional subsystems. The division of labor as a prominent example of functional differentiation in industrial societies is not even the decisive feature. Far more important are the *differentiation and constitution of subsystems* such as science, politics, economics, etc., which become autonomous in a particular sense by reproducing themselves according to their own orientation patterns and no longer following a development logic of society as a whole.

3.2 Follow-up problems

The switch to functional differentiation is associated with decisive consequential problems. The integration of society is no longer achieved through the successful coexistence of people, but rather through the *interplay of the individual perspectives of the functional subsystems*. Values or actions no longer form the ultimate reference points of society. The human being as the center of society is losing its fascination and significance. Functional differentiation results in an "increase in the ability to dissolve" (Luhmann) all social facts, i.e., there is no longer anything outside of society. Even nature is only significant as the environment of society; it has no quality of its own that is distinct from society. "The grove became a grove." This sentence by Hegel outlines in a nutshell the process of rationalization and disenchantment that began with industrialization and is still ongoing today. Everything is socially mediated insofar as it only gains meaning if society communicates about it (Luhmann 1986). There are no longer any "natural facts," only relations and relational structures. This may also be the deeper social reason why the categories of traditional metaphysics, such as substance and movement, have lost their persuasive power as grounding concepts (on the context of this discussion, see Habermas 1988).

3.3 Loss of overall social representation (of the general interest)

Functional differentiation leads to an a-centric society. In the social transformation from segmentary differentiation to functional differentiation, hierarchical relationships are replaced by circular and counter-circular relationships. No subsystem of society can any longer claim to represent society as a whole or even to speak for it as a whole. What began in the 18th century with the splitting up of state and society has intensified into an evolutionary process in the following period. *Modern societies no longer have a central authority for self-reflection and control.* Neither the state nor capital, and certainly not the proletariat, represent the place where the general interest of society is anchored, because such a general interest no longer exists. Luhmann rightly points out the associated consequences:

> This makes it difficult and actually impossible to reach a consensus on what is and what is valid for society as a whole; what is used as a consensus function in the form of a recognized provisional arrangement. In addition, there are the actually productive function-specific syntheses of reality at the complexity levels of the individual functional systems, which these can each achieve for themselves, but which can no longer be added up to the overall view of a world in the sense of a *congregatio corporum*, a *universitas rerum* (Luhmann 1980, p. 33).

3.4 Shifting the time horizon

The time horizon of modern society has shifted from the past to the future (Koselleck 1979, p. 17ff.). Not only has society's range of possibilities increased immensely, but the fact that the past no longer forms the standard of orientation for action, but rather an uncertain future, is probably of equal importance for modernity. More and more decisions in the life of the individual are taking the form of a risk calculation. In other words, decisions where it will only become clear in the future whether they were right or wrong. *Social contingency is becoming the dominant life experience* of modern humans. Every action can also be carried out differently. Every social situation is constituted by a decision and is therefore, in principle, also conceivable in a different way. The pressure to make decisions has therefore increased immensely in modern society. Even living conservatively is based on a decision, and preservation (*conservare*) becomes a selection process.

3.5 Orientation toward curiosity

Modern societies are characterized by the prevalence of cognitive, adaptive and adaptive expectation structures, whereas normative, moral expectations are on the retreat. The subsystems of business, science and, more recently, technology have become the leading systems in society, from which the most important innovations come. Science, with its *early orientation toward curiositas*, has provided the decisive breakthrough here. *Curiositas* not only means curiosity, but also that everything in the world can also be researched with the help of scientific means and methods (Blumenberg 1971). More precisely, this means: Science operates in an infinite world that can only be limited by itself, namely by the limitations of scientific tools, theories and methods. It is only in the face of this new situation that the sentence that you can't do everything you can gains meaning – and exposes itself as a helpless triviality. Although research can be prohibited, the potential to research what is prohibited cannot be prohibited.

If these broad characteristics roughly apply to important structural features of modern societies, this essentially means two things for our analysis:

- Functional differentiation leads to a structurally induced overproduction of opportunities in society as a whole. This results, for example, in an increase in opportunities, but also in the compulsion to select, higher improbabilities and riskiness in every type of decision, in every type of determination and a generally open future.
- As science becomes a leading subsystem of society, a risk awareness develops that is based precisely on the uncertainty of scientific knowledge. Knowledge generated by research increases knowledge and ignorance at the same time. The modern risk society is not only the result of the perception of the consequences of technical realization. It is already inherent in the expansion of research possibilities and knowledge itself.

4. On the structure of risk in the modern age

Whether life in a scientific and technological world is more dangerous – this may or may not be the case – one thing is certain however; that it is likely to be riskier in any case, if only because it has become both richer in possibilities and more selective. This can be deduced from the structural framework conditions that have become the constituents of modernity. It is no longer possible to return to these, unless one wants to reverse the evolution of the social system as a whole.

In this respect, Adorno was ironically right when he defined freedom, with critical intent, as "only those who do not have to submit to alternatives would be free." There is indeed no alternative to the modern scientific and technical world in the process of self-realization, but only alternatives in society. At the same time, however, these also form the horizon in which today's society creates, perceives and processes dangers.

An essential experience of the present is the self-endangerment of society through the consequences of its developing structural principles: functional differentiation, future orientation, and scientification. In this context, technical-ecological risks play a prominent role.

The concept of technical-ecological risks has created a problem formula with which society alerts itself. They represent a type of risky decision that has become the focus of public attention and discussion.

Technological-ecological risks can be distinguished from other risks, such as the risk of unemployment, career decline or the risk of finding oneself in hell after a laudably spent life, on the basis of their form, their time structure and their social effects (Lau 1989).

4.1 Form and type of technical-ecological risks

A distinction can be made between sudden disasters in the form of major accidents (Lagadec 1987) and "creeping disasters" such as irreversible changes in ecology (Gottweis 1988). Japp and Perrow see their differences, but also their comparability, in the principle of coupling (Japp 1990b; Perrow 1987).

- Modern *technologies with a high disaster potential* are systems whose components are closely coupled and have a high density of action. These are usually technologies that release toxic substances during their operation, such as nuclear power plants, genetic engineering laboratory tests, and chemical production plants. The risk rationale for this type of systems is to prevent the release of toxic substances, or more precisely, the uncontrolled release of toxic substances. The system must therefore be as causally determined as possible in its functional sequences, and the technical manufacturing process must be strictly separated from its environment during normal operation. It may only correspond with its environment on the basis of predetermined relationships. Perrow has now shown that this principle of fixed coupling is susceptible to unpredictable incidents due to unpredictable interactions in the case of high internal complexity, which can escalate into catastrophes in a short space of time. In view of the fact that incidents can always occur that nobody can foresee, and have already occurred in many cases, Perrow calls them "normal accidents," and concludes that "high risk technologies" are uncontrollable in principle due to their existence. Not every "normal accident" immediately triggers a catastrophe, but it has the potential to do so. One wrong move, one piece of misinformation, or one misinterpretation of the display of a measuring device – and an emergency can occur, the extent of which is ultimately unknown.

- "*Creeping disasters*," on the other hand, usually take place in ecosystems. Here, the principle of loose coupling predominates, with diverse and complex interactions. In contrast to technical systems, ecosystems control themselves through the principle of "order through fluctuation." This self-controlling and self-organizing process is so complex that it defies any causal technical access. However, external intervention can disrupt the processual structure of the ecosystem, causing it to lose its internal flexibility and trigger a gradual catastrophe that can lead to the entire system toppling over. Soil karstification due to over-fertilization, forest dieback due to high levels of pollutants, and river pollution, are examples of this developing type of danger.

What interests us here, however, are not the associated horror scenarios, which are immediately aired when another of these disasters becomes public, but rather the peculiar relationship between risk and rationality.

> Under the conditions described, causal-technological rationality produces technical and/or ecological risk potentials which, due to the uncontrollability of complex interacting and tightly coupled systems, elude almost any causal-technological rationality. To an extent, these risk potentials are formed behind the back of the technologies and their rationality thus becomes paradoxical. They are rational (with regard to their causally intended purpose), and at the same time they are not (with regard to their "built-in" risk potentials) (Japp 1990b, p. 45).

Pointing out the paradoxical nature of technical rationality is a well-known game of any progressive and conservative critique of technology (instead of many: Horkheimer 1974). But is there an alternative? Or can the paradox be de-paradoxed so that we can live with it?

4.2 Time dimension and technical-ecological risks

Technical and ecological risks also create a time problem. For structural reasons, there is a lack of time to analyze and regulate them. Anyone who has dealt even superficially with the assessment of the consequences of technology knows that it is difficult to capture the full complexity of the effects within a fixed time frame.

In order to consider all possible consequences in the analysis, one would in principle need to have infinite time (Bechmann 1989). The prognosis of possible damage and benefits of a technology causes the researcher to swarm into the future, from which they can only be brought back with the help of the bureaucratic time machine of the deadline constraint. Any technology assessment can only be a selection of relevant consequences or, as the lawyer would say, consequences selected by practical reason. The time limit for the research process is both a structure and a relief.

There is a second restriction. Every investigation takes time, some more, some less. Nevertheless, the development of technology and its integration into the social fabric of society continues and raises new problems. During this time, both the questions and the data change. If you still want to conclude the research and decision-making process, you have to ignore new data from a particular point onwards. The decision is then partly made on the basis of fictitious facts and outdated observations. Marquart sees this as a general feature of our technical-scientific culture: the increase of the fictitious (Marquart 1986). According to Marquart, where everything is in a state of flux, every action or decision forces us to flee into fiction. The boundary between reality and dream dissolves on the horizon of declining rationality of purpose.

The selectivity in determining technical and ecological risks*, which* in principle *cannot be eliminated in terms of time,* leads directly to the thesis of the observer dependency of knowledge, and to Popper's theorem on the indeterminability of the future. Observer dependence means that the phenomenon to be analyzed can only ever be perceived in perspective. At best, one can in turn observe how an observer observes, how an observer observes the observer, etc.

The "Popper theorem" (Lübbe) states that whatever we may know in detail about the future of our world – one thing we cannot know is what we will know in the future, otherwise we would already know it. This indicates a *fundamental limit to the predictability* of scientific and technological development. Since knowledge and science have been transformed into the form of research, there is no longer any comprehensive, ultimate knowledge (Henrich 1982; Heidegger 1972): this is also a consequence of the self-actualizing modern age, which extends to the problem of risk.

4.3 Technological-ecological risks and the social dimension

Technological-ecological crises trigger severe social crises – this is the new experience in highly industrialized countries over the last twenty years. The protest against technology has become a protest against society per se (Touraine 1982). It can be seen as an expression of a general awareness of values and culture (Inglehart 1989), or interpreted as the struggle between two paradigms – the idea of life and the idea of progress (Raschke 1985). These may all be important and accurate insights, but they do not make it plausible why the conflict is primarily ignited by "high-risk technologies" and articulated in the form of fear.

It seems more plausible to assume that with the development and implementation of new technologies and an increasing number of irreversible interventions in the environment, a *new line of conflict* is emerging that runs between decision-makers and those affected, and symbolizes the issue in dispute with the distinction between risk and danger.

Although all threats of a technical or ecological nature today are caused by actions and decisions – the thesis that society is endangered by itself says nothing else – technological and ecological threats are perceived as risks by some and as dangers by others, and action is taken accordingly. There are several reasons for this:

- In the case of technical-ecological risks, costs and benefits fall apart or are not related to one person, so that a cost/benefit calculation is no longer instructive for the decision. Many people who are particularly at risk from new technologies, such as residents living near nuclear power plants, inhabitants of certain industrialized regions, or neighbors of large chemical plants, have to endure disproportionately high disadvantages, while the benefits are spread across everyone.
- Secondly, risk originators, or more precisely risk decision-makers, are now fundamentally different from those affected by risk. On the one hand, this is certainly a consequence of the differentiation of society with its functional systems: decisions and the consequences of decisions no longer coincide spatially, temporally and socially, as the chains of action and effects have been extended enormously. On the other hand, they can hardly be perceived without scientific measuring instruments and are difficult to attribute to the originators due to their complexity (Lau 1989).
- Thirdly, technological and ecological hazards are social risks. They are imposed on us, we do not take them voluntarily. Whether ecological risks are caused by the actions of many (forest dieback), or technical risks arise from the decisions of a few, one thing is certain: the individual neither wanted them, nor were they able to decide on the conditions under which they were taken. To an extent, they are brought into the world without their knowledge,

will or participation. In view of this situation, the individual's only option is to evade the dangers, to accept them – or to protest.

In other words, as soon as risky decisions are made in the field of ecology or technology, the *difference between the decision-maker and the person affected* arises. The decisive factor is that this difference no longer separates people, no longer discriminates on the basis of class or makes social distinctions. The separation of decision-maker/affected party is aimed at the division of functions and power. Who is allowed to decide and who is affected is thus a social question of attribution of self and others, which is decided on an individual, organizational and social level. The difference is institutionalized with the functions of the subsystems. Incidentally, this is also one reason why ecological protest is so difficult to organize in the long term: It runs into the pitfalls of functional differentiation.

The perspectives are correspondingly different. *From the decision-making perspective, the threat presents itself as a risk; from the perspective of those affected, it presents itself as a danger.* The decision-maker tries to rationalize the decision with the help of calculations, estimates, scenarios etc.. They even go so far as to take the perspective of the person affected into account by factoring in the question of acceptance and even providing information about the risk. No matter how complex and presuppositional the decision about possible risks may be, there is one thing it cannot do: see the risk as a danger and thus switch to concern.

Conversely, the person concerned perceives the consequences of the risky decision as dangers. The person concerned sees themselves exposed to a danger that they had no say in creating, that they cannot control, that they are at the mercy of, and of which they only know that it represents a risk from the perspective of the person who caused it – they are left with uncertainty and fear.

"Communication of fear" now also has its own specific social rationality (Luhmann 1986; Delumeau 1990). It creates solidarity and causes alarm in society. In dangerous situations, common ground is established, mutual help is organized and social differences are smoothed out. At the same time, blame is apportioned externally and those responsible for the impending catastrophe are sought. In short, *communication is moralized and ideologized.* In the face of danger, it is a question of humanity's chances of survival, or at least the preservation or destruction of the "natural" foundations of the species. Those who think in this way must dispense with rational decision-making, but focus on the "risk of rationality" (Japp 1986). From the decision-maker's point of view, the aim is to eliminate the potential for catastrophe through risk calculations, risk strategies and safety measures: This is precisely what is declared by the affected person as a failure of the decision-maker and made the crystallization point of fear and warning attention. Both perspectives thus reveal themselves as selections that deal with the uncertainty generated in society in different ways. One is the blind spot in the eye of the other. Thus, a dual perspective on the technical-ecological hazards in society is institutionalized: Some act in a risky way, others warn. But who is in the right will be decided in the future, which is unknown but is already being put up for discussion today, both in terms of risk and danger, and which contains both.

Technological-ecological hazards generate dissent, namely dissent in relation to a future that is expected to be a risk or a danger. Every decision, every action in this context can be dichotomized according to the risk/danger difference, and this because of the "contingency factor" implicit in it. Precisely because uncertainty has become the secret common denominator, and the future the point of reference, there is no overarching rationality criterion for resolving this conflict. In view of the technical and ecological problems, it is not a question of right or wrong calculations, but of the *limits of decision-making rationality.* On the other hand, renouncing risk also means renouncing rationality and the limited control of uncertainty.

If we consider this mutual exclusivity of the danger standpoint and the risk standpoint, we can see – as second-order observers – that a conflict has arisen here that is related to the constitutive structural features of modernity (functional differentiation, scientification and future orientation), and for which there are no satisfactory solutions in society to date. All attempts to rationalize this difference have so far failed due to their own preconditions. In the following, the three main approaches will be discussed: acceptable risk, expert decision, and risk communication.

- From the very beginning, the declared aim of risk assessment was to determine and set limits for the risk to be tolerated (Starr 1969). The history of these efforts can be described as a history of failure. Instead of finding a generally accepted measure of risk, the result was the realization that there is no such thing *as an* acceptable risk, but rather different perceptions and evaluations of risk that cannot be aggregated into a common value. In the course of the discussion, the optimization problem became a *problem of social acceptance* (Ueberhorst/de Man 1990; Otway/Thomas 1982). The result of this research can be briefly summarized: Acceptance and acceptability of risks are not fixed values and cannot be determined and defined independently of the preferences of those affected. They are always social constructions, processes of attribution and definition, which involve different ideas about the sensible shaping of society's future and which have to be negotiated through consensus/conflict processes in society. The conflicts surrounding the new technologies convey to the contemporary observer that the irreconcilability of the contrast between danger and risk is more likely to generate more dissent than to open up opportunities for consensus.

- A similar impression is gained when one sees *the shake-up of expert status* that has taken place in the field of science and technology in connection with this conflict. An expert is someone who has specialized knowledge and is trusted to make the right decisions for others (Bechmann 1990). In view of the undeniable catastrophic nature of modern technology, trust in experts is dwindling. It is ruined by the harshness of the contrast between risk perception and hazard perception, to the extent that the danger is no longer due to natural events but results from the decisions of others. When error, misconduct – and even worse, new knowledge – can no longer be ruled out, trust in the self-confidence of others dwindles, especially in the case of potential damage that simply eludes precautionary measures and insurance.
- The demand for more *communication with those affected* was derived from the experts' loss of trust (Weber 1986, p. 184). In science, a term was immediately coined for this, which can be used to apply for funding, hold conferences and fill positions (Jungermann et al. 1990). "Risk communication" is intended to help where trust has been destroyed (Plough/Krimsky 1987). Leaving aside the fact that in many cases communication is only intended to generate a willingness to accept by having the affected party take on the perspective of the decision-maker, the question arises as to whether dialogue in this context can achieve what is expected of it. Communication initially generates a multiplication of topics, an increase in the amount of information and an expansion of possibilities. Not only solar energy as an alternative to nuclear energy, but also saving energy or changing the entire energy industry can be considered as possible decision alternatives. However, the threat of catastrophe is also increasing the pressure to act; not everything can be discussed. Both the expansion of decision alternatives and the potential dangers force selectivity. Communication aimed at making decisions must be interrupted at some point. Making risky decisions always means acting without knowing exactly what to do. Risk communication must also be terminated by virtue of authority, as there are no limits within it. The only question is, by virtue of which authority, that of the decision-maker or that of the person affected? But there is another. In view of today's knowledge about the side effects of risky decisions, the decision-maker reveals that they cannot

control the consequences. Despite all the discussion, we end up back at the problem of decision-making under uncertainty and the difference between risk and danger.

These three examples should only illustrate the structure of the conflict that has arisen with the distinction between decision-makers and those affected. The risk and hazard perspectives are irreconcilably opposed both in terms of the control (tolerable risk) of knowledge (experts), and in terms of understanding (risk communication).

5. Ethics and rationality

In the conflict over high-risk technologies, hope has been placed in an "ethics of responsibility" (Jonas 1979) and in comprehensive rationality after politics was unable to reach a consensus and the law was unable to create peace. The only question is whether the control of risks with ethics as a control criterion and non-halved rationality is not an escape into the 19th century.

5.1 Ethics and risk

Following Luhmann, one can differentiate between morality and ethics and understand ethics as the reflection or theory of morality. Morality, on the other hand, has to do with rules of mutual respect and disregard that are communicated and institutionalized (Luhmann 1978, p. 43f, 1990, p. 17f; also Tugendhat 1990). Morality distinguishes between good and bad, whereas ethics specifies when this distinction should be applied, in which cases it applies and how it can be generalized and universalized. If we take this distinction seriously, we can see three things.

(a) Many treatises that are traded on the public engagement market today under the "headline" of technology and ethics reveal themselves on closer reading as *moral treatises* dealing with the good or bad sides of technology. Their preferred form of reflection is the formula "indeed ... but," or, "on the one hand ... on the other hand" (Kluxen 1987; Lenk/Ropohl 1987; Zimmerli 1991; and many others). Only a few deal with an ethics of technology (Lern 1990) and they come to a skeptical conclusion about the efficiency of ethical principles in determining the regulation of technology. Today, ethics in the field of technology seems to have become a moral enterprise.

(b) *Overall social morality and functional differentiation are mutually exclusive.* The evolutionary novelty that prevailed with functional differentiation and on which it is ultimately based was that the individual functional areas with their fundamental orientations detached themselves from the contexts of morality and religion and specialized in various codes. The neutrality of politics toward questions of religion and morality, symbolized by the rule of law, the independence of science from social constraints, symbolized by the principle of freedom of value, and the freedom of love, symbolized by the value of passion, testify to the process of the increasing indifference and autonomy of these areas toward regulatory guidelines other than their own codes. Scientific truth, political decisions or dealing with money can no longer be made dependent on a generally binding morality. Modern society can no longer be integrated via morality (Luhmann 1990a, p. 25).

(c) Anyone who speaks of ethics or morality also means responsibility. The *concept of responsibility* presupposes two things: precise knowledge of the secondary consequences, and an agent to whom these secondary consequences can be causally attributed as an action. Both have become problematic in the field of technology development. We no longer live in a guild society; modern technologies are not produced according to the craftsman model. They are characterized by incompleteness and uncertainty about their side effects. Only in the future will it become clear whether the predicted advantages and disadvantages will materialize, and the future can be distant, as we know from the field of "small-dose effects." Often, however, unexpected consequences occur that no one has taken into account. But how can we take responsibility for this, when at least the recognizability of the consequences of our actions is a prerequisite for responsibility? Whatever we know about major technical innovations and their consequences, one thing is certain: the more planned a person's actions are, the more effectively they are affected by chance (Dürrenmatt). Even recourse to ethics of conviction cannot resolve the dilemma. Dealing with technology in particular has taught us that good intentions can have bad consequences and vice versa. Who wants to trust their own conscience – only to be condemned afterwards? The uncertainty of the future and the limitations of consequence analysis have blunted the weapons of ethics. In functionally differentiated societies, the consequences of scientific and technological progress are no longer in the hands of one person; neither in the hands of the scientist, nor in the hands of the politician, and certainly not in the hands of those affected. At no point in society can

> these effects be overlooked or controlled as a whole. Unless God is restored to his former rights.

As we remember, risk is the form of a decision that attempts to bind the future and in doing so creates decision-makers and those affected who treat the consequences of this decision according to the risk/danger scheme. If this is the case, the dilemma of the morality of risk quickly becomes apparent. Morality, but also ethical reflection, presupposes that one knows the actions and their consequences that are attributed to one, and according to which one is sorted into good and bad. We must at least be able to assume that they are foreseeable. If this is not the case, morality comes to nothing. This uncertainty about the possible consequences of actions also explains a contradictory experience in dealing with risk. As empirical risk research has determined, there is a "*double standard*" *in risk behavior.* Risks that I expect myself to take are assessed as incomparably lower, accepted more readily and, above all, taken far more frequently (even risks of death) than risks that others expect me to take. Riding a motorcycle is hardly controversial, while emissions from coal-fired power plants are a matter for the Bundestag. People do not die from food chemistry, but from poor nutrition, not from industrial exhaust fumes, but from tobacco smoke (Luhmann 1986).

These few empirical examples already show that there is no consensus and no reciprocity of action maxims in the area of risk assessment and risk perception. Familiar risks receive a higher level of approval than unfamiliar risks, even though statistically the probability of damage is the same or equally low. Risks where the damage only occurs after a delay are more likely to be accepted than risks with immediate damage. Accordingly, nicotine and alcohol are perceived as less risky than road traffic (Bechmann 1986).

This empirical research can be summarized as follows: *There is no uniform assessment of risks* in society *and no chance of consensus for a uniform risk policy.* A morality based on reciprocity and an ethics based on universalizability will fail precisely because of this connection between social conflict and expectations for the future. Risk-taking and responsibility for consequences are seen from different perspectives – as a danger or as a risk. And because we are talking about the future, which can also be different, there can be no reciprocity. With an unknown future and uncertain consequences, who wants to be loved by their neighbor as much as they love themselves? Dealing with one's own future leads to the burdening of others, and even then, or rather especially then, when one wants to rationalize the future as a risk.

5.2 Rationality and risk

The idea is obvious – if technical rationality leads to paradoxical results and decisions that cannot be legitimized, then an attempt can be made to expand its basis in order to change the "constraints" of a pure means-ends relationship or cost-benefit calculation, thereby transforming the "halved rationality" (Habermas) into a comprehensive one. Under the title of "*social compatibility*," this attempt has been made to expand the limited decision-making rationality of technology policy (Wiesenthal 1989; Tschiedel 1989). Although the term itself remains unanalyzed – in its use it oscillates between a normative guiding idea (Meyer-Abich/Schefold 1986), an empirical decision-making method (Renn/Häfele 1985), and a procedural proposal (v. Aleman/Schatz 1986) – it has inspired entire research programs and attracted funding for social science research. Meyer-Abich/Schefold advocate an optimization strategy for technological decisions. In addition to the economic costs, the legal, political and social consequences of modern technologies should also be included in the decision-making process in order to arrive at an optimal decision by comparing all possible advantages and disadvantages.

In contrast, Renn/Häfele (1985) start from an empirical problem: the attempt to rationalize the pluralistic and divergent value preferences in society and, if possible, to make them representable in a decision tree. Their aim is to increase the value consideration potential of the decision, in the sense that more people see themselves represented in the respective technology policy decision.

The third attempt to determine "social compatibility" aims to institutionalize a new procedure for making decisions. The aim is to achieve comprehensive participation of all those affected by innovations (v. Aleman/Schatz 1986). The new procedure should be anticipatory, offensive and general. Anticipatory means that all possible consequences of the respective technology should be recorded and taken into account in their ramified effects. Offensive refers to the way in which the participants become active. They should gather information independently and, if possible, also research the anticipated consequences. The procedure is general when the entire development and innovation process of a technology is included and a comprehensive awareness of the consequences is created among those involved (Wiesenthal 1989, pp. 136–137).

Increasing options, increasing the potential for value consideration and participation are the strategic guiding principles of the "social compatibility concept," to which its protagonists are oriented and through which it has gained its socio-political relevance. When it comes to risk decisions, its solution capacity fails due to the novel combination of the time dimension and the social dimension.

The idea of increasing options is still rooted in optimization thinking. Meyer-Abich/Schefold only want to exchange and increase the criteria. There is nothing wrong with that. Only the selectivity of the decision with all its temporal and social consequences remains. This is aggravated by the fact that objectives are not the final fixed points for a decision, but are themselves subject to change. What is considered acceptable today is not necessarily acceptable tomorrow. Both technological development and social structures are subject to evolutionary – and sometimes revolutionary – change. In the hands of the decision-maker, "social acceptability" can change from a catalog of criteria to a relational concept that slips from a firm grasp and only becomes tangible again through social consensus. However, as we know, social consensus is difficult to achieve in risk decisions and cannot be assumed as a basic consensus in a plural and contingent world.

Value preferences can be surveyed. The first question that arises here is which ones and to what extent? The problem of aggregating value preferences is crucial, but also more difficult to solve. Renn/Häfele (1985) see this as a task for science. Experts create a value tree, determine average values and homogenize differences (critically Bechmann/Gloede 1986). Only through the authority of science can unity be created where there is dissent – a unity that is based on the contingency of knowledge and is ruined by the divergence of experts.

The most far-reaching proposal is to define "social compatibility" through participation. Participation in decisions increases the number of decisions (Luhmann 1987). Additional decisions must now be made about the procedure, the voting mode and the right to participate. If you really want to get involved in what those affected think and want, you are under time pressure. This can be countered by scheduling consultation times, breaking down problems, and forming subcommittees whose results are summarized by a senior committee. To gain time, you no longer look for optimal decisions, but only useful ones. And if these are not achievable, decisions are taken. At the end of participation there is not half a rationality, but a fragmented rationality (see Lindner 1990). Wiesenthal's verdict on this variant of "social compatibility" is correspondingly apt and devastating at the same time:

> Situationality and past reference of preferences show political concepts to be under-complex, which are aimed solely at overcoming the obstacles that stand in the way of the wishes of those negatively affected. In a society whose fragmentation into self-referential subsystems has led to existence problems in the natural environment, it is not merely a matter of making different choices in the "feasible set" of particular action alternatives, but of modifying the "constraints" of the set if overall systemic decisions are to be made possible (Wiesenthal 1989, p. 152).

On closer inspection, we are back to the non-rational preconditions of rationality, and are once again confronted with the "risk of rationality," which was supposed to be defeated by the concept of "social compatibility."

6. Outlook: Living in a hypothetical society

The thesis that risks are social constructs (Douglas/Wildavsky 1982) is still too closely tied to the psychological approach to perception to be able to grasp the broader significance of the concept of risk. It is true that there are no "objective risks." They are always perceived, interpreted, dependent on the respective context and determined by a specific culture. Accordingly, the perception, description and assessment of risks also differs within the population. Nevertheless, this does not explain why the question of risk has become a secular problem for all industrially developed countries. Today, it is no longer the class issue that concerns the public, but the management of the ecological crisis and the associated risks that divide society into new conflicting parties. In contrast, it has been argued here that the significance of the risk issue must be understood in the context of social transformation processes, which have led to a new, paradoxical type of action and a new social conflict. As society becomes more functionally differentiated, a uniform meta-social order is lost. Today, neither religion nor science can offer people a uniform world view in which the most important orientations are anchored. Instead, more and more system-specific perspectives are gaining ground, each of which has its own rationality and can no longer be standardized or even universalized. At the same time, or in connection with this, the time structure of society is changing, the past no longer has any orientation value, the future is becoming the goal of action, and this can be seen most clearly in the acceleration of scientific work. Scientific work is per se future work (Nowotny 1989, p. 77ff.).

The loss of a uniform culture and the opening up of the present to an indefinite future creates enormous pressure to make decisions and a high degree of social contingency within society. This can be seen as the new aspect of the risk society, namely that in the course of the functional differentiation that has become established, the possibilities for decisions have expanded enormously and at the same time the social wealth of alternatives has increased. This process has also had the effect that former dangers have been transformed into risks in such a way that soon there are only risks and no dangers. However, the difference between risk/danger now emerges as a social difference. For the decision-maker, the control of an uncertain future is transformed into a risk that can be calculated either way; for the person affected by a decision, if they cannot influence it, a danger arises, but this danger is socially generated – and this gives the risk issue its explosive power.

If we understand risk as a "decision-related, calculable uncertainty" (Beck), then a paradox quickly becomes apparent. Every decision that relates to an uncertain future is exposed to a double problem. It has to calculate costs and benefits – and at the same time determine the risk of not making the decision. Decisions that are not made can also have bad and good consequences; in any case, they are not neutral with regard to the future. The "two-sided nature of risk" (Rapoport 1988) points to the self-reference of risk. If deciding or not deciding in relation to the future is equally uncertain, then any striving for security that does not want to risk anything falls into the black hole of risk rationality (Baecker 1989).

If we consider the paradox of risk and its social anchoring in the evolutionary development pattern of functional differentiation, we can see that many of the ways out of the risk society that are offered lead directly back to it.

In a society that generates new risks on a daily basis, Ulrich Beck's proposal to rely on the self-destructive forces of large-scale technology is reminiscent of the recipes from the arsenal of an objective philosophy of history that still believed in the teleological meaning of history. Even an extension of the selection criteria to include ethics, democratic co-determination and veto institutions, breaking the "grip of the economy" on the use of technology (Beck 1991), does not lead out of the fundamental dilemma of risk policy, since only the number of decisions would increase, but not the possibility of clearly discriminating between good and bad consequences. Apart from the fact that the invocation of danger and the radical countermeasures derived from it completely forget that the production structure, which is cited as the source of all dangers, is the basis of all life that needs to be saved.

Similarly, the suggestion of placing *our hopes in the zero option* does not seem to work (Offe 1986). In view of the ever-increasing acceleration of scientific and technological progress and the resulting unforeseeable side-effects, the idea of moving into the time dimension is initially captivating. Today, the real utopia is no longer the increase of options, but clever and rational self-restraint (Offe 1986, p. 113). Only those decisions should be made that are manageable and reversible in the near future.

> Such a criterion of rational decision-making, disciplined in the time dimension, would also correspond if decisions were not made methodically under the time pressure exerted by competing decision-makers, but instead – for example by introducing moratoria or iterations – the time necessary to make possible effects of the decision more assessable and to avoid hastiness (Offe 1986, p. 115).

But the option for the zero option is also an optimization calculation in which the "renunciation of an increase in options is extrapolated against a gain in controllability" (p. 116). The risk of the decision remains. Quite apart from the fact that, of course, the preference for reversibilities can only be based on irreversibilities, which must be determined one way or another over time. Every attempt, as Luhmann puts it, to keep the future open only determines the irreversibilities in a different way: by omission or by unintended actions (Luhmann 1990b, p. 166).

Considering the new situation created by the risks of modernity, it is important not to prematurely advocate solutions that make their uselessness visible in the very terminology used. The intention of this work is to raise awareness of the *social dimension of risk*. With the advancing scientification and mechanization of society, but also with the increasing differentiation of the social sphere, the problem of risk takes on the same importance as the question of poverty in the 19th century, and the question of insurance in the 20th century.

Similar to this, the question of risk forces a revision of the basic concept of social theory. Risk makes us aware of the contingency of social life – everything could also be possible differently, and at the same time refers to the future in the present – every decision can have both good and bad consequences.

Aware of these facts, approaches in science that make *uncertainty the starting point of* their considerations are gaining importance. Rorty, for example, makes contingency the starting point of a new philosophy of freedom when he writes:

> It is not any great, necessary truths about human nature and its relations to truth and justice that will determine the nature of our future leaders, but only a set of small contingent facts (Rorty 1989, p. 304).

Only by accepting the risk can we avoid failing because of it.

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2.
TA as advice – the consultative dimension

Renate Mayntz

Learning processes: Problems of acceptance of TA among political decision-makers

1. The function of TA for policy development

Although political decision-makers are only one of the target groups of TA analyses, this target group will be the focus of the following considerations. Normatively speaking, the function of TA in the decision-making process is to increase the substantive rationality of political decisions by providing a broader information base. The substantive rationality of a decision lies in its ability to produce a desired effect at a reasonable cost and without negative side effects that exceed the value of the desired goal. TA is not a unique tool in this context, as forecasting techniques, cost-benefit analysis, policy analysis, and evaluation research have also been developed for the same purpose. In fact, TA merely combines elements of several of these analytical approaches; it is characterized only by its object, namely technology. There is no need to go into detail here about the elements of TA and the information it can provide to decision-makers; nor is it necessary to specify here for which decisions this information is important. However, it should be emphasized that the goal of political control of technological development associated with TA is particularly difficult to achieve. This is at least partly due to constitutional conditions that limit the possibilities for legal state intervention: Both the production and the use of technological innovations are largely left to the decisions of autonomous subsystems of society, e.g., the scientific and economic systems. Under these conditions, state control is mainly relegated to the use of indirect instruments such as the setting of positive and negative incentives and selective support measures. Of course, this does not mean that TA can provide decision-makers with less relevant information than, for example, policy studies do for policy areas where direct state intervention is more common, but it does have consequences for the way in which TA is applied in the policy process – and, incidentally, for the normative definition of its target groups: The relevance of the requirement that TA results should be made accessible to the general public is at least partly based on this fact.

2. The context of TA use: the nature of political rationality

In discussions about the usefulness of various approaches to increasing the rationality of policy decisions – TA included – it is a common argument that their actual influence falls far short of their potential impact – and the experience with Planning, Programming, and Budgeting Systems (PPBS) in particular clearly supports this argument. As far as TA is concerned, this neglect is often attributed to its largely undisputed shortcomings and inherent methodological weaknesses. Consequently, greater acceptance of TA by decision-makers appears to be achievable primarily only by improving the quality of this advisory instrument. However, this is at least partly an illusion: The ability of TA to rationalize political decision-making processes is not only, and not even primarily, limited by qualitative deficiencies, but rather by the fact that substantial rationality ranks low on the scale of criteria for political decision-making.

It is a commonplace of political science that politics is not primarily about finding effective solutions to problems, but rather about gaining and maintaining power. All actual political decisions are subject to certain political constraints. The criterion of political rationality, which is geared toward political survival, determines the general rationality of a political decision. Avoiding losses of solidarity, being able to demonstrate visible success, or at least receiving applause for oneself, one's party, or the current government are decidedly rational goals of action with regard to the general goal of political survival, and accordingly political decision-makers also focus their attention on this (Mayntz/Scharf 1975, p. 91). Their primary interest when assessing proposals for action is therefore often directed toward their likely consequences for the current balance of power between the parties, parliamentary groups, political groups, and individual office holders.

However, the ability of politicians to act substantially rationally in the sense defined above is not only limited by personal political survival strategies. Another important criterion is the practical feasibility of measures, i.e., they must be able to find support among those actors who are involved in their formulation and subsequent implementation. This is why policy development processes often involve compromises between divergent interest groups, without whose support or at least acquiescence a policy could never be implemented – and all too often such compromises are paid for at the price of knowingly reducing the effectiveness and problem-solving capacity of such projects. In this context, the head of the French Commissariat au Plan, Masse (1981, p. 40), once reported that a lack of consensus between important players in economic policy had forced him to forego what he considered to be an optimal solution according to objective standards and to seek an acceptable compromise on the basis of the existing, restrictive institutional framework conditions; impressive further examples could certainly also be cited from the field of environmental protection.

In addition to political feasibility, financial constraints play an important role in decision-making processes. The cost-benefit ratio of a project is often less decisive than the ability of its advocates to assertively demand the necessary funds. This in turn depends less on the economic situation of a state and the overall size of its budget than on the applicant's position of power and the assumed (not necessarily objectively proven) urgency of a project. In this context, it is often helpful for the implementation of a political program if a given situation can be conceptually defined as a crisis, or if a dramatic incident provokes the general feeling that something must be done (Russ-Mohl 1981, pp. 83–85). Again, it is obvious that questions of power play an important role in such considerations. Whether a political decision really meets the standards of substantial rationality – defined above with reference to the criteria of effective problem solving, cost efficiency, and the avoidance of negative side effects – is sometimes only considered last, but never or rarely first, in the concrete case of a decision. This could only change if the proof of having made effective problem-solving decisions were also a condition for short-term political success. However, it would be wrong to criticize this state of affairs as opportunistic and to blame politicians' lack of morality for it. The extraordinary importance of the aforementioned criteria – ensuring political survival and the political enforceability of measures – for political decisions is a direct consequence of the structure of parliamentary democracies with their regular elections, limited terms of office, the dependence of governments on parliamentary majorities, and the dependence of incumbents on electoral success. Political support is the most important prerequisite for a policy (and a politician), because without this support there can be no policy. Finally, the weight of financial considerations in the political decision-making process is ensured and reinforced by institutional requirements such as the veto power granted to the finance minister in the cabinet and his powers vis-à-vis other ministries.

In reality, therefore, the ideal of rational policy decisions is not missed primarily because of cognitive and analytical deficits, but is rather due to the orientation patterns that generally prevail among politicians, which mean that little attention is paid to precisely the information that policy analyses in general and TA in particular provide – e.g., information about the effects, consequences, and relative costs of alternative possible measures. Moreover, this substantial rationality is particularly irrelevant where purely symbolic policy is concerned. If there is no intention from the outset to change a given problem situation, or if the purpose of a political decision is already achieved when parts of the public or the political clientele come to the conclusion that the government is committed to doing the right thing, then it is obviously uninteresting from this perspective what the consequences would be if the decision were actually put into practice. Consensus building, not problem solving, is the goal of such policy decisions, and here opinion polls that inform the decision-maker of what the public wants to hear are far more important than policy analyses that carefully work out the multiple effects of the available decision alternatives.

Finally, there are also cases in which substantial rationality tends to argue against making policy decisions on the basis of the greatest possible knowledge about technical and social development processes and the probable effects of possible alternative courses of action. Given our notoriously deficient knowledge of the conditions that influence the outcomes of a policy, it can sometimes be quite appropriate not to want to act on the basis of systematic knowledge, but to pursue a trial-and-error approach in which the details of the initial assumptions on which they are based do not play a major role, insofar as subsequent program modifications based on experience are provided for in this concept from the outset. This view essentially corresponds to Lindblom's incrementalism, which he understood not only as a critical description of political practice, but also as a prescriptive model (Lindblom 1965). Evaluation, feedback, and flexible adjustments allow for a learning process, and this can indeed be understood as a rational approach; the more uncertain and unsettled our knowledge of factual contexts, the riskier our predictions.

3. Consequences for the use of TA

If the expectation that TA should improve the substantive rationality of political decisions is based on a rationalist misunderstanding of the nature of political decision-making processes, then it may be appropriate to briefly consider how TA is actually used by decision-makers. As an instrument of scientific policy advice, the relationship of TA to policy is also fraught with the wide range of communication problems, priority conflicts, and ambiguities that generally characterize relations between scientific advisors and policymakers (Mayntz 1977, 1980). According to a widespread assumption, science provides objective information that should enable decision-makers to choose the best possible decisions from their own value point of view, i.e., the most cost-effective way to achieve a given policy goal.[1] This common conception of the relationship between TA as a form of scientific advice and policy is based on the assumption that the knowledge provided by TA is or should be used, and that only cognitive deficits may limit this use. This assumption is wrong for various reasons.

The offer to provide politicians with useful information is by no means as seemingly modest as it may sound, because in fact political influence is claimed with this advice to an extent that must almost inevitably lead to a conflict between the people and institutions that produce TA and the politicians who, by virtue of their office, see political influence as their privilege. Such conflicts are already inherent in some definitions of TA, such as Bartocha's:

> It can be defined as a systematic analysis, where all impacts and implications, direct or indirect, real or potential, present and future, beneficial or detrimental, of a technology are defined, evaluated and measured, and the cause-effect relationships identified. The results of a technology assessment should include alternative solutions to a problem, ranked according to their social cost-benefits, and recommendations for policy changes, control or mitigation options, or new initiatives (Bartocha 1973, p. 339).

Quite apart from the fact that this definition is clearly utopian, it is also technocratic, i.e., it contains a de facto claim to power by the TA producers. Confronted with this claim, any politician who does not firmly believe in the superiority of TA and is willing to follow its recommendations will rise up to fight against this threat to their legitimate functions.

A second reason why the availability and quality of TA analyses do not determine the extent to which they are implemented in the political process lies in the normative implications of these assessments. Politicians who do not share the value premises that underlie the evaluative component of a technology assessment will reject it – not because of its cognitive content, but because of the invitational nature of such studies to adopt the values on which it is based. Even where an attempt is made to clearly separate prognosis and evaluation, there is a tendency to reject the analytical content of a study along with the recommendations derived from it.[2]

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1 The claim of TA is perhaps even more immodest, as it involves not only the prediction but also the evaluation of technical developments and their consequences in relation to certain *social* value patterns.
Editors's note: See also Chapter 6 by Gotthard Bechmann.

2 The same applies to Böhret and Franz's assessment of various forms of institutionalization. The models of institutions that rank first in their list do so because of the great

The third and most important reason why TA, insofar as it expands our factual knowledge (leaving aside cases in which this happens only incompletely), does not directly determine political action lies in the dominance of political rationality in the process of policy development, as already discussed. In such a context, TA is only used if and to the extent that it serves political purposes, and accordingly TA will tend to be instrumentalized in the sense that, instead of being the basis for decisions, it is used to justify decisions (or non-decisions). In this respect, TA shares the fate of "policy research" and scientific advice on policy in general. In an interesting German study analyzing the use of scientific advice by senior civil servants in state administration, it is reported that two thirds of the civil servants interviewed explicitly pointed out the political functions of scientific advice (Friedrich 1970, pp. 161–189). The most frequently cited function of expert opinions was to be able to scientifically justify decisions (or non-decisions) that had already been made or were about to be made. According to this study, the purpose of being provided with "objective reasons for rejecting undesirable demands" is also an important political motive for obtaining scientific opinions, since in this way, for example, pressure from organized interests can be counteracted.

On the other hand, in those cases where the results of a TA study suggest that a measure under consideration should be abandoned, this recommendation is rarely followed. The ineffectiveness of scientific advice often results from the fact that advisors take the publicly declared objectives of a particular policy seriously, while the real political motives behind it may be quite different. In such a case, TA simply misses the point – just as it would be wrong to try to persuade a young man not to go swimming because the weather is not as good as he thinks it is, when his real intention is not to cool off but to meet a young woman in a swimming pool.

While aspects of policy advice were addressed in general in the previous section, some particular difficulties arise with regard to the implementation of TA results, which can be traced back to the special subject area of TA, namely technology. In the present day, decisions that have to be made in technology policy are often particularly politicized in the sense that they are extremely controversial and the controversies are linked to fundamental value decisions. It is not possible at this point to attempt to analyze the reasons for what is often described as

importance attributed to TA *for the public*. If someone does not agree with the normative premise that this is one of the most important goals of TA, they will tend to reject the entire analysis (Böhret/Franz 1982).

a fundamental crisis of acceptance of science and technology. However, it is obvious that with the growing politicization of a field of action, with the increase in public attention, and the associated increase in emotional influencing factors, the chance of using TA to place the discussion on a more rational basis decreases – and does not increase, as one might assume. Where the choice of a particular policy becomes or seems to become a matter of life or death (or at least of jobs or unemployment) from the point of view of many people, i.e., where a lot depends on the validity of a forecast, the willingness to accept TA results without further ado is low.

In this context, the methodological uncertainties and weaknesses of TA also play an important role; not because they diminish the information value of TA per se, but because they can easily be used to justify the rejection of TA results and recommendations. In general, the results of policy research are never questioned as to their methodological foundations by those who find their results politically useful; but even more so by those who are looking for a good reason to reject the research results as flawed or irrelevant (Derlien 1976). However, to the extent that TA increasingly includes the assessment of social and societal consequences of technological innovations, the objective uncertainties in the foresight of technological developments and their consequences grow (Goldberg 1980). There is no reason to underestimate these methodological problems. However, I would like to make it clear that this cognitive uncertainty is often a welcome argument in the political context for dismissing TA and its results as irrelevant.

4. Measures to extend the influence of TA

So far, I have tried to show that the political nature of policy decisions limits the possible rationalizing effects of TA to a greater extent than its methodological weaknesses and cognitive uncertainties. But while there can be no doubt about this finding, it is equally true that, in the absence of reliable information, even the most motivated politician cannot base his choice on a careful assessment of alternatives. Conversely, the availability of information does not guarantee its use.[3] Consequently, the question arises as to what – if anything – can be done to increase the practical significance of TA for politics. To this end, it is certainly

3 There is something of an inverse relationship between benefit and availability in that knowledge that TA results are needed, can stimulate their production, but conversely only repeated practical application can lead to the urgently needed methodological improvement of TA.

necessary to improve the methodological foundations of TA and thus increase the truth content and compelling persuasiveness of its results and conclusions; however, this is not enough. Even more important is the creation of an institutional framework that can generate pressure to ensure both the provision of TA results and their consideration in political decision-making processes. The influence of TA can be increased not only by the mere availability of TA studies, but also by the – legally and politically anchored – necessity that these must also be taken into account in decisions on the development and application of technologies. Incidentally, this applies to all scientific methods that have been developed in the last 20 years to increase the substantial rationality of policy decisions.

The problem with trying to extend the influence of TA is that the results of TA are not neutral to existing power structures within and outside the political system. By their very nature and structure, TA studies explicitly or at least implycitly provide recommendations for action, and these in turn will always selectively favor a particular industry sector, consumer group, etc.; accordingly, options for action based on TA information will have proponents and opponents within the political system. Consequently, it is completely unrealistic to expect the tension-free climate for TA that would be necessary for purely scientific (or cognitive) arguments to dominate and determine action. TA therefore needs advocates with sufficient power within the political system.

A consideration of the various practical possibilities for institutionalizing intelligent political decision-making processes with instruments such as TA could start with the distinction between procedural and organizational institutionalization. In the first case, the use of methods such as TA or cost-benefit analyses would either be prescribed by law or become a procedural norm in the legislative process. Well-known examples of procedural institutionalization are mandatory hearings, legal regulations on the evaluation of program results and the presentation of this evaluation to parliament, "sunset legislation," "zero-base budgeting," or the introduction of a "regulatory budget." In the case of organizational institutionalization, special institutions for the preparation of TA studies are created, or this task is transferred to existing institutions. The fundamental decisions to be made here concern the structural embedding of such an institution (with the legislative or executive branch or institutionally independent) and the degree of its independence (full integration, e.g., as a department within a ministry, partial integration, e.g., in the form of a scientific staff or a commission directly linked to specific institutions such as parliament, the government, or a specific ministry; or complete autonomy). Other important decisions related to the organizational institutionalization of TA concern, for example, the nature of the control of such an institution (e.g., political, scientific, or both) and the extent to which substantive scientific work is carried out by the institution itself or contracted out (Böhret/ Franz 1983). None of these latter aspects is free of political implications; this also applies to the different political contextual conditions for the institutional and procedural anchoring of TA functions in different countries, which will be discussed as a final point.

5. National differences and their consequences for TA

The institutional and procedural arrangements that have been developed in various countries in connection with the introduction of cost-benefit analyses, policy studies, forecasts, and occasionally even TA offer a broad spectrum of models. To what extent is it possible to generalize the experience gained in this way and to adopt promising forms of institutionalization from other countries? Of course, foreign experience with the problem of harnessing TA can be generalized to the extent that the use of analytical knowledge in policy development is inherent to the nature of Western parliamentary democracies. However, the country-specific differences in the relative distribution of power and the roles played by the main actors in the political system are important for the selection of an adequate and promising form of institutionalization of TA.

The indirect question posed here as to whether there is a single correct path or whether promising solutions should be adapted to the specific national political context addresses the problem of the influence of existing national "political cultures." I will not spend much time here trying to define this elusive concept of "political culture" or in what Max Kaase (1982) so vividly described as trying to nail a pudding to the wall; very often, however, the term "political culture" is used to refer to the attitudes of the population toward the political system. In contrast to this, in a recent five-nation study (Feick et al. 1982), which sheds light on the influence of specific national contexts on government action programs developed to solve quite identical problems, we applied a different concept, focusing in particular on the institutional framework, decision-making styles, and the intervention philosophy of top politicians. In any case, these factors in the respective national context must be taken into account to a large extent in the search for effective institutionalization options for TA.

The obviously most important factor in the national context is the distribution of power among those actors who play a more or less important role in the political decision-making process. Although the main types of relevant actors can be found in all Western democracies, their function in the political process can vary considerably, as can be seen, for example, in the different political influence of national parliaments and state administrations. Systematic comparisons have shown, for example, the particularly important role of parliament in the policy process in Italy, where most draft legislation is drawn up by parliamentary commissions and not, as is the case in the Federal Republic of Germany, by the ministerial bureaucracy.[4] It may therefore follow that in Italy a TA institution should be located in the legislative rather than the executive branch. In any case, with regard to the goal of integrating TA into the political process as effectively as possible, the negative conclusion can be drawn that an institutionalization of TA at the upper level of state administration would be less effective in Italy than in Germany, where the ministerial bureaucracy plays an important role in drafting legislation.[5]

TA institutions that are tailored to the information needs of parliament can hardly escape the danger of being drawn into political controversies between the governing and opposition parties, and even between different factions or currents within the main parties. It is inevitable that the actions of parliamentarians, which are strongly influenced by party political positions, must reinforce tendencies to instrumentalize TA, and may even prevent TA studies from being carried out where it is foreseeable that their results could benefit a weaker party or parliamentary group. The conclusion that can be drawn from this, at least for the time being, is that TA generally has a better chance in countries where the ministerial bureaucracy plays an important role in policy development. Despite their politicization, and despite their willingness to pay attention to political restrictions that determine the success or failure of administrative initiatives, top officials are often far more inclined than politicians to pay attention to the substantive rationality of a bill or other proposal because of their training and orientation.

In the case of the institutional integration of TA into the state administration, however, it must also be ensured that no competitive situation arises that blocks the potential influence of this institution. In the Federal Republic of Germany, for example, the federal ministries have a high degree of autonomy vis-à-vis the political management level. A TA institution that is to gain influence on policymaking and at the same time is located parallel to the existing ministerial

4 On this point, in addition to the above-mentioned research report, see also the country comparisons in Rose/Suleiman 1980 and Suleiman 1984.

5 *Editors' note*: Please be aware that these statements mirror the situation in the 1980s. There may have been many changes since then.

organization – i.e., not integrated into it – would be perceived here as an attempt to impair the autonomy of the responsible ministry or ministries. The alternative solution of creating an institution within the remit of the ministry responsible for technology policy could be more promising, but would not be able to avoid all conflicts, as TA also affects various aspects of economic policy, among other things.

Parliament, the political executive, and the ministerial bureaucracy are not the only relevant players in policymaking. In some countries, extra-parliamentary commissions have traditionally played a central role in drafting legislation – in the UK, for example, the well-known Royal Commissions. However, if such commissions were set up in other countries and given the scientific authority and resources, they would not necessarily have the same importance for policy development. Attempts to influence policy formation processes on the part of such a commission would be subject to specific restrictions within an existing network of institutions as long as they are not regarded as a recognized tradition, but rather as usurpatory. On the other hand, where advisory and research commissions already play an important role in the political process, i.e., where the power of such actors is supported by a specific political style, namely the tradition of consultation, they can also be used as a promising form of TA institutionalization.

Commissions, but also experts who perform advisory functions outside the political system in the narrower sense, may play a greater or lesser role in various national contexts, but they are rarely completely absent. However, there is also the interesting case of national advisory institutions which, deeply rooted in the respective national political and advisory culture, have no parallel in other countries and can hardly serve as a model for other countries. Böhret and Franz (1982, p. 220) mention, for example, the Swedish Secretariat for Futures Studies [since 1987: Institute for Futures Studies], an important and apparently successful institute in dealing with TA in Sweden, which is part of a research administration that has no direct equivalent in other countries. In the Federal Republic of Germany, some of the TA-related information and consultancy services provided by the Swedish institute are fulfilled by the German Research Foundation (DFG). However, a TA institution affiliated with the DFG would probably have relatively little political influence due to its carefully maintained distance from politics, which conversely limits its institutional integration with the political system.

Another national characteristic that must be taken into account when considering the appropriate institutionalization of TA is the degree of centralization of state and political decision-making structures. The term centralization can be given two different meanings: Structurally, it refers to the extent of political decentralization to subordinate territorial authorities such as states and municipalities; procedurally, it refers to the extent to which government regulations are either formulated down to the last detail at the central level, or enforcement bodies at lower levels are given leeway in their application. If it is crucial for TA institutions to be in direct contact with the important actors in the political process, it follows that the higher the degree of centralization in the sense of one or even both of the above meanings, the more influential TA institutions are at the national level. Where important political decision-making processes are decentralized, TA should of course also be anchored at the corresponding lower levels. If important technical development decisions are even made at the local level, it is difficult to establish any form of state TA institutionalization that could exert influence on the actors there. Such an institution would have to limit itself mainly to pure information strategies.

A final aspect of the contextual conditions to be considered for the institutionalization of TA is the consideration of the prevailing policy styles. In the above-mentioned studies (cf. Feick et al. 1982), it was shown that different policy styles can be found in different European countries, whereby the most important distinction of interest here concerns the importance of consultation and deliberation as well as the participation of interest and reference groups in policymaking. There is a strong tradition of consultation not only in the UK, but also in the US. The large, very flexible groups of advisors, which at times work at the highest level of the American executive (with the President, but also with the departmental ministers) and are affiliated there, have no equivalent in countries such as the Federal Republic of Germany. The existence of such advisory forms in turn supports and strengthens the willingness of decision-makers to involve external advisors in their decision-making processes. Only against the background that policy studies and scientific advisory groups have traditionally played a major role in the American political process can it be understood that an entire research industry has been able to develop there. Such a tradition certainly also offers good conditions for the establishment of independent TA institutions outside the administration. Similarly, it should also be considered whether societal interest groups are firmly integrated into the policymaking process; they should then not only be regarded as another group of potentially influential addressees of TA information; rather, with reference to the existing organizational patterns of consultation and decision-making, it should often be obvious to include such representatives of interest groups, if a TA institution is to be created, in the staffing of its supervisory bodies with the aim of broadening the basis of support for its work.

To summarize, we can state that the political acceptance of TA is determined by two different, equally important facts in the political context: First, the application of TA is less dependent on analytical quality than on political implications, and second, the influence TA can have depends on the location of its institutional placement within a specific national political system. The acceptance of TA is a spectacle played out on the stage of politics – and this is one of those facts of life that scientists must accept.

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Gotthard Bechmann

Consequences, addressees, patterns of institutionalization and rationality: Some dilemmas of technology assessment

Preliminary remarks: TA – what else?

Technological development and its effects have been caught in the crossfire of public debate. The demand for an appropriate assessment of technical products and sensible social and political control of scientific and technological progress is sometimes elevated to a secular problem for the survival of highly industrialized countries. Nevertheless, the mechanization of nature and society continues unabated in both East and West. The simultaneity of the actual acceleration of technological development and the increase in critical discourse about the consequences: This is the dilemma of today's social situation.

If we look back at the history of industrial societies and consider the social controversies of the last eighty years, we can see that the public discussions about the prerequisites and consequences of technological development and the social evaluation of technical products and processes are not so new.

In a historically oriented study, Meinolf Dierkes shows that the history of technological change and the associated process of industrialization have always been characterized by political and social disputes that focused on the social impact of new technologies (Dierkes 1986; Sieferle 1983).

Similarly, since the industrial revolution, there has always been an evaluation of technical products and technical production processes. The market and the state were the central bodies for regulating technical progress. All of this has been reflected in the innovative behavior of companies and in government regulations for technical standards (Wolf 1986). Nevertheless, it would be wrong to regard today's controversy as *a* repetition of old arguments.

The current public debate differs from all previous social debates about technology in at least three respects. Today, three topics are the central focus of interest: the cultural self-image of humankind, the legitimization of the industrial-technical model of progress, and the ability of politics to control. The linking of these three aspects makes the critique of technology the center of social power struggles, as new structures of influence and new patterns of legitimation for the exercise of power are being fought over.

Cultural self-image

The process of mechanization no longer takes place centrally in the production sector of industrial society, but rather, due to the development of large-scale technologies such as information and biotechnologies, almost all areas of society are confronted with an increased use of technology and placed under pressure to rationalize. At the same time, areas of the human being that previously constituted its uniqueness are being mechanized: mental activity and biological reproduction. With interventions in these areas of human existence, human nature is made contingent (van den Daele 1985, 1986): For the first time in evolutionary history, human beings can change the conditions of their own evolution.

As we can learn from the debate on artificial intelligence and genetic engineering, this awareness has a profound impact on our cultural self-image (OECD 1983; Hohlfeld 1988; Turkle 1984). The demand for new ethics is probably only the initial stage of a changed view of humanity. The potential dangers of modern technologies and the novelty of technical access to natural processes are changing all previous standards and evaluation criteria. There is a need for a public discussion of the consequences of scientific and technological progress.

Loss of legitimacy of scientific and technological progress

In the last decade, the legitimacy of scientific and technological progress has been publicly questioned to an unprecedented extent in most highly developed industrial societies. In the 1950s and 1960s, technological change enjoyed a broad consensus among the population. Technological progress was seen as a necessary condition for increasing individual and collective prosperity. The increase in social prosperity was seen as compensation for the frequently registered negative effects of technological change, such as de-skilling, de-professionalization, redundancy and unemployment. The universally legitimized separation between the prerequisites and consequences of technological progress provided the basis for reducing the problem of the social costs of technological development to questions of regulation and distribution, which could then be solved in monetary terms. With the emergence of the environmental protection movement, a protest potential arose on the periphery of society that called this basic consensus into question (Braczyk 1986; Raschke 1985). The thesis of the ecological crisis means more than just the elimination of unpleasant consequences of technology; it questions the preconditions and the meaning of technological development as a whole. The protest is not defending old privileges or threatened values – at its heart is the rejection of a socialization process that is in the process of destroying its own foundations. The industrial system itself is thus put up for debate (Eder 1986; Touraine 1986). The collapse of the previous social consensus model becomes clear in the opposition to the most brilliant products of technical progress: instrumental reason and large-scale technologies.

The point seems to have been reached where the social and cultural costs of further technological development can no longer be offset by economic benefits. The integrative power of the scientific-technical consensus model has become fragile. The path to post-modernity has many forks (Offe 1986).

Loss of political control

The change in cultural awareness and the loss of the legitimizing power of technological progress have also left their mark on the institutions of the political system. The demand for the institutionalization of technology assessment in parliament […] indicates that the consequential problems of technological development are also increasingly playing a role in politics. As early as the 1960s, Ernst Forsthoff pointed out the structural change in the state triggered by technological change ahead of his time (Forsthoff 1965).

Forsthoff saw the identification of the state with the technical process as a danger of losing the autonomy of state decision-making. This could happen either by transferring decision-making power to the technical-scientific elite or by incorporating technical goals into the state's objectives. Forsthoff's fears have been far exceeded by actual developments. Not only has the state become the promoter of the technical process in many areas of technological development – the cases of nuclear energy and biotechnology are just two particularly spectacular examples of the state's involvement in technical realization – it has also lost the power to define the legal and ethical boundaries (Luhmann 1986). Two complementary developments play an essential role here:

- The risks that can arise from the use of technologies and the implementation of major environmentally relevant projects have become more far-reaching and complex.
- Public awareness of the risks associated with the use of technology has grown considerably.

Both developments mean that technology control has become more complex and more demanding. Today, it is not only economic and health assessment criteria that are decisive for the areas of technology standardization. Social and ecological risks must also be included in the assessment system, particularly due to pressure from public opinion.

However, what is perceived as a danger and what is to be assessed as a danger is largely determined by science (Beck 1986). In the field of technology control, politics is already dependent on science when it comes to defining and determining possible and necessary courses of action. The Chernobyl nuclear reactor accident in 1986 made this drastically clear to the public (Krohn/Weingart 1986).

The changed cultural situation, the decreasing legitimizing power of technological progress and the lack of political control have led to an intensified public discussion of technology assessment. Today, the search for a social technology assessment procedure determines the social discourse in the field of scientific and technological progress. But what can be understood by technology assessment?

1. Technological consequences and "forecasts" of technological development

The term "technology assessment" or "technology evaluation" stands for a program of a new form of interdisciplinary technology research. With the help of TA analyses, the effects of the initial application of new technologies or technologies under development are to be researched and evaluated systematically, comprehensively and as early as possible, with a focus on the unintended secondary and tertiary effects, which often occur with a considerable delay. At the heart of the analysis is the foresight of possible positive and negative consequences of a technological development, as well as the provision of scientifically sound and decision-oriented information on the basis of which it is possible to shape technological progress in a way that is both socially and environmentally compatible (Bechmann 1986; Lohmeyer 1984).

TA analyses are *problem-oriented* research that is located between basic research and applied research (de Bie 1973). While basic research is to some extent self-reflective, answering only the questions of the research itself, applied research follows criteria of useful application and thus means the practical application of knowledge, problem-oriented research starts from a socially defined problem and attempts to find solution strategies.

The theoretical core problem of a TA study is the prediction of technology-induced or technology-influenced changes. This opens up two problems that have not yet been solved satisfactorily:

- What are the consequences of a technology?
- How can they be predicted?

Let us first look at the concept of consequences. At first glance, it seems trivial to talk about the consequences of individual technical artifacts. Doesn't the telephone directly change the way we communicate? The consequences of a technology are then understood to be changes in behavior, attitudes, opinions and knowledge that are directly caused by the use and application of the technology. In many cases, the consequences are interpreted within the framework of a stimulus-response model, namely in the sense of technological determinism, which claims that the development of technology is controlled by its own laws and that people's behavior and the structure of social institutions are determined by the technology (Ogburn 1969). The problem with this approach is that the state of technology is seen as an independent variable and thus postulated as the actual cause of social change.

We should be extremely cautious about these ideas or monocausal explanatory strategies, because at second glance – which should actually be scientific – we see that it is not technical devices or technical development that are the cause of human action, but that each stage of technical development is compatible with many more behavioral patterns than technological determinism suggests.

Industrial sociology has amply demonstrated that the "consequences of technology" depend on the way in which it is implemented, so that the respective form of social embedding must be regarded as an intervening variable in the causal relationship between the technical innovation and its social consequences. Social or societal consequences of technology are primarily *consequences of the actions of actors.* Nevertheless, the scope for action in the application of technologies is of course not arbitrarily large; it is limited by the technologies themselves. With reference to numerous empirical studies, G. Mesthene, the director of the former Harvard University Program of Technology and Society, has attempted to grasp this connection between technology and social structure more precisely (Mesthene 1970). He formulated a theory of "soft" and "probabilistic determinism."

Technical innovations create new possibilities for action and choice, new potential to achieve new goals or to realize existing goals in a different way. However, in order to be able to use these possibilities in a planned manner, new ways of social organization and institutional changes are required. Technical innovations change hierarchies of goals and values and therefore also social conflict patterns – but only in the medium of social communication. "Soft" determinism can be described as the realization that new technologies open up opportunities for action, devalue social institutions and make cultural patterns of action less persuasive. At the same time, however, it remains open to an extent how this newly created space for action can be filled, or regulated by new institutions.

One can also speak of a trend reinforcement that is achieved through technical possibilities in the social sphere. The use of technologies is determined not least by existing social interests and forces. Reese even believes that the existing development trends in the respective area of application are merely reinforced (Reese et al. 1979). Examples of trends are administrative rationalization, corporate concentration, increased control measures, etc. Recently, reference has also been made to the different lifestyles that determine and shape the consequences of technology application (Rammert 1989).

All in all, the concept of consequence effect, which is too tempting for deterministic ideas, should be replaced by the concept of potential.

This is where a theory of the use of technology, or a "theory of dealing with things," should start (Joerges 1979). According to this concept, technical artifacts only have a "potential function," while the real function is only constituted in the concrete ways in which they are used. Once the potential functions of a technology have been determined, one can attempt to grasp the real function with the help of social science research, whereby the technical possibilities must always be understood as social and societal possibilities for action.

The *prediction* of possible or probable social developments in connection with technical innovations is a topic of particular interest to scientists and politicians in connection with TA studies (Frederichs/Blume 1990).

Forecasting can be understood as the attempt to use as much available information as possible to determine which future developments in a defined area can occur with a certain probability under certain conditions. According to Knapp, explanatory forecasts should be distinguished from so-called "inexact" forecasts (Knapp 1978). Explanatory forecasts have long been the subject of scientific-theoretical discussions, whereby forecasts in this context are understood as statements that can be derived purely logically from laws and boundary conditions. In the case of TA, this type of forecast is likely to play a minor role, as the necessary legal knowledge will rarely be available. Forecasts are characterized by two features: Their statements are statements of expectation and the expectation preferences expressed in them must be justified. If this justification cannot be made on the basis of legal knowledge, one will have to resort to trend forecasts and expert forecasts (Helmer/Rescher 1959). In both cases, an attempt is made to describe the basic structure of a change, and the direction and the speed of changes as both tendencies and inherent possibilities. In addition, a well-founded assessment of a development is required, which then results in the preference of one future extrapolation over possible other extrapolations.

Empirically meaningful statements can only be made if the most important parameters are fixed over a defined period of time. A special form of this so-called conditioned prediction is the action-dependent or action-related prediction. Here, the occurrence of the predicted states and events is made dependent on specific actions of the forecaster or other persons, so that the actor has particular possibilities to influence the realization of the prediction, i.e., to bring about the conditions. The decisive question and thus the central problem of prognostics is how probable a given prognosis – wherever it may come from – is in absolute terms, or in comparison to alternative prognoses, and whether the empirical basis presented for its empirical-inductive justification can be regarded as sufficient according to intersubjective criteria and requirements. Additional difficulties arise in the field of social sciences and in particular in the area of the interdependencies between technological development and social change, as there is only a limited amount of theoretical knowledge and well-founded empirical data available. In contrast to the economic sciences, where there is agreement on the concept of national accounts, no valid measurement and classification system for technical progress has yet been developed. Each analysis works with its own concept and definitions.

Furthermore, it has not yet been possible to isolate the effects of technological developments, e.g., on labor market conditions, qualification and economic structures, from other influences, such as economic cycles or the influence of global economic development. So far, only relatively arbitrary attributions exist. The development of early indicators for chains of effects that can indicate the diffusion of technical development with a degree of reliability is encountering major difficulties.

This is a link with innovation research, which describes what is technically possible or has already been developed, but cannot indicate which innovations will spread in which way, at what speed and in which area. The decisive factors for this are economic aspects such as cost reduction, cost structure, demand, price elasticities, etc., which are not accessible to technical research instruments.

It is even more difficult when it comes to forecasting changes in values or organizational changes. Futurology, which used to be conducted with great enthusiasm, no longer seems to be in vogue.

If exact statements about possible consequences or side effects of technical innovations are not possible, then TA analysts should commit themselves to developing structural analyses and theoretical knowledge that can then guide the impact analysis, whereby it is initially important to identify bottlenecks, important development trends or contradictory patterns of action. An important task thus arises in the continuous observation and analysis of technical and social change, whereby an attempt should be made to link exploratory forecasts with empirically sound assumptions.

Kern/Schumann have introduced the term "bandwidth determination" for this purpose:

> We can thus characterize our method of prediction in summary as theoretically guided and empirically supported bandwidth determination. "Theoretically guided" because we refer to a theory of capitalist development that is based on the distinction between logic and forms of rationalization and contains specific assumptions about the change of form [...]. "Empirically supported" because we use empirical means to prove that the old forms are beginning to be replaced by new concepts of production. The concept of "bandwidth" is intended to define fields and boundaries within which the development can be expected (Kern/Schumann 1985, p. 378).

Thus, in a purely logical sense, forecasts of the indicative type are dispensed with, and one restricts oneself to naming danger points and limits of development. However, this is an opportunity to obtain empirically sound statements without having to submit to the constraints of a deductive forecast.

2. Technology assessment in the political process

The interesting thing about technology assessment is probably its close links with politics: it is constitutive for TA and the real cause of annoyance for critics.

Only this direct link between TA and social practice explains why the TA debate includes not only questions of scientific analysis but also questions of the governance of scientific and technological progress, and questions of institutional reform of the political system. The problems and difficulties associated with this will be examined below (Paschen et al. 1992).

2.1 Discrepancies between scientific and political action orientation

As differentiated systems of action, politics and science differ significantly in terms of their objectives, working methods and forms of organization, meaning that the knowledge generated in the science system cannot be directly translated into political action. It is therefore right to speak of a transformation or implementation process in this context.

The researcher is obliged to comprehensively process existing knowledge and to systematize it from a theoretical and empirical point of view. The aim must be to gain knowledge about reality strictly according to methodological rules that can be verified intersubjectively. Scientific work is a lengthy process that requires both coordination with one's specialist colleagues and discussion in the wider scientific community. Research processes often require long periods of time, and the results are sometimes controversial and in many cases hypothetical in nature.

Politics is quite different. Political action is based on consensus and conflict processes and is aimed at reaching binding decisions. Decisions usually have to be made under time pressure with no certain consensus. Information is important for decision-making, but the information base is limited and solely aimed at facilitating the decision to be made, not at comprehensively illuminating the decision-making problem. It is about dealing with a unique situation, not about finding laws. Complete information that meets scientific standards would lead to an oversupply of information and thus make political decision-making more uncertain.

This brief comparison of politics and science already shows that the mediation processes cannot be solely a matter of communication problems, as is often suggested in the literature (Bartholomäi 1977). Instead, one must start from the structural discrepancy between the two fields of action and attempt to mediate the different orientations institutionally. This is necessary insofar as policymakers are dependent on scientifically sound support.

Renate Mayntz has pointed out that the process of translating scientifically generated knowledge into political decisions is not primarily about the instrumental processing and implementation of knowledge, but that contextual factors of political action play a much greater role than is generally assumed. It is not the most effective solution to a factual problem that is at the center of the politician's action orientation, but rather the speed of the decision, the conservation of scarce resources such as money or prestige, the avoidance of unnecessary conflicts and, last but not least, the possibility of political self-expression (Mayntz 1977, 1983). Improving the rationality of political decisions through science thus comes up against limits set by the political system.

2.2 On the specific implementation problems of TA studies

It seems as if the existing difficulties in guiding political action through scientific analysis are becoming even more acute in the field of TA. The original hope that better information would be generated with the help of TA studies, which would then automatically lead to better decisions, has been significantly relativized in the course of TA discussions.

A TA study faces at least three fundamental problems that need to be solved before it can be translated into practical action. These can be described as scientific, organizational, and power-related barriers to the application of TA.

The *scientific difficulties* result from the interdisciplinary nature of projective TA studies. The scientific disciplines involved have varying degrees of ability to provide the necessary information on developments and interrelationships. Since every impact assessment has to deal with different variables, developments and interrelationships in both social and ecological systems, the specific investigations fall within the scientific scope of numerous disciplines. The diversity of possible effects (economic, technical, ecological, social, political, legal, medical, etc.) as well as the fundamental interdependence of technical development and change in many non-technical areas of reality make the cognitive components of the TA process a necessarily interdisciplinary task. The particular problem now is to combine the specific research perspectives, theories and methodological tools in a targeted manner. It is therefore necessary to turn pure multidisciplinarity, in which the knowledge of different disciplines is merely brought together, into *integrated interdisciplinarity*, which is based on the genuine integration of individual perspectives. In addition to the problem of interdisciplinarity, there are also epistemological limitations that play a role in the application of TA.

When predicting consequences, TA researchers generally have to deal with non-linear and non-deterministic systems. Neither the technical entities themselves, nor their embedding in non-technical framework conditions, nor the reaction of individuals, social groups and institutions, nor the intervening socio-cultural processes can be precisely described in advance. Unforeseen developments in science and technology, exogenous events such as natural and technical disasters, and political and social changes can render all forecasts and simulation models useless. No anticipatory impact assessment can capture all influencing factors whose possible variations may affect the complex and dynamic interdependence of technical and social change. Complete information remains an illusion. The unavoidable occurrence of uncertainties seems to be the salient feature of all attempts at technology assessment.

Scientific analysis cannot provide binding guidance for political decision-making. Statements about the consequences of technology are largely hypothetical in nature. The implementation of such interdisciplinary and projective research therefore requires additional communicative effort in order to clarify the hypothetical nature of these statements to the users.

Due to the projective nature of TA studies, subjective and value-based decisions are unavoidable. All effects and interdependencies can never be fully understood; at some point, the study must be terminated. Normative points of view and strategic considerations thus form the framework of a TA study, which, however, do not necessarily have to be shared by all customers. It is therefore necessary to disclose all value decisions, all delimitations and selections, and in particular also assumptions that are necessary because sufficient data is not available. Only an impact assessment that is "objectified" in this sense allows for systematic control and criticism.

In view of the different interests, values and preference structures in society, TA studies always run the risk – due to their cognitive uncertainty and explicit normative commitment – of triggering conflict processes in socio-political disputes, so that their actual statements are pushed into the background in the face of controversial evaluations. As Renate Mayntz has rightly seen, social promoters of TA analyses are needed here (Mayntz 1983).

The organizational barrier for the application of TA results from the difficulty of prediction and control due to the fact that technical development is not produced centrally – rather the production and use of technical innovations falls within the decision-making competence of different social groups. TA analyses must therefore always be oriented toward different interest groups, which naturally differ in their assessment of the costs and benefits of a technology. This makes agreement on the normative premises of an investigation an essential prerequisite for successful application.

TA analysts must ensure that not only their research results are interpreted appropriately by the user groups, but also that by intensifying cooperation it is ensured that problem definition and problem solving are coordinated with the requirements of compromise formation between the relevant political groups. This presupposes that a transformation of scientific knowledge into action knowledge takes place in the application process – in other words, scientific knowledge is placed in a concrete norm and application context. The prerequisite for this transformation is the orientation of the TA analyses toward three requirements:

- the degree of pragmatic statements,
- the degree of compatibility with the existing values, goals and norms of society,
- the degree of evaluative interpretability.

The more pragmatically oriented knowledge is, the better it can be translated into technical recommendations for action. In this respect, the engineering sciences, medicine and also jurisprudence have fewer problems with the application of scientific knowledge than the so-called humanities, where the act of verbalizing and interpreting the results of scientific expertise must still be added for a meaningful translation into practical knowledge.

The discussion about the consequences of technological development today is to a large extent a discussion about the values of those involved, be they producers, politicians, those affected or other stakeholders. The process of technical innovation is always a process that involves the distribution of risks, benefits and costs and in which fundamental value orientations are affected. Where fundamental value decisions are affected, the willingness to accept TA results – especially since they still have an uncertain cognitive basis – is low. Uncertainty in the prediction of technological development and the incomplete determination of its effects enable interest groups to ignore TA analyses due to their value orientation and political objectives.

The question of the compatibility of the TA analyses with the values is also related to the degree of evaluative interpretability. The degree of evaluative interpretability primarily determines the possibility of reading information with regard to different values and objectives. The more clearly recommendations are made, the easier it is to make decisions. The disadvantage of this application reference, however, is that the more concretely the decision-making aid is formulated, the more likely it is that the TA analysts will have to take sides and thus destroy the very basis of their statements, i.e., scientific independence.

The third barrier that determines the application of TA analyses is the *integration of TA processes into the power relations of the political system*. As applied, practice-oriented research, TA must be related to the political decision-making process, but it must not be appropriated by short-term objectives and problems and thus eliminated from its actual role. TA research is faced with the difficult task of finding a sensible balance between integration and distance. If we bear in mind that the most important decisions in a TA process take place in the triangle formed by science, politics and the public, we can immediately see that TA is embedded in a field of social debate.

Since TA provides information both for political decision-makers and for the public, TA producers find themselves in a power struggle because their analyses affect the value premises and justification strategies of those involved in TA processes. Whether they like it or not, the TA analysts are ascribed a part of the political decision-making power and thus enter into competition with the political decision-making bodies.

Renate Mayntz has derived three restrictions for the application of TA analyses from the reference to political power:

- The seemingly modest claim of TA to provide information for political decision-makers is in reality by no means modest. It implies a claim to participation in political power and brings the people who produce TA into conflict with political decision-makers who, by virtue of their office, regard this as their own prerogative.
- Political decision-makers who do not share the value premises underlying the evaluative component of a TA study will not reject the TA results because of their cognitive content, but because of the implied political recommendations for action.
- In the context of political rationality, TA will only ever be used to the extent that it serves or can be made to serve political intentions. Consequently, there is a tendency to instrumentalize TA politically by using it to legitimize decisions instead of basing decisions on it (Mayntz 1983).

To summarize, it can be said that if TA is not to remain a purely academic exercise, then scientific research must always be related to the political process with its conflicts of interest and problems of consensus-building as well as to existing, restricted scopes of action.

2.3 Impact orientation in politics

As an institutional proposal, the TA concept makes demands on different social subsystems and has the function of linking the activities of these subsystems with one another:

- The scientific system has the task of drawing up analyses, forecasts and assessment perspectives that can be used to analyze and evaluate the consequences in an interdisciplinary manner;
- With the help of TA, policy should be placed on a scientific information basis in order to be able to act in an anticipatory and controlled manner;
- With the help of TA, the public, politics and science should be interlinked in such a way that the stakeholders and those affected by scientific and technological progress can reach a consensus on the goals of technological development.

At its core, the TA concept therefore has a scientific-analytical, a decision-related and an institutional consensus-generating component. In our context, we will focus solely on the problems of integrating TA into the political system.

A technology assessment that is intended to deliver decision-relevant results cannot be carried out solely as a purely scientific knowledge process. Carpenter refers to the two main components of TA as *impact analysis*, which focuses on recording the effects, and *policy analysis*, which first classifies the effects as undesirable or desirable in order to then formulate policy alternatives (Carpenter 1982).

Scientific investigation and political discussion must be related to each other in an interactive process in such a way that cooperation between the analysis team and political decision-makers arises as early as the problem definition stage and then subsequently during the formulation of policy alternatives. Ideally, the organization of the TA process should make it possible to link scientific research, public opinion and political decision-making. TA studies are thus located in the intermediate area of science and politics, which is neither adequately defined by the decisionist model of policy advice, in which scientists and politicians are separated, nor by the technocratic model, in which the political decision is replaced by scientific analysis. Instead, it is a decision-making process in which different interests are balanced and an attempt is made to reach consensus, both taking into account and drawing on research findings. TA does not so much establish direct decision-making concepts, but rather forms the intellectual basis for the conception, orientation and empirically based generalization of policy alternatives. It is not possible to deal in detail with the associated problems of a complex link between political decision-making and scientific analysis. For example, questions of the organization and cooperation of scientific experts, decision-makers and affected citizens would have to be discussed, or the question of participation and democratic control raised.

However, reference should be made to a structural change in politics that is associated with an orientation of political action toward consequences. By opening up the political decision-making process to a stronger future orientation, which is enforced by TA analyses, the certainty of decision-making in the political system itself is affected.

Three consequential problems of this orientation toward the future must be considered, which become characteristics of a policy oriented toward consequences and whose consequences are difficult to assess:

- With the help of TA, the success of a policy should be measured by its consequences. Since this impact test can be very risky for the political system in view of the fact that changes in values and norms can never be ruled out, the obvious demand is to include the change in values in the calculation. However, the question then arises as to how diverse and in-depth a factual breakdown of the consequences to be considered can be without the decision-making process or the discussion of consequences being used to legitimize non-decisions.

This question involves both the unresolved problems of decision-making technology (how accurate and how realistic are impact forecasting and impact calculation?), and questions of political decision-making legitimacy. If the analysis shows that the probable social costs are greater than the expected benefits, should citizens take action and prevent the introduction of the technology in question?

- A consequential orientation can have a de-differentiating effect if the aspects to be considered are highly interdependent. With the possibly enormously increased variety of consequences and effects to be considered, the only way out may be to forcibly harmonize contradictory purposes and different orientations in order to establish a uniform standard of value. Closely related to this is another danger, which can be described as a subjectivization of the basis for decision-making. Since every consideration of consequences represents a selection, the selection criteria require justification: it therefore becomes clear that one could have used other criteria than those chosen. The burden of justifying the selections is therefore passed back to the political system. Looking at the political process within the TA paradigm, the paradoxical situation can arise that the only decisions that can be expected to be prevented are those that have demonstrably scandalous consequences, but that the consideration of consequences cannot provide a viable basis for fundamental "alternative courses of action."
- A third consideration relates to the legitimization mode. Since the social and political consequences can be broken down as far as desired, the discontinuations, reductions in vision and reductions must be justified when considering the consequences. As a result, there is a risk that the argumentation becomes circular: Politicians want to exonerate themselves legitimately by referring to consequences, but cannot refer to an authority – least of all to science – that can legitimize the discontinuation in the consideration of consequences, unless this discontinuation is dogmatically legitimized.

These three problems of an increasing focus on consequences in politics, namely the shifting of the test of political decisions into the future, the subjectivization of the basis for decision-making and the danger of a dogmatic conclusion to the consideration of consequences, also address problems of the institutionalization of TA in the political process itself.

3. Institutionalization patterns of TA

In the more than twenty-year history of technology assessment, the most diverse ideas of TA have been tested in practice. It soon became apparent that an exclusive focus on the implementation of studies and their methodology limited technology assessment to an overly narrow management-oriented and technicist approach and completely excluded questions of citizen participation. It was not until the reorientation of TA philosophy at the beginning of the 1980s that TA was not only seen as a means of decision support, but – inspired by the institutiona-lization debate – the TA concept was also discussed in terms of its social objectives and uses. Three models emerged with regard to the definition of functions, which signify divergent objectives for technology assessment and also imply different institutionalization measures:

- the “instrumental model”
- the “elitist model”
- the “participative model”

These different conceptualizations of TA differ in the mediation between science, politics and the public, and thus indicate how the evaluation process is to be organized in society and how it is to develop procedurally.

The *instrumental variant* is characterized by the direct link between science and political decision-making processes. It is the original idea of Daddario’s TA draft, which is ultimately based on an “instrumental model of action.” As an element of political decision-making, TA is intended to increase political control potential on a scientific basis through the early identification, assessment and evaluation of the consequences of scientific and technological development and the determination of alternatives and options. The foresight of the political system should be increased through the institutionalization of technology assessment and thus enable a “preventive technology assessment.” By defining and assessing the consequences at an early stage, technology policy decisions are to be placed on a secure foundation and become a mechanism for creating acceptance and legitimacy.

In this way, TA is intended to improve the effectiveness of political and administrative action by organizing available knowledge and broadening the basis for political decision-making through natural, technical and social science expertise.

TA means scientific methodology extended into politics and represents a step toward the "scientification" of politics. With the help of science, the political-administrative system attempts to overcome its constraints on action through new options and at the same time submits itself to a scientific, i.e., experimental paradigm when determining its strategies for action (Bechmann/Wingert 1981a).

TA remains as input into the decision-making processes in the existing decision-making structures and, depending on the intention, remains an information and control instrument of the legislature or an early warning instrument for "anticipatory consequence management" by recognizing the opportunities and risks of technical developments.

In this context, the public is only granted a passive role in which it is *informed* about the problems and consequences of the technology policy decisions made as part of a public dialog. Forms of this public participation can be seen in the "Technology Policy Dialogue" or "Citizens' Dialogue on Nuclear Energy," which was launched by the German government at the end of the 1970s. However, the intended mediation function between technology policy decisions, social values and interests remains "synthetic" here in that the public is ultimately not granted any real influence on the decisions. The significance of TA here is limited to a pure evaluation activity for the political-administrative system.

The main aim of the "*elitist model*" is to channel political and public discussion. The various models of the "Science Court" and the example of the "Royal Commission" point to the installation of an "arbitrator function" in the technology policy debate. The "notables" of these approaches attempt to provide the basis for defusing public controversies and for the evaluation of facts and decisions by determining "factual knowledge" and broad public reference. In this model, science has the most important function in the dispute over the direction of technological progress.

In addition to the traditional decision-making bodies such as the government, parliament and the courts, a new institution is to be created that is essentially staffed by renowned scientists who are to decide on questions of scientific and technological development in the manner of a court of law. In this way, scientific and technical problems are being removed from the political responsibility of democratic institutions and shifted to a body of experts that has scientific competence but is not appointed according to democratic principles. Ultimately, science sits in judgment of its own projects. The discourse on fundamental decisions on social development is thus reduced to a small elite of "experts." In the true sense of the word, this suppresses the cause that gave rise to TA: namely the insight that the conflict over scientific and technological projects should be seen as part of a larger social restructuring process involving far-reaching cultural, social and political modernization. In these considerations, the public only has the passive role of observer, who then has to agree with the experts in their assessments.

The "*democratic model*" of an institutional orientation of TA fundamentally changes the constellation of science and politics by assigning the public a constitutive function in the evaluation of technology. Against the background of the conflicts surrounding technological development, TA is given the task of providing factual information about technology and its consequences on the one hand, and identifying and disclosing interests and affected parties in technological development on the other. In this conflict-oriented approach, TA supports the public "discourse" through scientific expertise, problem structuring and conflict transparency and thus expands social reflexivity. TA thus forms a decisive element in a conflict-oriented social learning process in which technical and economic feasibility and compatibility are communicated. This also provides the opportunity for a significant broadening of the basis of TA itself.

In this approach, explicit reference is made to the social conditionality of technological development and it becomes clear that social institutions require progressive supplementation and restructuring as a result of technological change.

4. Limits of instrumental reason

Two constitutive features of TA lie in the model of instrumental rationality and in the means/end scheme, as well as in the requirement to base decisions on their consequences and to use these as evaluation criteria for political measures: instrumental rationality and impact orientation. However, these have limits, which are also a challenge for TA.

It is part of the established program of critical discussions of TA to confront it with its own claims. In a bitingly ironic commentary, Ida Hoos complains that the analysis of institutional aspects of the decision-making process, originally the program of TA, was neglected in later analyses (Hoos 1979). Or Wynne, in an analysis rich in quotations, reproaches TA proponents for the fact that the TA concepts pursued to date contain a false understanding of social and, in particular, political processes, the core of which lies in a one-sided scientist concept of rationality, so that TA can be recognized as no more than a "rhetoric of consensus politics" (Wynne 1975). To disavow scientific contributions to politics itself as a political game is often true to the factual role that science plays, but on the other hand it is also part of the criticism game. However, contributions based solely on criticism only take the necessary analyses further to a limited extent. It seems to make more sense to work out basic decision-making models and to ask how these can be reconciled with different political contexts (Bozeman/Rossini 1979). In the following, such an analysis, which would show the limits of instrumental rationality, for example by pointing out that the "rational actor model" can only be fitted into particular political contexts, will not be added. Rather, some fundamental arguments on the limits of instrumental rationality will be mentioned (Tribe 1973):

- There are inherent limits to instrumental rationality that have to do with the resolvability of a decision situation into a collection of alternatives, the differentiability and clear delimitation of these alternatives, and with the measurability and attributability of effects. This has often been described in the criticism of formal models, especially cost-benefit and related models.
- More fundamental is the objection that instrumental reason neglects process orientation in technology development. It is often not so much a matter of knowing the results and the effects, but of estimating the costs of the process itself and paying attention to the psychosocial and social dynamics that people's self-image experiences, or even suffers, in dealing with their technical artifacts. It is equally important not to know the values of the future in order to assess the possible effects of this anticipation in retrospect, but to examine how we can develop and set more appropriate values.
- In many respects, technological development does not consist in the choice of alternative means-ends relations, but rather technologies develop their own dynamic, against which ends and means can hardly be chosen. With some technologies (e.g., the seemingly possible biotechnical or asexual reproduction of humans or the biomedical perspectives of electrical stimulation and manipulation) that Tribe discusses, the question of the consequences simply becomes pointless because the integrity of the human being is directly affected. With regard to such technologies, there is only a moral and ethical answer.

It can also be seen as a merit of the TA discussion to bring such questions, as paradigmatically discussed by Tribe, into sharp focus without immediately demanding a solution technique or having one ready.

These three key arguments outline the limits of a program that is described and criticized in today's discussion as the concept of instrumental reason (Horkheimer 1967, Ullrich 1987). What is meant by this is that the Enlightenment concept of reason is reduced to the subjective moments of a pure means-ends relationship. According to this view, only the optimization of means in relation to the ends set by the subject is rational. Only this relation is accessible to the rationalization efforts of the individual. This understanding of reason and rationality corresponds to an understanding of politics and technology that sees politics as the authority that sets the binding ends, and technology as the authority that provides the means to realize the ends in the best possible way. Technology as an instrument and politics as a decisionist authority for the realization of values – this has been the secret paradigm of TA from the very beginning, and this idea still lives on today in the institutionalization debate (Dierkes 1985, Deutscher Bundestag 1986). This is not the place to repeat this criticism; instead, some comments should be made on how the dilemma of the instrumental understanding of TA can be resolved:

First of all, it must be made clear that an orientation toward consequences implies an orientation toward an uncertain future. Dealing with the control of consequences and the planning of consequences is known from the debate on planning optimism, and the TA movement could learn from this (Tenbruck 1972). At the same time, the concept of consequences implies the deliberate termination of the analysis. In no case can all consequences, secondary consequences or consequences of consequences be analyzed.

Consequential considerations are associated with selections and discontinuations. But how can these in turn be justified? If one considers that consequences are always artificially isolated aspects of a future reality, then the problem of justification shifts to the selection of relevant consequences on which consensus must first be reached (White 1986). Considerations of consequences thus inherently point to consensus strategies. In order to find such stop rules for the analysis, there are several possibilities, all of which, as far as can be seen, have already been practiced:

- The problem of justifying the selection can be left to the expert – with the consequence of delegitimizing the expert.
- The choice can be made from an ethical point of view – with the consequence of ethics becoming contingent.
- You can leave the choice to boredom – after the 50th study on forest dieback, society moves on to another topic.

- And you can try to organize a public discourse with the result that more nos are produced than yeses; i.e., in the end the dissent is greater than the consensus.

In other words, the choice of consequences, but also the termination of the causality of consequences and their attribution, *presents itself as a decision-making problem that must be socially clarified in some form*. Since Western rationalization was understood by Max Weber as a cultural implementation of rationality of purpose, and it is precisely this rationality of purpose that has pursued both the disenchantment of the world with private purposes and values as the ultimate instances of action, only to then itself fall into the reputation of the ideological, it has become increasingly difficult to justify general normative orientations. Incidentally, an ethics of the technical also suffers from this dilemma (Lenk/Ropohl 1987).

As an alternative to this model of means-ends rationality, which is recognizable in its limits, forms of argumentative justification of action are sought today for the area of dealing with people, which are supposed to have their rationality in the fact that they must convince everyone under extreme conditions ("freedom from domination," unlimited time, equal opportunity socialization). The idealized boundary conditions have the same function here as the optimization conditions of the calculations of the means-ends scheme: they steer the rationality model into a marginal position that can never be achieved in reality, but which, it is demanded, should be kept in mind with an oblique view (Habermas 1983, 1985). The classical rationality criteria referred to the means-ends relationship and defined their demands for optimization in relation to this. To date, TA has also adhered to these basic concepts – without ever being able to achieve them. Similarly, orientation, justification and the achievement of intersubjectively acceptable consensus are likely to fail because rationality is understood as a regulative idea. We know that regulative ideas take no account of time and therefore fail in the face of reality. The resources of time, money and personnel form the limits both for a rationality that is oriented toward optimization goals and for a rationality that is oriented toward justification structures. The need to come to terms with rationality barriers in the decision-making process has led to the search for weakened rationality. The Arrow theorem, the prisoner's dilemma, or Herbert A. Simon's criticism of the optimality maxim have led to a new view of rational decisions (Elster 1987).

The core of these theoretical efforts is the attempt to find useful decision rules that take into account the "constraints" of the decision instead of optimal rationality criteria. Three consequences can be drawn from this for TA analyses.

Firstly, if the termination of the consequence analysis is to be rational to a limited extent without ignoring the restrictions, then the uncertainty as to which consequences are relevant can be reduced by means of tests. The problem of rationality is partially reformulated here as a problem of the validity of tests or other diagnostic instruments. Or secondly, the solution may consist of a biased assessment of the risk of error. The main aim is to avoid the worst consequences. The concept of the worst-case scenario is an example of this. Thirdly, hard and soft selection criteria can be combined. This would mean a detailed selection of possible consequences, followed by a more limited investigation of their effects.

All three strategies have the advantage that they can also be used in combination and provide a rational connection. The process of impact analysis can be interrupted without a final judgment having to be made. TA then presents itself as an iterative process in which the questions of consequences can be raised and discussed again and again. Nevertheless, this type of consideration gives rise to situation-specific criteria of usefulness that need not deny their social constitution. *This process could be called rationality with explicit rules of error.*

5. Concluding remarks

The political, but also the scientific discussions about the possible institutionalization of a TA system have shown that both the scientific and the political resources are not yet available to use TA in its comprehensive claim. In this sense, TA studies initially have the task of sensitizing political decision-makers and the public. As an element of a social learning process, albeit one fraught with conflict, they help to reveal the problems and lines of conflict in technological projects. In this respect, their value may initially lie more in raising critical awareness than in contributing directly to decision-making.

However, it seems clear that a new arrangement between scientific analysis and political-public discussion must be found in view of the increasing risks of modernization. What the specific forms of social organization might look like in each case depends on the political and social balance of power within which the development of technology takes place. One thing the technology debate has made clear is that technology is a social project that is subject to the public negotiation process of social actors.

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Thomas Petermann

Away from TA – but where to?

Preliminary remarks: The TA debate between continuity and innovation

The 1980s reinvented the criticism of the paradigm of technology assessment (TA). The conceptual problems and practical deficits that had already been criticized in the 1970s have been reactivated and presented, verbally revamped, as a reckoning with "consequence-free impact research" (Langenheder 1986), "first-generation TA," or "reactive TA."[1]

In most cases, the step toward the "better" is also recommended: "innovative technology assessment" (Ropohl 1985) is launched, TA for the new generation (Spinner 1989) is raised on the shield, "constructive TA" (Rip/van den Belt 1986)

1 A few notes on the characterization (of a critique) of critique:
It is often not clear what the object of criticism actually is: In Spinner's case, Hans Jonas' philosophy of technology is TA (Spinner 1989)!
Too little distinction is made between concept and practice: The criticism that claims that TA is "reactive" in concept does not take note of the concept with its principles ("*early* warning"/"timeliness").
Deficiencies are attributed to the concept (or practice) which are far more likely to be rooted in the subject matter or the context in which TA is used: Attributing the "lack of impact" of TA to the TA *concept* is at least one-sided.
Too little *empirically* based criticism is presented: I know of hardly any criticism that takes the trouble to evaluate TA studies in order to substantiate its statements. What is also striking are the sometimes adventurous "development phases" that TA is supposed to have gone through. In contrast, Naschold's description of the development of TA reads nicely – but remains empirically unsubstantiated. Naschold believes he can identify four "methodological stages of development": from a "social science extended cost-benefit or risk analysis" at the beginning to a comprehensive "identification and analysis of the entire range of [...] effects of technological development." Subsequently, "highly selective analyses for the identification of risk constellations" came to the fore, whereas today this approach is being broadened "in the sense of an intensive 'comprehensiveness'" (Naschold 1987, p. 14f.).
Requirements are formulated that are incompatible with the TA approach: Where this is aimed at policy advice, for example, it is in some ways pointless to constantly criticize the resulting analytical limitations.
Almost every critical topos of the 1980s was already formulated and discussed in the 1970s: But as a rule, no reference is made to them.

is sent into the race as a trendsetter. Complementary as well as alternative research efforts on the subject of "technology impacts" are being called for and in some cases also practiced: Model assessment (Dierkes 1988), technology genesis (Rammert 1988, 1990) and (socially acceptable) technology design (von Alemann/Schatz 1986) appear as new paradigms on the stage. Reversal and renunciation are demanded: The application orientation and practical relevance of TA are problematized, and in the light of "fruitful theoretical perspectives" (Dierkes 1988, p. 51) and a theory-led analytical curiosity, "research" rather than "assessment" efforts[2] (von Thienen 1989; Spinner 1989; Lutz 1990) now seem to be the order of the day.

Shouldn't all this be seen as positive? Has the "caravan of science" (Knie 1989) not rightly moved on, and have the research interests not formed differently and innovatively[3]? Such an assessment should by no means be contradicted at this point. But is it still possible to keep track of this new formation? And where has the "caravan" now reached in its movement away from first-generation TA toward "second-generation" TA (Memorandum Verbund Technikforschung 1984) – or is it still on its way? With so much movement and reorientation, what would be "contemporary" for technology research (Hack 1989, p. 71), and where would we find the functional place for technology assessment (modernized) in view of the "massive additional need for technology research" (Lutz 1990, p. 621)?

This is where the following considerations come in: First, we should briefly recall what Naschold calls the "classical paradigm" (Naschold 1987) of technology

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2 The official language of the BMFT [German Federal Ministry of Research and Technology; the editors] now distinguishes between technology *assessment* and technology impact *research*. *Assessment* means (systematic) "efforts to enable the most rational possible evaluation of technical progress and the solutions to problems that can be achieved through technology." *Research* is defined as the "scientific, i.e., theoretically oriented and methodically controlled acquisition of necessary information" (BMFT 1989, p. 10) and is regarded as a prerequisite for consultation in discourse, i.e., assessment. Incidentally, the tenor of the official characterization of the SoTech program in North Rhine-Westphalia is very similar.

3 There is also a lot of activity elsewhere, where many new things are being tried out and old ones revived. Examples can be found in Joerges, who reports on the design of a "New Sociology of Technology" (NST) (Joerges 1989), or Eichberg, who retrospectively reports a "paradigm shift" from the guild of historians of technology (Eichberg 1987). Finally, Hack informs us about a "new type of technology studies" and its programmatic foundations, as it emerged at an international workshop of technology sociologists and historians in 1984 (Hack 1989, p. 72ff.).

assessment, as it was introduced and (mostly differently) practiced as an analytical and advisory concept at the end of the 1960s.

Criticism of and alternatives to TA will then be examined. This includes, in particular, social science technology (impact) research, from whose ranks fundamental criticism of TA can be heard. It is of particular interest insofar as it works both explicitly and implicitly with maxims and strategic research imperatives, which are claimed to be the basis for an analytically (and sometimes also politically) appropriate approach to the object of knowledge, technology (consequences).

Finally, we should discuss whether such "extra-paradigmatic" developments (Naschold 1987, p. 30ff.) could be made usable for the classical TA concept and its working practice.

1. The classic TA paradigm

The starting point would be the assertion that there is (or has been) such a thing as a "classic" paradigm of technology assessment. This requires a little reminiscing – remembering the concepts of technology assessment that first emerged in the United States in the mid-1960s. These were a reflex and part of increasing discussions about the significance and – in particular negative – consequences of the use of certain technologies. In this context, the question of the limits and possibilities of political control and shaping of technological development was also raised.

The qualitatively new aspect of technology assessment, which at the same time distinguished it from related impact analyses and research directions, lay in a sum of regulative points of orientation, which can be reconstructed from the conceptual ideas of the time about a new, application-oriented technology analysis in the following way (Paschen 1986; see also Gray 1982; Lohmeyer 1984, p. 56ff.; Paschen/Petermann 1992):

- Systematic identification of as many socially relevant effects as possible (comprehensiveness):
  The positive and negative effects of a technology or technology family should be analyzed in as many sectors as possible, such as the economy, politics, society, law, ecology, etc., as well as their interrelationships.
- Anticipatory orientation (early warning):
  Possible "futures" should be described and evaluated in order to be able

to react in good time ("timeliness") to undesired consequences or to bring about desired consequences.

- Focus of the analysis on the consequences that are not immediately recognizable:
  Where traditional impact and risk analyses tend to refer to consequences that have already occurred or are imminent in the short term, technology assessment should analyze and evaluate long-term secondary, indirect, and synergistic consequences in particular.
- Recording and evaluating social opportunities and risks:
  As far as possible, impacts should be analyzed and evaluated in a comprehensive sense, going beyond the merely quantifying, technically-oriented impact assessment to also include qualitative, social costs and risk potentials.
- Interdisciplinarity of the analysis:
  In line with the diversity and complexity of the impact areas, TA should be designed and carried out on an interdisciplinary basis.

This – more scientific – side of the program of technology assessment was enriched on the one hand with the demand for participatory design and on the other hand was constitutively coupled with the postulate of application or decision orientation. Therefore, the following continued to be essential for TA:

- Participation:
  Affected individuals and interest groups should be involved in the analysis and evaluation in order to improve the information base and document the different points of view and assessments.
- Identifying options for action:
  The aim was to formulate various options for action in terms of alternative possibilities. Options and alternatives should relate both to the technology and to the surrounding social structures. As a contribution to planning and decision-making, technology assessment was conceived as part of the decision-making process of individuals and institutions.

TA was thus – on the one hand – from the outset a utopian program of knowledge production with practical intentions. Accordingly, concrete TA activities – measured against the program – always had to be deficient in some respect.

On the other hand, however, TA as an interdisciplinary and multi-perspective analysis concept represented the approach of an integral technology analysis in terms of research strategy, which is nowadays demanded by consensus. It is true that TA was and is not based on the idea of integrating the determinants of technology into a "techno-*genetic* explanatory scheme" (Schneider 1989, p. 27;

emphasis added by the author). However, the description and explication of the status quo and future developments were and are always strategically guided in such a way that the various relevant factors of developments and the development possibilities of individual technologies can be addressed through interdisciplinary work.

If one reconstructs the classic TA paradigm at the conceptual and strategic level, it becomes clear that much of the criticism of its shortcomings that is voiced today in a tone of conviction is in fact preaching to the converted. This is because the *programmatic* interpretation of TA has always been such that the majority of critical elements have always been taken into account.

To name just one example: The assertion that TA is "reactive" and not interested in the timely design and control of technologies. Read Daddario, who emphasizes that the expected effects of technologies should be identified "in advance of their crystallization," the public informed and measures taken against problematic developments – "to eliminate or minimize" (cited in Lohmeyer 1984, p. 5). In view of these and other statements, what is supposed to be new about the concept of "constructive TA"? I don't know. It will also be interesting to see when and how the supposedly new paradigm of "constructive TA" materializes in studies, research results, and consulting practice.

Irrespective of the fact that the concept and strategy of classical TA certainly corresponded to a large number of the current demands for an interdisciplinary, design-oriented analysis of technology that takes social contexts into account, there is still the criticism of the inadequate implementation of the TA postulates and certain technocratic and scientistic stunting of the concept. And this indeed has sufficient empirical validity (OECD 1978, 1983; Shrader-Frechette 1982; Conrad 1986; Jochem 1988).

2. The classic criticism topoi of the 1960s and 1970s

Early on, the danger of the embarrassment of ambitious programs through practice became the focus of the TA debate. It was noted above all that the usual assessments of a technology were based on a false concept of technology: Technologies were seen as predetermined and unchangeable, their social constitution was at best implied by the trivial formula of the Janus-faced nature of use: "Technology may be used for good or evil." (Winner 1977, p. 357).

Wynne criticized the prevailing understanding of technology as a purely material artefact and expression of rationality and objectivity as a "technological superfix" of TA with a specific consequence: The description and "evaluation" of technology and its consequences proceeded in a technocratic-rationalistic linguistic style, as if the emergence and use of technology could be negotiated exclusively and appropriately "objectively-scientifically,"[4] i.e., without touching on the ideological, symbolic, and political implications of processes of technology development and use. However, as Wynne later explained following some findings from the sociology of knowledge, different social paradigms of the perception and description of reality always exist side by side. A single paradigm for describing, for example, a large-scale technology (and its risks) can therefore never fully capture reality and only feigns "objectivity" (Wynne 1983a).

For these and other reasons, an alternative approach to research was called for: Away from the assessment and evaluation of a technology as such toward an analysis of society – "the proper point of departure is not to assess technology but to assess society"; away from the misunderstood impact analysis toward the generation mechanisms of technological innovations – the analysis of the

> [...] mechanisms through which social, economic, and political forces manifest themselves to give rise to new technologies. Public policy, therefore, should not be aimed so much at controlling specific new devices, as it should be directed more at identifying, analyzing, and perfecting the inducement mechanism (Holt 1977, p. 285).

Finally, a critical reflection on the fundamental problems of scientific and technological civilization was called for, "technology criticism" instead of an affirmatively charged "technology assessment" (Winner 1977, p. 350).

Critical social analysis and reflection on the conditions under which technology is created and implemented, however, require interdisciplinary technology research that goes beyond technology-focused approaches, according to another criticism. In this sense, Hoos criticized the methodological narrowness of so-called TA studies and the technicist orientation of the institutions conducting them. The technocratic bias, as expressed in the unreflected adoption of systems

4 "By reference to the objectivity of scientific knowledge and to the purely material character of technology, the proponents of the econometric systems language, and its 'social indicators' twin can assert that the employment of this paradigm as the only mode of cognition is an objective act in itself. When we understand that the very act of entry into such a mode of discourse involves the acceptance of a particular frame of reference, and of a wide range of culturally conditioned associations, meanings, etc. of which one may not even be aware, and which are beyond one's own control and personal definition of the situation, then we are in the position to reject their colonization of social reality" (Wynne 1975, p. 136).

analysis and cost-benefits analysis, results in rigid economism and the neglect of social values and interests (Hoos 1977). "While paying lipservice to 'social aspects'" – Skolimowski diagnosed – "the overall tenor, methodology, and conclusions are technical: a technical exercise performed by technicians" (Skolimowski 1976, p. 422).

Finally, as the fourth dimension of the TA criticism syndrome, the demand was emphasized that TA should not remain confined to the given technologies and the political decisions behind them, but should aim at a technology introduction and design that is socially acceptable to all groups. Furthermore, alternative technologies, strategies of non-introduction, and the social, non-technical possibilities for action and design should be included in the analysis – and this using participatory approaches (Lohmeyer 1984, p. 171ff.).

This aspect indicates that criticism of the *analytical approach* and *understanding of technology* could not be separated from the question of the use and objectives of anticipatory technology research. A look at the criticism of the 1960s and 1970s shows the paradoxical situation (which is still widespread today) that, on the one hand, TA was seen as a counterproductive thoughtfulness that could hinder the rapid implementation of technical innovations – whether through political regulation based on TA or through TA-induced technological skepticism among the population – and, on the other hand, was attacked as a particularly perfidious variant of technocratic, capitalist elites for the implementation of technology.

Technology *assessment* thus shared essential deficits that were also diagnosed in the old paradigm of technology *research* – Hack calls it the "clearly predominant sociological form of thematizing 'technology' until well into the 1970s."

In Hack's depiction – from the "enlightened" perspective of the 1980s – the "basic pattern of sociological technological determinism" of the 1960s and 1970s is characterized by three aspects:

- The development of technology and the underlying scientific and technological knowledge were understood as processes exogenous to society, i.e., as something that took place and had to take place "outside of society," as it were, and according to its own laws. Sociology, like other social sciences, ultimately had to deal with the social consequences – such as changing qualification requirements, job losses, productivity increases, etc. – and, if necessary, with the conditions that could inhibit or promote this autonomous process of scientific and technological development. The development of science and technology was seen as a "black box" that social scientists (and politicians) should keep their hands off.

- "Technology" was primarily understood to mean individual technical artifacts, tangible items such as machine tools, motor vehicles, telephones, or phototypesetting machines. The social significance of such a technical "object" lay in the object itself and therefore had nothing to do with the process of its production.
- This in turn meant that technologies were seen purely statically, "ontologically" so to speak: they were "there" and their mere existence implied social opportunities, problems, and dangers (Hack 1989, p. 728).

The 1960s and 1970s were already familiar with the main features of all those disputational topoi that are celebrating their heyday today: The analytical limitations and technocratic orientation of TA, the suppression of criticism and alternatives with regard to the object of knowledge "technology," and the TA analysts' lack of value sensitivity and willingness to shape. In addition to the continuity of this criticism, the 1980s also saw a qualitative intensification and supplementation by social science technology research, which will be of particular interest in the following.

3. TA as a deficient entity – especially from the perspective of social science technology research

Possible points of criticism, which prove to be consistent despite certain modifications, are the supposed presumptions inherent in the concept of TA. For example:

- TA means cognitive arrogance:
  Correct forecasts are neither possible, nor is it justifiable to derive consequences for policy action from forecast attempts that are doomed to failure (Radaj 1988).
- TA as science with practical (political) intent means crossing the border into the realm of politics. This is technocratic manipulation of freely elected politicians. Science should withdraw to the scientific (Pinkau 1987). Or: In order to avoid confusion between being and ought, a clean separation should be sought: Technology assessment research procures information (by scientific means) which is to be evaluated rationally (in a non-scientific way?) (BMFT 1989).
- TA implies "technology arrestment" and freedom-threatening subversion of the social market economy (Meier 1987).

- TA means a lubricant for the increasing mechanization of society and affirmative adaptation to the technological imperative of capitalism (Büllingen 1984) and its elites (Reese 1986).

Other critics provide important modifications of well-known TA criticism – despite an unmistakable continuity. Their concern is to expose the analytical deficits of "impact" assessment. Relative novelty can be attributed to the messages of those participants in the debate who have set their sights on impact research without consequences and its alleged passivity with regard to the design of technology.

- TA takes the second step before the first. What it lacks is a theory of technical change, understood as essentially social change and as a theory of the use of technology (Ropohl 1985, 1989; see also Lutz 1987).
- TA as "impact research" is in need of supplementation. It needs to be expanded "to include the process of generating and implementing technical innovations, which has been far less well researched to date" (Memorandum Verbund Technikforschung 1984).
- TA comes too late. What is needed is timely observation of the beginnings of technical innovations, especially the generation of knowledge (Ropohl 1985; Steinmüller 1987; Spinner 1989), possibly by the technology developers themselves (Langenheder 1986).
- TA is insensitive to values and norms. What is needed today is the value-conscious construction of futures and the discussion of the "why" of technology and its compatibility[5] (Zimmerli 1982; Roßnagel 1984).
- Because it is latently "deterministic," TA dethematizes the ways in which technology is used and how society deals with it. TA is therefore not seriously interested in a "design perspective" and based on "consequential determinism" (Ropohl 1985).
- TA is too scientistic and elitist. What is needed is a stakeholder orientation and decentralization as well as a strengthening of its discourse function.

5 "It is therefore a matter of us agreeing on what we want in such a way that we obtain a common picture of the desirable future, initially only a medium-term future. At this point, it becomes clear that both TA efforts and the efforts that have been increasingly observed in recent years and summarized under the term 'professional ethics' are turning into politics, i.e., into actions to generate consent or to reduce the refusal of acceptance. TA studies have to provide *casuistic* evidence in the form of 'if-then' scenarios segregated according to probabilities, while a politically approvable hierarchically structured value system of medium temporal range as 'residual ethics' co-determines which scenario will become the reality of the future on the basis of various professional ethics." (Zimmerli 1982, p. 154).

TA should not be conceived as an "expert model," but as a "social process" (Naschold 1987; Fricke 1989).

With this in mind, let us now take a look at some examples of alternative approaches to a renovated TA concept: Pinkau's "mission of technology assessment," Ropohl's "innovative technology assessment" and NOTA's [Netherlands Office of Technology Assessment; today Rathenau Instituut] "constructive TA."

- Pinkau's complaint is that the magical boundary between scientifically proven knowledge and political evaluation and decision[6] has been crossed, which he sees as a corruption of science (with detrimental consequences). Pinkau uses an absolute criterion of truth or a strict concept of law as the selection criterion for TA objects of investigation. All objects of knowledge that do not satisfy this methodological purism are eliminated, so that the only remaining objects of knowledge are those that permit statements of a legal nature, i.e., "extrapolations of the effects of natural sciences and engineering." This ensures the supposed neutrality (or reputation?) of science and, above all, solves the problem of action orientation through non-treatment.
- Ropohl criticizes the sleepiness of "reactive technology assessment": it waits "until certain technical developments have already taken on a certain form" instead of tackling "the sources of that stream" (Ropohl 1985, p. 236). Furthermore, since there is a lack of "basic scientific research" that provides "reliable" assumptions about effects, as well as a lack of "theories" that describe and explain "lawful relationships between technical objects and their non-technical fields of action" (Ropohl 1985, p. 234), TA is doomed to failure as an attempt to evaluate technology (too late, without orientation, taking the

6 Breaking down a TA process into two phases is a very plausible idea, but it suggests a *separation* and a *sequence* of scientific and non-scientific discourse that does not exist in reality. Firstly, in the "phase" of (in the language of the BMFT memorandum) technology assessment research, there are certainly not only elements of "science as such" (unless one subscribes to the fiction of pure scientificity), and that the "evaluation" phase should be unscientific – this idea is probably due to the opinion that one can make scientific statements about wheat prices, energy equivalents, and emission values, but not about interests, values, and motives. Secondly, technology impact research does not start from scratch, but is already influenced by assessment processes relating to a technology that take place before the so-called scientific analysis. And this is itself (at least implicitly) an act of evaluation or part of overall social evaluation processes.
Perhaps it would make sense to understand research and evaluation aspects, whose existence is not to be denied, as different *functions* of a TA process, and not to start from the idea of a pure separation and sequence of two different activities.

second step before the first).

Ropohl believes that by intensifying (exemplary) research efforts (on case studies of technical change) on the one hand and theoretical work on the other, i.e., by formulating a theory of technical change that enables statements to be made about cause-and-effect relationships, the information and forecasting problem of prospective technology analysis can be better overcome. This then becomes a prerequisite for not only "reacting" to developments (as TA does), but also for being able to intervene in a normative and formative way at the beginnings of technological development.

- The NOTA approach addresses the unsatisfactory results of TA from the perspective of the "control dilemma" (Collingridge 1980), on the one hand, and from the perspective of mediation or the addressee, on the other hand. Similar to Ropohl, a timely *and* active (= constructive) influence on technology design is postulated (i.e., considered possible) and programmatically supplemented by the claim to organize this design mandate in democratic and transparent processes with those affected. Following Naschold, Fricke ascribes the following characteristics to "constructive technology assessment" or "technology assessment as a social process": process orientation, use of empirical knowledge, participation concepts, and a combination of decentralization and forward-looking regulation of technology design (Fricke 1989, p. 23ff.).

However, a review of the nagging discourse on TA would be incomplete without a more precise insight into the debates in social science technology research. The motifs of interest for our context revolve around the central critical topos of technological determinism, which, originally directed at other approaches and research directions, is also blamed on TA.

In most cases, this means that TA is (politically or in the process of gaining knowledge) fixated on a given technology, ignores social causes and framework conditions, and ultimately discusses consequences with the appearance of inevitability and a lack of influenceability. This criticism, which often also presents itself as a debate about an appropriate concept of technology, conveys different things: Firstly, the assumption of technological determinism is varied as a lack of critical reflection and discussion of available technologies, secondly as a danger of reducing the analysis, and thirdly as an assumption of a lack of interest in practical design options. From Ropohl's point of view, the first two aspects could be classified as "genetic" determinism, the third as "consequential" determinism (Ropohl 1989).

- A large number of TA studies, it is claimed rather than proven, create the impression of uncritical acceptance due to their concentration on a given technology and its possible consequences and, by failing to problematize *this* technology and, above all, by ignoring *alternatives* in the form of *other* technologies, suggest that this technology is simply there, that one has to make use of it and adapt to its (inevitable) consequences. "The 'technology factor' thus remains to certain extent 'outside,' is de facto treated as an 'exogenous variable'" (Joerges 1989, p. 58). Even "social strategies" as non-technical solution options would be ignored by such a form of fixation on technology. A sub-case of this accentuation of criticism could be seen as the demand to make the social "desirability" of a technology the topic instead of its "actuality" – TA as the construction of desirable futures, the answer to the question of "what for"? For a long time, this and the fact that TA was closely linked to the political system led to the dominance of profitability analyses and feasibility studies, based on given technologies that seemed to have no alternative.
- The accusation that TA is subject to analytical (and, where it is popular, political) reductionism is also articulated and varied, insofar as it allegedly or actually does not sufficiently address the social and political environment in which a technology is embedded. This criticism points out that technologies cannot be reduced to artifacts, but must be understood as "networks" or complex socio-technical systems. For this reason, the social and political, but also technical "boundary conditions" of a technology in their interplay with its "form" and functional fulfillment (or failure) are a *constitutive* part of a technology assessment. However, it is not possible to capture this adequately if one concentrates too much on the "real technology" or the artifact – as is usually the case with TA – and hardly accounts for the social environment and its actors.
  Since TA is also not dedicated to the "social networking of scientific technological production processes" (Hack 1989, p. 77), since it does not follow the early tracks (Knorr-Cetina 1984; Hack/Hack 1985) of a technology (which begin in the laboratories of basic research), since it does not take into account the interests and values, the knowledge structures and world views that "materialize" there in technologies, it never reaches an adequate understanding of its subject and is therefore also not in a position to make accurate statements about "consequences."
- The third form of the accusation of technology determinism and the "consequence fixation" of TA focuses on the possibility or willingness to contribute

to the “design” of a technology by means of an impact assessment. On the one hand, this variant of criticism also has something to do with a (real or assumed) deficient concept of technology: If technology (development) is understood as an autonomous process (or exogenous factor) and not as a social process, then the “shaping” perspective is a priori omitted, or it is reduced to adaptation. Secondly, the criticism is also articulated as a reference to the unresolved “control dilemma” (Johnston 1984) of TA: It always comes too late to be able to really decisively change (shape) techniques that are already “entrenched.” Finally, a variant of the criticism of design blindness could be the insinuation that TA targets the wrong addressees, namely so-called decision-makers at a distance, the “application elites,” but not those “affected” on the ground.

4. If there were something to be learned – what would there be to learn?

If we now apply these requirements to TA, it would have to reorient itself in the following respects:

(a) Its concept of technology should abandon a “naïve *technological* determinism” (Winner 1980), without being taken in by a voluntaristic idea of the *social* determinism of technology.
It must be admitted that for a long time, the practice of TA was dominated by a mostly implicit, but nonetheless effective, understanding of technology as an artefact that could at best be understood phenomenologically: Either technologies were regarded as the *results* of diffuse innovation processes, which in turn were declared as not worthy of further analysis. Or: they were understood as an unquestioned, predetermined component of social reality, which, so to speak, causes consequences of *its own accord* (autodynamically), to which individuals or systems have to adapt through political, economic, and social structural reorientation *due to practical constraints.*

A reorientation of TA practice – which can already be seen to some extent – will have to be based on a fundamental insight. Regardless of whether technology is understood as an unexplained *resultant* in terms of its generation patterns or as a largely unquestioned *cause* of certain consequences in terms of its form determination and modes of action: The reciprocal entanglement of technical and social processes can only be insufficiently addressed in a technology-centered stimulus-response scheme, let alone meaningfully analyzed and evaluated.[7]

Technology in the trade-off between the control intentions and control performances of cooperating and competing actors, technology as the result of their negotiation processes, the social form of technology, influenced by social subsystems such as science, law, the market, and politics, technology as a social process (Fleischmann/Esser 1989; Hack 1984; Weingart 1989) – these aspects should become self-evident orientations for common forms of technology assessment.

(b) The social interdependence of technologies means that any attempt to realize an "objective value-free analysis of the consequences of technological applications for society" (Wynne 1983a, p. 117) and a mode of TA as "non-partisan" (Gibbons/Gwinn 1986) is not feasible and must miss the social implications and symbolic dimensions of technologies and their character as a "social figuration" (von Borries 1980). The insight that "technology is a central element in the symbolic networks of society, legitimating certain forms of social conduct and organization by molding our consciousness via that implicit, condensed information which it transmits to us" was obscured not least by misunderstood postulates of value neutrality and a one-eyed addiction to quantification (Schrader-Frechette 1982). Technology itself now embodies certain institutional values, interests, and purposes" (Wynne 1975, p. 136).

It is the persistent positivist hesitancy of TA (Carley 1986) that has almost always marginalized the "value" of socio-technical systems as a question to this day.

In addition, the prevailing rationality of TA goes hand-in-hand with the adaptation to the actions and interests of (traditional) decision-makers as addressees. Interest in technology as a "function," for example, prevents interest in technology as a "symbol" (Hörning 1985) from arising in the first place. As a result of its finalization by politics, other concepts (problem-oriented TA), other time perspectives (long-term, retrospective), other dimensions of use – discourse

7 In particular, the cognitive dimensions of *technology development* and its organizational orientation and institutional framework conditions are neglected, and the actor-specific strategies of selection, interpretation, and design of technologies in the *context of development and introduction,* the "institutional focusing" (Dosi) of a technological paradigm, are inadequately taken into account. Finally, the "appropriation" dimension in the *implementation and utilization phase of technologies*, i.e., the integration or non-integration of human and technical actions and their interpretation in society, is at best a marginal issue (Joerges et al. 1985).

instead of decision, conceptual instead of instrumental use, consulting instead of decision support – and other thematic orientations – TA as "cultural analysis" (White 1986) – has hardly any market.

(c) A narrow concept of technology and the scientistic and elitist orientation of TA have also frequently obstructed the possibility of understanding technologies as being capable of being staged and shaped in line with specific social objectives (and of conceiving technology assessment accordingly as a component of processes of overall social technology assessment). In this sense, Arie Rip has pointed to the socio-cognitive dimensions of technological developments (Rip 1986) and at the same time to the lack of interest of traditional scientific analysis in the modes of discursive appropriation of technologies and technological consequences.

Whether such appropriation takes place as company negotiation processes or large-scale social disputes – these and other stylistic devices of staging are likely to have a significant influence on the "social form" of a technology and the so-called "consequences." From this perspective, it would be desirable for TA to be deliberately fed into social discussion contexts, i.e., to intervene in discourses (not only of elites) or even generate them. If TA were really to be understood and practiced as a "social assessment of technology" – as has long been demanded[8] – there would be no way around addressing and filling out this dimension in particular.

A number of conclusions for TA can be drawn from the maxim of analyzing technology as a social, value-based, and (potentially) shapeable process. They are, of course, of a general nature, one could also say "programmatic," so that for each specific TA process it would always have to be asked anew whether and to what extent the substantive and methodological concretization and practical research implementation could succeed.

- In order to avoid analytical "shortcomings" (Winner 1980), which can be detected time and again in concepts of technology assessment (Joerges et al. 1985), a view of technology should be adopted that conceives of social dimen-

8 However, it is then clear at least that the self-image of an institution practicing such a TA would have to be significantly different from what has (generally) been the case to date. It would have to understand its science as an interpretive and advocating research activity (and not leave the interpretation to politics/society).

sions of action in close connection with the factual character of technical artifacts[9].

- Technology assessment should be more interested in the reciprocal links between scientific and technical developments, as indicated by the trends toward the scientification of technology and the mechanization of science. Modern technologies are always also coagulated knowledge that essentially determines their logic. Such techniques can only be described from a narrow perspective if one does not take into account the institutional and cultural conditions of the production of scientific knowledge – including the engineering "construction styles" (Knie 1989) and "design hierarchies" (Clark 1985) that become effective here. Appropriate approaches for a "science assessment" would therefore have to be developed and tested (Deutscher Bundestag 1986). The same applies to the utilization of technology genesis research and a (yet to be developed) "sociology of invention" (Gilfillan).
- Technology assessment should, more than in the past, address the forms, strategies, and media of control of scientific and technological developments, both within and beyond the company, that are applied in cooperation and opposition by corporate (Nutt 1984; Thurley/Wood 1983), political-administrative, military (Tirman 1984), industrial, and scientific actors. If it does not sufficiently grasp these social processes of control or the determinants of the evolution of technologies, its conceptual deficits contribute to creating the appearance of a self-running technology. Therefore, "social risks" should be identified more consciously than in the past, insofar as they are induced by new technical principles and processes, more emphasis should be placed on analyzing the "decision-making calculations and constellations of interests that are decisive here," and it should be clarified "which problem situations, tensions and conflicts, unmet needs, or inadequately processed distortions exist" (Lutz 1986, p. 568f.).

9 In such an understanding, artifacts have the "character of action" (Braun 1986, p. 19). As an "intermediate element of human action," they constitute "technical social relations," in particular "through the institutional interlinking of the human parts of action with technology-integrated contexts of action" (Braun 1986, p. 23f.). However, technology also determines the social forms of action in relation to nature: "Technical relations contain an increasingly important section of social relations to nature" (Braun 1986, p. 25). The binding of human action to artefacts and the "socialization of nature" not only through its subjugation, but also through its "construction" are thus to be appreciated equally analytically (Joerges 1984).

From an action-theoretical perspective, however, a *voluntaristic* understanding of control and an overestimation of the creative openness of technologies must be avoided, as their "relative autonomy" (Dosi 1982) or "momentum" (Hughes 1969) should not be underestimated, nor should the stubbornness of social actors. Moreover, it is essential – especially if one wants to sound out the potential for design and action – to concentrate on the scientific-technical characteristics of a socio-technical system, i.e., the description and prospective analysis of the "real technology" (Ropohl), the appreciation of its respective "materiality" (Mambrey et al. 1986).

- TA should also consider the modes of cultural "staging" of technology (e.g., Rammert 1986, p. 33). New classifications of technical and human action systems, changed risk assumptions and perceptions, and the effects of the substitution services of technical systems must be culturally appropriated. Processes of such "transculturation" take different forms: The stubbornness of social actors can resist the intended use of technologies and technical innovations can also "generate" adjustments in attitudes and behavior – both with more- or less high social costs.
- Of particular importance from the perspective of cultural appropriation are the discourses and public debates that accompany technical innovations, the institutional-cultural embedding of actors who drive or slow down the process of technical developments, the media by means of which technical developments and development possibilities are negotiated, such as political discourse, morality, and law. Finally, these include "metaphors" (Zashin/Chapman 1974), "images of technology" (Huber 1989), "guiding principles" (Dierkes 1987), and myths, which are *also* an "expression" of the appropriation of technology, but are always more than this. This is precisely why they should be made the subject of technology assessment processes. Research in the social sciences and the history of technology has shown in many case studies that such discourses and images, as *social interpretations* of chosen paths of technologization, as elements of social appropriation of technologies, as representations of one's own and other people's interests, contribute significantly to social change in the context of technological advances. The assessment of their functions could therefore provide insights into the defense against or appropriation of technologies and the resulting repercussions on their form and perspectives of use.

In the face of such desiderata, debate is necessary, but composure is also called for. This is not so much because the shortcomings mentioned in the analysis of techniques are by no means limited to TA, but also need to be remedied in other areas (Ropohl 1989, p. 1; Lutz 1990). Rather, *direct* research-pragmatic consequences for TA can only be drawn to a limited extent from the considerations outlined and the maxims formulated. The requirements discussed are more likely to be met directly by the *sociology of science,* which is better suited in terms of time perspective, content specialization, and specific epistemological interest, or critical technology-related *social research,* which – as a "descriptive concept" (Hack 1989, p. 81) – deals *ex-post* or *concomitantly* with the reconstruction and analysis of technological advances in the context of socio-structural change processes.

Lutz has described the previous "path to a new paradigm of technology research" as one that proceeded in two stages: The overcoming of technological determinism and the development of an understanding of technological development as a social process. At the same time, however, he points out that the development to date has taken place "without [...] the consequences of this having really been systematically drawn in research practice and scientific discussion" (Lutz 1990, p. 617).

As far as the practice of TA is concerned, a similar argument will have to be made: The "new questions" about the causes of the emergence of technologies that are used and appropriated by the actors, about the control of certain technologies and the neglect of others, and about the forces, interests, and arguments that play a role in this – *technology research* is struggling to answer these questions (Lutz 1990, ibid.), and *technology assessment* has at best made timid attempts to address them and is probably still a long way from finding answers.

The analytical dilemma is obvious: The characteristics of technical development

> [...] – industrial organization; gradualness; market mediation; surplus application potential; control by socio-economic interests and problems – can still be captured and described relatively easily retrospectively on the basis of earlier, long-past technical developments. This is much more difficult in the case of developments that are still in flux and the corresponding technological lines (Lutz 1990, p. 619).

And this dilemma continues in the attempt to "assess possible future courses and ramifications of technical lines of development" (Lutz 1990, p. 619).

The interest in explicative elements of a technology analysis is also difficult enough to implement in technology research – for TA as a prospective analysis, at best plausible argumentation steps remain here in order to be able to assert possible correlations or constellations of social and technical parameters in evolutionary developments. If technology research intends to "reconstructively catch up with the mechanisms and tendencies operating blindly" (Hack 1989, p. 96) in addition to analyzing intended, planned research activities, it is obvious what difficulties a *prospective* analysis would have with this. After all, it lacks precisely the historical material that is available, for example, previous attempts at technology genesis research.

For a technology assessment of *future* developments or development possibilities that is concerned with utilization and usefulness, the new perspectives of technology research mentioned above can hardly be directly translated into application-oriented research strategies and project designs, let alone conceived in the foreseeable future as advisory discourses for decision-makers working with other rationalities. There are evident methodological and epistemological barriers to this – not to mention the conditioning of individuals and institutions by their clients and sponsors.

However, certain barriers may need to be overcome. This presupposes that general requirements for an appropriate analytical approach to technology, such as the thematization of actor aspects (Rammert 1986), the consideration of "contexts of use, production, and disposal," "eco-contexts" (Joerges 1989), "cultural milieus" (Nedelmann 1986), etc. are operationalized for tangible TA topics. There may be good reason to call for a shift in research interest away from the analysis of consequences and toward issues of production and use (Memorandum Verbund Technikforschung 1984) – good reasons for intensifying TA research using findings and methods from research on genesis and use must be asserted in more than just the abstract. If the claimed *complementarity* of generation- and impact analyses is taken seriously, it would have to be examined whether there could be a pathway between social science technology research and TA that enables meaningful transfers that stimulate the TA practice of anticipatory analyses. The same applies to the question of common intersections between historical-empirical technology research and theory-based technology research.

I would like to cite three examples of communication transfers:

- The question of a connection between TA and a theory of technical change is still awaiting at least an attempt at an answer.
  In this context, Ropohl speaks of the "lack of theoretical, interdisciplinary technology research" and asks: "How can technology impact analysis be carried out in practice if there is a lack of scientifically tested hypotheses about eco-technical and socio-technical interdependencies? How can the results of a technology assessment be fed into the mechanization process if the 'mechanisms' of technological development have by no means been

theoretically clarified? Technology assessment studies thus prove to be ad hoc undertakings that attempt to take the second step before the first, so to speak. In any case, a technology assessment that not only reactively considers the consequences of an innovation that has already been implemented, but also wants to intervene innovatively in the design of new technologies, excludes any technological determinism; this naturally also applies to technology research that is intended to create a theoretical basis for such technology assessment" (Ropohl 1989, p. 1).

In my opinion, we do not need a "theory" of technical change in order to conduct TA, but we do need systematic orientation.[10] These can be gained from theoretical work on the explanation of innovations, from theoretical and empirical work on the actors and determining structures involved (Ridder 1986), and from predominantly empirical studies on the development forms and phases of individual technologies.

Conversely, the "bundling" of TA results could also make a contribution to the "systematics" of socio-technical development processes if such singular results were integrated "into generalized bodies of knowledge about the relationships between technical development and social, ecological, economic, and political systems" (Dierkes 1991, p. 24).

- The Bremen Expert Commission "Arbeit und Technik" [Work and Technology, the editors] concretizes its concern for historical-social science technology research in the form of two steps (Sachverständigen-Kommission 1988, p. 90ff.):
  - the empirical-statistical long-term analysis of the objective developmental moments of the emergence, introduction, and spread of new technologies and
  - the historical-genetic interpretation of design theory and the development of engineering methods as well as the analysis of specific problem-solving patterns and strategies for individual techniques.

10 We may, for example, learn from the abundance of technology-push and demand-pull studies on the dissemination of technological innovations (Mowery/Rosenberg 1979) that – even in retrospect – the course of these processes is almost "Tolstoyan," i.e., its determinants can be roughly described but ultimately cannot be (rationally) explained. We *do have* material that could be used to develop a theory of technical change. But the material shows us (so far?) that the goal of finding and combining generalizable, time- and space-independent statements/explanations is hardly achievable.

As has become clear in similar programs, but also in individual projects in social science technology research, the objective of such analytical approaches could certainly be achievable:

— Data on volume and structural develop-ment from specific sectors of the manufacturing industry or the products and processes to be examined could provide assistance in classifying the preferred problem-solving strategies in each case.
— Long-term observations could relativize the "laws of development" of energy and information technologies that are often regarded as valid – which often obstruct alternative perspectives.
— Quantitative analyses of individual – completed – technology developments could, in particular, work out the characteristics of design goals, principles, and problem-solving patterns, identify abandoned technology developments, and neglected design scope.

A TA that learns from history could benefit from such comparative approaches in technology and engineering research. But again the central problem of the transferability of findings gained from retrospective research to assessment processes that aim to anticipate lines of development arises here.
Nevertheless, the benefits of long-term technical assessments of selected branches of technology or comparative re-evaluations of technology-specific development patterns should not be underestimated for anticipatory analysis and evaluation. In the discussion about the assessment and evaluation of the potential consequences of individual technologies and in the search for perspectives for problem-appropriate technology design, the "design-oriented historical-comparative analysis" could provide argumentative support to "break up the appearance of a natural, logically determined technology genesis and development" and "expand the technical-scientific problem-solving horizon of future technology designers."

- Dierkes and Marz have concretized their considerations on "Leitbildforschung" (Dierkes/Marz 1990) to the extent that they have made proposals for the utilization of this approach for technology assessments (and thus for the control of technology). Their programmatic demands focus on three aspects:
  — Since TA has difficulties in determining the point in time at which the action strategies it formulates have to be applied in view of a certain stage of technological development, it could draw on insights from technology genesis research: "It could determine this critical point in perspective, if

not absolutely exactly, then more precisely" (Dierkes/Marz 1990, p. 39). The results regarding the diverse factors that control technology genesis ("factor network") could also be expected to contribute to the formulation of refined "control strategies" that are no longer "one-dimensional and microstructurally" oriented (Dierkes/Marz 1990, p. 40).

— Research on risk perception and the interaction of organizations, social movements, media etc. in the development of acceptance and acceptability of technologies could "reveal new control potentials outside of classical strategies" (Dierkes/Marz 1990, ibid.).
— Terms and concepts of the techno-genetic research approach such as "construction and research tradition" (or "style"), "organizational and corporate culture," and, last but not least, the "mission statement" could stimulate reflections on complementary or alternative models of technology management.

It seems to me that there are interesting parallels between ex-post oriented genetic research and anticipatory assessments of pre-competitive technologies, in that early technology assessment is to a certain extent following in the footsteps of an emerging technology, so to speak. If, for example, the AFAS[11] – as in some projects in the field of information and communication technologies and artificial intelligence – uses the methods of personal experience with the technology or the means of prototype development (as a method of technology research) to seek information about possible future consequences, then something like an analysis of the factors of technology genesis is also carried out here – only prospectively. These parallels and similarities would be an interesting point of contact for joint communication between technology researchers and TA analysts – irrespective of differences such as methods and interest in knowledge

5. Concluding remarks

There is no need to warn against high expectations regarding communication between technology research and technology assessment – they are unlikely to arise. I see a possible modest yield for TA – assuming a mutual acknowledgement – on the level of intellectual stimulation and a strengthening of the awareness that for TA technologies are to be described more as social processes than before.

11 *Editors' note*: AFAS – Abteilung für Angewandte Systemanalyse (Department of Applied Systems Analysis) of the former Research Center Karlsruhe.

The – indirect – benefits to be gained from social science approaches to technology research, the sense of thematizing and reflecting on the concept of technology, the yield of technology-historical studies (Kranakis 1987) could lie for TA on the one hand in a (self-)enlightenment function and on the other hand in the possibility of obtaining topics, questions, and (meta-)criteria for the assessment and evaluation of technologies or technology families or their alternatives, as well as associated possible social change or persistence tendencies.

TA as a "social assessment" of technologies could do with further development. Not least because of this, it would perhaps also be possible to awaken an understanding of the fact that social consequences can neither be directly derived from the technical-physical characteristics of a technology nor from economic data, nor can the social desirability of a specific use of technology be justified.

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Technology assessment as policy advice

Introduction

Technology assessment (TA) as technology research and policy advice has been under scrutiny, sometimes even pilloried, since its beginnings. From time to time, we also receive reports of its demise. A brief preliminary remark may be appropriate here.

Messages about the demise of this TA concept – often referred to as the classic concept – can be heard in very different discussion contexts. One of these is the criticism of TA as an expert event, often with the implication that a democratic process of technology assessment by laypeople should be organized (instead). Embedded in overarching debates about extended opportunities for citizens to co-determine and shape environmental and technology-specific planning and decision-making processes in politics and administration, citizens' forums, consensus conferences, sometimes also planning cells (and citizens' expert opinions) are discussed as contrasting with "elitist" TA and as a medium for the "democratization of expertise" (Saretzki 1997). It is not always entirely clear whether this conceptual discussion is taking place with the intention and result of supplementing or replacing expert advice.

Criticism of expertise and its cognitive and social limits has highlighted many of its deficits, and the loss of trust in experts has evident and justifiable causes. However, I have yet to see any convincing arguments as to how democratized expertise could *substitute* the problem identification and problem-solving skills of experts in an equivalent way.

It would therefore probably make more sense to install and test new "forms of problem-related cooperation between different knowledge carriers and certain groups of affected parties, interested parties, and decision-makers" (Saretzki 1997, p. 306). As a result, the field of policy advice would be characterized by different but complementary communication relationships between science, politics, business, and citizens (and thereby also between expert and lay understanding). However, it will hardly be possible to do without the reflexive and strategic skills of experts – also for the formulation of scientific, technical, and social goals and paths in the globalized risk society. However, traditional expertise must face criticism and questions.

Since the first hesitant steps toward establishing its practice – and especially with regard to its institutionalized forms – TA has been accompanied by the question of its implementation and "effectiveness" (Petermann 1991, p. 151ff.), including the accusation of lack of impact. The question of the "implementation" of expertise in political action is legitimate, and the question of inconsequential research is rightly raised. However, it would be desirable to recall some of the internal structural features of scientific policy advice and its essential framework conditions when discussing it.

In the following, I will highlight such structural and framework conditions of TA as policy advice and at the same time address some myths and misunderstandings that obstruct or impede the view and understanding of TA (and policy advice in general) and its possibilities. I do this in three steps:

- Firstly, I would like to remind you that policy advice, especially when it takes place in close communication processes, can only be adequately understood in terms of its possibilities if it is understood as a social process. In this process, two professions cooperate with each other. They do this not only rationally, but also irrationally, not only factually, but also emotionally (Bonus 1982). As two different professions with different perspectives and prerequisites relate to the same subject in the counseling process, it must be taken into account that counseling is always also a social competition – "competitive cooperation." This is not least about prestige, status, and power. "Implementation problems" (and possibly lack of consequences) are already inherent here.
- Secondly, it must be taken into account that the object to which the process of "self-consultation" is directed with practical intent is a highly presuppositional section of social reality. It is not without reason that research into the characterization of innovation and diffusion resorts to terms such as chaotic, invents attributes such as "Tolstoyan" and takes refuge in images of "rat race dynamics" and "crazy companies" (Ausubel 1991). If one reviews even a fraction of the research on the genesis and use of technologies or on innovation and diffusion processes, it should be clear how misguided the idea of precise "control knowledge" is, which could be used to shape such processes in a targeted manner and according to universally agreed criteria.
- Thirdly, the fact that the addressee of TA (as policy advice), state policy, is neither the sole actor in the shaping of development processes, nor is it homogeneous as an actor, must be addressed. In addition, its capacity to act and its creative competencies suffer from the fact that state policy is fragmented both vertically (municipalities, federal states, federal government,

European Union (EU)) and horizontally (departments, committees). In view of the reality of a multi-level political-administrative system (Zürn 1996), an image that focuses on the unitarist nation state as a central center of state control is a travesty. It is far more accurate to imagine a state that is a *player in* the technology policy arena together with a large number of other economic and social players.

The discussion of these three aspects of the "consequences" of TA as policy advice should, I hope, at least help to put some hasty diagnoses of implementation blockages, unsuitability for use, or lack of impact into perspective and to arrive at a realistic assessment of the possibilities of TA.

1. Counseling as a process (The difficult dialogue)

The dialogue between science and politics has long aroused the interest of external observers or prompted participants to write partly scientific, partly anecdotal reports of their experiences. Scientists in particular describe and analyze their encounters with people from the political profession – sometimes as if they were immersed in another culture and were confronted (like a traveler or ethnologist) with foreign customs and traditions (Hoffmann-Riem 1988). The diverse experiences have one small common denominator: Cooperation between science and politics is not without its pitfalls.

A first misunderstanding would therefore be to understand scientific policy advice (only) as cooperation based on trust and perceived as helpful.

In an idealized and exaggerated view, science and politics are different worlds. Hence the talk of "communities," "ethnosociologies," and "linguistic communities," whose respective logics of action and rationalities (Petermann 1988, p. 418) are not always compatible with one another. From the wealth of field reports and the empirical and empirically enriched research on policy advice, we can gain a picture of the relationship conflicts between science and politics.

Their collaboration often resembles a complicated love affair full of disappointed expectations. It is therefore not surprising that an experienced observer of the consulting scene has come to the conclusion that scientists and politicians often "prefer to operate in an atmosphere of polite and mutual contempt," and do so with a "distance that roughly corresponds to the social distance between competing tribes" (Horowitz 1976, p. 48; see also von Thienen 1990). Much of what we believe we can diagnose as implementation blockages is probably due to these personal and system-related communication problems.

A second misinterpretation of scientific policy advice is based on the assumption that scientific rationality is superior to political rationality.

Even the – transitive – concept of consulting implies (unlike the reflexive form of “consulting with”) the premise of a specific asymmetry in the relationship (von Thienen 1990, p. 173ff.), so that the distribution of roles between politics and science is quite clearly pre-structured. The “shaper of society,” writes G. Weisser, referring to politicians, “desires interpretative help in fundamental decisions and instruction on the basic types of shaping social life that are historically available for selection” (1961, p. 96). In such a perspective of an “asymmetrical advisory relationship,” the advisor is

> [...] a confident of the decision maker, helping to bring order and perspective to the other voices and helping him/her to weight the different alternatives and their likely consequences (Zetterberg 1962, p. 187).

Accordingly, sources of this kind contain images of the function of science as a “signpost” or “lighthouse.” However, the metaphor of the orienting map and the paths marked therein for the consulting product is also not uncommon.

In this perspective, scientific information is often characterized, if not “already by the property of being true,” then at least by being “the product of an institution that has privileged ways of establishing the truth” (von Thienen 1990, p. 174). Furthermore, this idea has the consequence that the (probably widespread) selective use by the recipients of advice is classified as an “exploitation” of the “legitimation potential” of science “under false pretenses” (Schneider 1989, p. 318).

This illuminates an interesting aspect of the apparently entrenched myth of the science-practice relationship: Science provides objective facts and rational problem-solving knowledge – or even “truth” (Wildavsky 1979). If anything other than direct and unadulterated use is made of it, this is the result of tactical power and other calculations, the triumph of the instrumental rationality of politics over the substantial rationality of science. However, the assumptions underlying this relationship of superiority and inferiority are not necessarily convincing. After all, is scientific knowledge really so superior to common knowledge (ordinary knowledge)? Is scientific knowledge unambiguous or at least consensual? Rather no, if we bear in mind the trench warfare between disciplines when it comes to complex problems (“wicked problems”). Is scientific knowledge capable of increasingly resolving ignorance? Here too: Rather no. Rather, it is likely to be the case that as knowledge increases, ignorance also increases, or the “impossibility to know” (Beck 1997, p. 60) becomes clear. And finally, all expert and reviewer duels embedded in technology controversies show not only cognitive (data dissent) but also evaluative dissent, especially on the question of "what should be" and the desired purposes.

In view of recognizable cognitive and normative deficits in scientific knowledge in the face of complicated problems, the conclusion of a different kind of rationality of science (including its indispensable specific problem-solving potential) would at best be correct – but the assumption of its greater dignity would be wrong. However, this is often taken as a basis in the discourse on the consequences and impact of consulting – disappointment and incomprehension in the face of non-use or only partial use are therefore common, but by no means justified, assessments.

The expectation of direct, short-term, and complete adoption of scientific information by politicians is closely linked to the assumption of greater rationality.

This "model" of the impact of advice, which is often taken as a basis by critics, should be discussed in terms of whether the norm of "successful" policy advice it expresses is justified. Based on the available experience, such an idea (both empirically and normatively) appears to be a misguided measure of use and even more so of benefit. This is supported by the findings of several decades of "utilization research" (Beck/Bonß 1984; Wingens 1988). According to the sum of the insights gained, the relationship between information and politics is "complex," "chaotic," and "non-linear" (Bimber 1996, p. 4).

The impact of advisory expertise is complex and extremely difficult to understand. We should therefore start by moving away from the idea that knowledge is "applied" as it is delivered. A different and better understanding emerges if a concept of the "use" of scientific knowledge in a specific practical context is taken as a basis instead. This opens up a view of the fact that the actual transfer of consultancy results into practice is carried out by *their* actors.

> Use is therefore not "application," but an active co-production and re-production of the results, which thereby lose the character of "results" and are created in the context of action, language, expectations, and interests of the respective practical context according to immanent rules regarding their practical relevance (Beck 1991, p. 175).

The idea that scientific knowledge is used by the addressees in the sense of "identical reproduction" (Luhmann) is therefore unrealistic. Rather, the knowledge acquired goes through stages of selection and transformation. In the course of processing and editing by politicians, it is taken apart, so to speak, reassembled, and combined with other knowledge. Experience shows that such "deconstruction and reconstruction" of provided expertise (Jasanoff 1987) is by no means counterproductive or illegitimate from the outset.

Delivered knowledge can also become "invisible" in various ways. The basic messages, the data material, the strategic options are reformulated, incorporated into other linguistic contexts and thus experience a kind of rebirth in programs, regulations, laws, or in the rhetorical arsenal of practice (Weiss 1992, p. 15), or also in their world views and patterns of interpretation (Murswieck 1994, p. 105). This recurrence of the results of consultation can occur not only with a time lag but also in other local and social contexts (Beck 1991, p. 175). For example, policy advice can have an impact through its reception in public opinion and the media, and it can also happen that actors other than those directly advised make use of the results. All these consequences are also effects.

Finally, a trivial and actually self-evident fact should be remembered: Every advisory process takes place in a network of other advisory processes and in "competition" with them.

In 1984, for example, the Federal Republic of Germany counted 528 committees made up of 7,000 people for the federal government. These included such interesting bodies as the Poplar Commission[1] and the Cosmetics Commission. For the year 1992, an attempt was made to at least estimate the scope of the government's advisory system, and this more poorly than well. If we add up the departmental advisory bodies and the government's own research institutions, we arrive at 348 bodies and institutions, which together cost DM[2] 3.84 billion. If we also include federal and state institutions ("Blue List"), we arrive at a total of 430 bodies and institutions and approx. DM[2] 4.16 billion in costs. To this must be added the costs of so-called ad hoc consultation amounting to DM[2] 65 million (Murswiek 1994, p. 108ff.).

From the above, a trivial – but often neglected – circumstance with consequences for policy-advising TA becomes clear: It is surrounded by "competition" at the level of scientific policy advice (not to mention the influence of the interest-driven recommendations of associations and lobbyists). TA as policy advice is therefore not a singular, context-free process. The political apparatus does not stand still while busy TA experts are at work, nor does the opulent network of other policy advice processes rest. When making snap diagnoses about TA without consequences, it is therefore worth remembering from time to time that it is only *one* voice in a large and diverse choir.

1 *Editors' note*: The International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment is one of the oldest, firmly established organizations of the FAO (Organization for Food and Agriculture) of the United Nations.

2 Deutsche Mark, Former German currency

The results of science are hardly suitable for changing practical knowledge, everyday knowledge, in a short space of time. However, what can take place – in a process of "consulting with one another" – is what is referred to in the literature as "policy learning" (Sabatier 1988): A gradual and successive influencing of basic assumptions, perceptions, and habits of thought of decision-makers and, as a result, possibly a modification of state policy content and policy styles (Sabatier 1987, 1988).

2. Technology development as an evolutionary process

TA as policy advice has a practical purpose. So-called "control knowledge" is provided for a "control subject" with regard to a "control object." This object (and the subject of TA) is the development and use of technologies or their innovation and diffusion in a social context. Whether "control knowledge" related to this can become effective has a lot to do with whether and to what extent the "control object" is accessible to an intended influence at all. Let us therefore ask what the object of control in question is all about.

From the diverse observations of technical change by the scientific augurs of the various disciplines and their various factions, one can initially gain the impression that formerly clear terms and models are no longer adequate. Known and familiar distinctions between individual technologies are disappearing, product and process innovations can no longer be precisely separated, nor can development phases such as research, development, demonstration, prototype, etc. In particular, linear development models ("from basic research to diffusion") or other simple concepts such as the "trickling-down model" are increasingly being discarded. Instead, the search is on for concepts, theories, and models that reflect the multiple determinism of innovations well, prove themselves in empirical studies, and possibly provide starting points for active and targeted design through evidence of causalities or determinants. Relevant influencing factors of technology genesis or determined variables of innovation and diffusion processes are therefore abundantly traded. However, they cannot be determined from their colorful and confusingly diverse empiricism with sufficient precision, and beyond individual cases, to be transferable to other constellations and suitable for description, analysis, and explanation on the one hand, and targeted design and control on the other.

It is therefore not surprising that the sciences are not making much progress toward a theory of technology or (technical) innovation – "in search of a useful theory of innovation" (Bollmann 1990, p. 168) – or that they offer a picture of competing explicative paradigms (Sundbo 1995). Provisional and highly generalized insights into clusters of innovations (Ausubel 1991, p. 15) or trajectories (Dosi 1982), into "waves" or "cycles" of innovation processes (Sterman 1987) do succeed. For example, it has been established "that innovations are not even distributed over time, but are clustered around certain dates." At the same time, however, it must be conceded that "nothing definitive can be said regarding causality between these innovation peaks and economic or socio-political activity" (Shaw 1987, p. 241; see also Dror 1988, p. 69f.).

Contrary to what is suggested by the idea of a linear process, e.g., in a well-structured three-step process of invention, innovation, and diffusion, innovation is better understood as a networked, interactive process. There is feedback between the individual phases, then spillovers between different markets (Erdmann 1993, p. 211), and finally interactions between companies and factors external to the companies, for which the term "selection environment" has been coined (Nelson/Winter 1982, p. 262ff.).

One form of interaction is the exchange of experience between innovator and user (Silverberg 1991, p. 69). There seems to be general agreement that innovation processes are problem-solving- and learning processes and that information and knowledge play a key role here – even if they are scarce, unevenly distributed, and uncertain. Not least for this reason, technical change has rightly been characterized as "inherently inefficient" and accompanied by "duplication and waste" (Nelson 1987). Nevertheless, companies as innovators search, decide, and act, and do so in competition with each other – which not only knows success, heroic inventors, and winners but also "deaths," "lunatics," and "losers" (Ausubel 1991, p. 17). At a higher level of abstraction, innovation competition can therefore be understood as "a self-organizing system of non-linearly networked actors," "in which the relevant developments are a result of unintended (social) repercussions of intentional human actions" (Erdmann 1993, p. 7).

The fact that such "collective evolutionary processes" (Silverberg 1991) are basically overdetermined in their technical, economic, and social implications for an analytical understanding of underlying causalities is illustrated by the fact that the semantic field and the scientific rhetoric of innovation research is extensively characterized by linguistic, pictorial borrowings from other disciplines. We read about mutation and selection, along with variation, fermentation, or even retention (Weyer et al. 1997, p. 27ff.). Now and again, we find terms such as infection, metabolism, and growth or epidemic spread (Erdmann 1993, p. 26; Dreher 1997, p. 38ff.). As in the evolutionary processes of nature – as such and other metaphors suggest – individual lines of technology prevail over others. And it is no coincidence that terms such as "inherently stochastic" or "erratic" (Shaw 1987, p. 241), "non-linear," "haphazard," dynamic, natural, cumulative, etc. are used to characterize innovation and diffusion processes (Rip 1995, p. 418).

From the camp of social science technology research, we hear different messages in terms of terminology. However, their core statements signal a comparable characterization of their object of observation and knowledge:

- Technical systems are embedded in social, political, economic, and cultural structures ("embeddedness"/"connectedness") and their genesis and consequences are shaped by these "contexts" ("socio-economic orientation complexes"). They cannot therefore be viewed in isolation.
- Technologies are the result of human ideas and actions ("socio-technical process") and are therefore "socially constructed" and consciously shaped ("socially shaped"). In this respect, technological change must be understood as a "social process" (OECD 1988, p. 11), not as an endogenous factor.
- Of particular importance for technology genesis processes is the fact that possible development alternatives are blocked relatively early on due to design and construction decisions by developers and engineers (combined with strategic management decisions) and that certain choices and design options are no longer permitted within the selected technology line ("closure"). Once technology lines have been established, they also block attempts at political control that do not take into account the resulting narrowed corridors of action ("stubbornness of technology").
- Similarly, it is argued that when technologies, especially large-scale technological systems, have reached a certain "degree of maturity," design attempts (and alternatives) have little chance of success ("momentum" of technology/"entrenchment"). "Control at this stage, however, becomes increasingly difficult, since any changes are extremely costly due to the amount of technologically financial, institutional and cultural investments already made" (Aichholzer/Schienstock 1994, p. 14).
- Finally, numerous case studies from the history of technology are used to show that a large number of actors and networks of actors with different strategies and interests are involved in technical and social change processes. At company, social, and political level, "strategic games" and negotiations take place between those involved with the aim of asserting their own ideas of technology and use (competitively or cooperatively) (cf., e.g., Weyer et al. 1997).

So what can we say about the subject matter of TA? Research has now provided a wealth of empirical evidence in individual cases and individual conceptually interesting approaches or paradigms, with the help of which the evolution of innovations can be roughly and ex-post (!) deciphered despite theoretical inadequacies and practical deficits (Edquist 1994, p. 48f.). However, all track readers together – regardless of whether they are neoclassical or belong to the school of evolutionary economics – always discover the same characteristics that distinguish the innovation and diffusion process in highly developed economies:

- The processes in question are open future processes, not deterministic but stochastic.
- Although the actors involved (also) act intentionally, the results of these (diverse) actions are the result of unintended social repercussions and consequences.
- The knowledge of both the innovation participants and the "observers" is limited, and planning, assessments, and decisions remain fundamentally uncertain and risky.
- Because information is scarce and knowledge is uncertain, intentional actions and controlling interventions are also fundamentally limited in their possibilities.

Any hopeful prospects for activist and committed policy advice are therefore dimmed considerably if we take note of the wealth of research results. And it darkens further when we turn to another subarea, namely the question of the "control subject."

3. The state as a disenchanted center

In modern industrial societies at the end of this millennium, there is no central controlling authority. Even the state no longer has this role. Modern society has neither a center nor a top. In the literature, this is associated with dwindling opportunities for "active reform policy," the "crisis of regulative policy" or "regulative law" (Grimm 1990), implementation blockades in political programs, and restrictions on social controllability as a whole (Grimm/Hagenah 1994; Mayntz 1996).

In order to understand the limited role of state policy *today*, a little reminiscing about the 1970s and 1980s is helpful. In retrospect, both decades can be seen as a time of secular change, on the one hand in the state's problematic budget, and on the other – as a reaction to this – in the structures and instruments of the state. For the Western industrialized nations (but not only for them), the "brief dream of perpetual prosperity" (Lutz 1989) was abruptly extinguished by the mid-1970s at the latest. Inflation and stagflation problems as well as rising national budget debt brought other genuine problem symptoms into even sharper focus. These included, especially in Europe, the "crisis of the welfare state," new social movements, an increasingly unpredictable electorate, a change in secular values and attitudes, a problematic acceptance of technology, and new policy issues such as the environmental problem in particular. One result and at the same time a component of these problem constellations was a significant decline in the state's problem-solving competence and its ability to control, which had previously hardly been questioned.

Nowadays, the assessments are confusingly ambivalent (Zürn 1996, p. 28ff.). On the one hand – especially in the course of the globalization debate – few things are as readily invoked as the decline of nation-state politics. On the other hand, scope for action of no small importance continues to be identified (Eßer et al. 1996). Detailed case studies in the areas of economic, industrial, research, and technology policy also reveal new possibilities for shaping (national) policy.

But where and how, between the two poles of a depraved actor and new active statehood, is the role of the state to be located today? First of all, there is broad agreement that a *change in the form* of statehood has taken place.

> We are not dealing with a decline, but with a change in the form of the exercise of state power, through which the spectrum of coexisting forms of regulation has broadened (Mayntz 1996, p. 163).

On the one hand, this includes tendencies toward the (complete or partial) delegation of state tasks to intermediary organizations or private individuals. Secondly, so-called "network-like forms of government" are identified as new forms of cooperation between the state and society. Supporters of this appraisal operate with the thesis that network-like forms of cooperation between private and state actors have replaced the classic hierarchical political mode with direct control of society through money and law in many areas.

Although the state remains formally hierarchically organized, in fact,

> [...] the formulation and implementation of state policies proves to be the result of multilateral negotiations between a large number of state and non-state actors rather than the one-sided, hierarchical control intervention of a monolithic state (Scharpf 1992, p. 51).

Such appraisals of relatively new "horizontal policy coordination" in "joint decision systems" or "policy networks" (Marin/Mayntz 1991) of private, intermediary, and state actors hide long-established, but also relatively new forms of statehood such as privatization, delegation, corporatism, subsidiarity, self-administration, etc.

The transformation of the state into a "cooperative," "interactive," or "learning" state (Martinsen/Simonis 1995; Voigt 1995) is due, among other things, to the complexity of its environment and the significant increase in the number of problems the state faces since the 1970s. Because society is complex and contingent and because problem solving has become more difficult, the state is dependent on society and the competence and information available there in order to fulfill its tasks. Cooperation with social actors is the necessary consequence.

In this respect, the changed appearance of the state that has long been noted by political science is an adequate reflection of reality. This process includes changes:

- from a reactive to an anticipatory policy,
- from regulatory control to partnership-based cooperation,
- from centralized instruction to decentralized coordination,
- from standardization to conviction,
- from sovereign means of coercion to multilateral cooperation and negotiated solutions (Jänicke/Weidner 1995; Ritter 1979).

Some typical patterns of cooperation between state and society can be seen in the following cases and demonstrate the diversity of forms of governance between autonomous self-regulation by society on the one hand, and hierarchical state control on the other:

- The state delegates almost entirely the shaping tasks to which it itself is potentially entitled. This can be seen in examples such as collective bargaining autonomy, the chamber system, and self-administration in the healthcare sector.
- The state sets a framework and establishes certain testing mechanisms, but largely keeps a low profile. The result is "social self-regulation" – as in the case of technical standardization by industry associations and institutions (Voelzkow 1996).
- The state establishes advisory and/or decision-making bodies made up of representatives from science, industry, and society (sometimes also from politics and administration). Such "negotiation systems" for the purpose of consultation and the development of regulations (in the form of standards,

limit values, guidelines, etc.) are, for example, the Nuclear Safety Standards Commission, the Reactor Safety Commission, or the Radiation Protection Commission.

- The state delegates tasks to social bodies of "self-administration" and cooperates with the bodies responsible for self-administration (such as the Science Council) in specific committees. In doing so, it reserves the right to finance the activities.

Environmental policy and science, research, and technology policy are sectoral policies in which forms of the cooperative government have already advanced relatively far.

- The role and activities of the self-governing organizations of science, the DFG[3] and the MPG[4], which have to a certain extent made the funding of basic research their "domain with a claim to sole representation" (Braun 1993, p. 259), stand for a model of (self-)control by "intermediary organizations." With regard to research and technology policy in Germany, it can be stated that not only the large, but also many smaller-scale funding programs are negotiated in discussions between representatives of state- and scientific institutions and sometimes with the involvement of industry representatives. The literature contains numerous examples of such "discourses" in which the framework conditions, project topics, potential contractors, etc. for such programs are determined by the state together with social groups and also controlled in the course of the process (Martinsen/Simonis 1995, p. 388ff.). The state acts as a moderator here, which certainly includes the opportunity to implement its ideas. At the European level, comparable cooperation and consultation processes can be observed for EU research funding (Sturm 1995, p. 266).
  A large number of relevant analyses confirm the plausibility of the thesis that the state has developed into an "interactive state" with a now very differentiated technology policy with a focus on "soft" control media (Kubicec/Seeger 1993, p. 13ff.; Martinsen/Simonis 1995, p. 381ff.).
- In environmental policy, including environmental administration, the principle of cooperation is not just a noble maxim. In practice, the environmental policy decision-making system is characterized by agreements between the state administration and industry (in preparation of legislation, representa-

3 *Editors' note*: Deutsche Forschungsgemeinschaft (German Science Foundation).
4 *Editors' note*: Max-Planck Gesellschaft (Max-Planck Society).

tion of legislation, and enforcement of legislation). However, this should not distract from the fact that there was and is sufficient empirical evidence that, in addition to "negotiation" as a mode of intervention, "regulatory command-and-control policy" is still valid as a policy pattern (Jänicke/Weidner 1995, p. 20f.).

The joint handling of problems by the state and society is particularly evident in committees that act in an advisory capacity, but also prepare decisions (Hagenah 1996, p. 141ff.). These are institutions in which representatives from politics and science, and in some cases also from industry, work together. They are concerned with central issues of public safety and health, and certainly also – in connection with this – with questions of economic efficiency. One of the aims is to define binding technical standards, safety requirements, and threshold and limit values. The recommendations or rules drawn up are of an indicative and in some cases binding nature for authorities and industry. In such "societal negotiation systems" (Hampel 1991), areas to be regulated by the legislator, or by politicians in general, are actually shaped together with those directly affected and interested parties (i.e., the state relinquishes direct and hierarchical control options). It draws on the expertise of science and industry, and creates framework conditions and procedures that are not only efficient, but should also comply with democratic and constitutional principles in their internal structure. In environmental policy in particular, the state has increasingly become a state that "cooperates" and "negotiates" with social groups.

All in all, before singing a definitive sang off to the state, we should pause and take a closer look. The state is still present and is by no means just a passive "supervisory state" (Willke 1992), but an active player, not just a moderator, but often a decision-maker. Assessments such as those of a "new architecture of the state" (Grande 1993), the increased use of non-hierarchical forms of regulation and cooperative control (Sturm 1995), and a changed understanding of the role of the state as an authority for the common good and responsibility for the future are probably realistic. To quote Renate Mayntz: "There can be no question of a resigned withdrawal of the state" (Mayntz 1996, p. 163; see also Jänicke/Weidner 1995, p. 21ff.). And this probably also means that it is still far from being obsolete as a TA addressee.

4. Summary and outlook

As early as the 1980s, the Organisation for Economic Co-operation and Development (OECD) pointed out the need for a changed, appropriate understanding of technology and innovation as a "social process," not least based on findings from innovation, diffusion, and technology research.

- It has emphasized the importance of the *social context* for technological developments – both for analysis and for practical design (OECD 1988, p. 117). This insight into the interconnectedness of technology with society and its embedding in society has now led to calls for a systems approach in technology policy (Meyer-Krahmer 1993, p. 41), i.e., for an "integrative, overall restructuring policy." Accordingly, there is a demand for "a broadening of government policy into the socio-institutional sphere" (Roobeek 1990, p. 233). On the one hand, this means keeping an eye on the various levels of the innovation process (companies, sectors, social structures) in their context and, on the other, promoting the "innovation system" as a whole rather than individual technologies and individual companies. This is roughly the realization of the appropriateness of a policy approach that indirectly controls technologies in and through their context (Aichholzer/Schienstock 1994, p. 21) ("decentralized context control").
- The OECD has called for a "*communicative turnaround*" in technology policy – communication with the recipients of funding, the players in the innovation system, and the committed and interested social groups. Accordingly, the so-called soft control media of politics have now increasingly come into focus: Incentives, voluntary commitments, guiding principles, persuasion. If the thesis that decisions are increasingly being made in "policy networks" is correct, the communicative component must be intensified anyway.
- There is an overarching need to *network different sectoral policies* – in the sense of coordinating their "signals," or a comprehensive approach, to a socially oriented technology policy (Badham/Naschold 1994). "No longer should technology policy be separated from other policy fields. Rather should it be seen as an integrated element of social and welfare policy, education and science policy, environmental policy and healthcare, housing and transport, etc" (Roobeek 1990, p. 233; see also Smits et al. 1995, p. 278).

All three aspects are about nothing less than the validity of politics as a specialist for the general. The definition and discussion of goals, needs, strategies, and guiding principles are essential for fulfilling this role. Equally important are the methods of communicating them, because if only the *efficiency* of political work is increased without thinking about its communication, the *evidence* of what politics wants and does suffers.

Context orientation, communication, as well as *participation* and *networking* of politics internally and externally – the TA concept can be directly linked to these maxims and is ideally suited to the analytical, communicative, and political challenges inherent in these aspects. Because:

- TA as policy advice has always attempted to take account of *the contextual nature and multidimensionality* of its subject matter through a comprehensive approach to analysis and evaluation (comprehensiveness): The complexity and social embedding of technical innovations is to be taken into account by analyzing the various sectors relevant to their preconditions and consequences, such as law, politics, economics, ecology, social structures, and culture.
- As an analytical and advisory process, TA is participation-oriented and communicatively open toward stakeholders, but also toward those affected, not least in the development of policy options. This dimension of TA takes account – in its context – of the "communicative turn" in technology policy, which was only claimed much later by the OECD, i.e., the maxim of discussing objectives and measures with the addressees of political programs as well as with the affected and interested citizens.
- The "*policy component*" of TA takes account of the need for *sectoral networking* of specialist policies and the ability to connect with the interests and patterns of action of the actors in the innovation system. According to the claim, this has always been a cross-system approach. The charm of TA in the practical dimension is therefore to address sectoral/departmental options in their mutual relationship and, if appropriate, to bundle them into an overall political strategy. Also in this respect, TA is compatible with a research and technology policy "based on a systems approach" (Meyer-Krahmer 1993, p. 41).

For these reasons, TA can also do justice to the necessarily changed concepts of modern technology policy and the challenges of increased citizen participation in political and administrative decision-making processes. It is therefore not advisable to issue a death certificate too quickly.

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3.
TA as communication and participation – the discursive dimension

Herbert Paschen

Technology assessment as a participatory and argumentative process

1. Concept and purpose of TA; processing TA analyses

The term "technology assessment analyses" has recently been used to describe studies aimed at systematically researching and evaluating the effects of the initial application of new technologies or the increased or modified application of known technologies, with a focus on the unintended secondary and tertiary effects, which often occur after a considerable delay. Technology assessment studies should anticipate and assess the effects of technology application in as many (affected) areas of society and its natural environment as possible.

TA analyses should therefore be systematic and comprehensive and pay particular attention to the side effects of technology applications (without neglecting the intended primary effects). In addition, the "*objectivity*" of TA studies is often claimed or demanded, and they should therefore be conducted by *"neutral" institutes* that *are independent* of certain interest groups and carry out these studies in interdisciplinary teams.

Various analysts have proposed "*methodologies*," "*models*," and "*schemes*" for the approach to TA studies. These schemes usually contain the instruction to

- define and delimit the problem and the assessment task, and describe the technology to be analyzed as well as supporting and alternative technologies,
- develop an information base,
- identify, analyze, and evaluate potential consequences,
- design possible options for action (to reduce or increase the impact of the technologies), and
- draw conclusions and possibly also make recommendations.

These schemes are usually seen as fundamentally *sequential*. The MITRE Corporation[1] has tried to increase the practical benefit of its flowchart for technology

1 *Editors' note*: For further information, see: https://www.mitre.org/ (accessed: 14.04.2025).

assessment studies by drawing up *checklists* for the specific execution of the individual steps.

The declared purpose of such studies is to create a broad and high-quality *information base* for governmental and corporate decisions regarding the development, modification, and application of technologies, and thus the prerequisite for avoiding or reducing the risks associated with the application of technology for humans and their environment. TA is therefore a *decision-making process*. However, the close connection between the TA analysis process and the decision-making process is – rightly – emphasized by most authors: TA can only become effective if it is integrated into the decision-making process.

2. Critical comments on the TA concept

The problem known as "technology assessment" is of course nothing new in principle; there have always been studies on the consequences of the introduction of technical innovations. However, certain consequences have usually been overlooked or deliberately ignored. What is new about technology assessment is above all the demand that the unintended, indirect effects of technology applications, which in the long term can be far more serious than the intended primary effects, should also be taken into account in an appropriate forward-looking manner, and that the analysis should not be limited to effects in the technical and economic areas.

The methods and techniques previously used in TA investigations have also been known for a long time: They are not characteristic elements of TA.

With regard to the claim or demand for "*objectivity*" of TA analyses, it must be said that objectivity in the (scientific) sense cannot exist in such studies. The results of every technology assessment study depend on the assumptions on which the analysis is based, on the delimitation of the study, and on the evaluative decisions made in the course of the technology assessment process. The results are therefore value-laden and subjective. If other assumptions were chosen, if the scope of the examined impact area were defined differently, and if other value judgments were made during the investigation, then the results would be different and equally subjective. This also means that what the research team assesses as "important" or "main" may differ from what critics of the studies assess as such. The frequently heard criticism that the studies are not "comprehensive" can be interest-driven: Only the knock-on effects that strengthen one's own position and those that weaken the position of others are missed.

In this context it should also be noted that – as with other planning and decision-preparatory studies – there is no quasi-logical limit to what must and must not be included in the technology assessment studies, as a result of the problem under investigation. The scope of the study – apart from factors such as the team's work productivity, etc. – is only limited by the client's requirements, the deadline by which the study must be available for decision preparation, and the amount of funding provided.

And a further comment should be made in this context: the *future relevance* of consequences is difficult, if not impossible, to assess given the current state of development of the social sciences. In order to be able to assess an impact that does not (yet?) appear to be relevant by today's standards, the *future value standards* would have to be known. Incidentally, the future value standards must also be known in order to be able to determine the future relevance of impacts that may differ from the current relevance. Without this knowledge of future value standards, technology assessment studies lead to an evaluation of future impacts within the *current* value system and not to an evaluation of future technology impacts within the *future* value system.

As far as the *institutes* that are to carry out the TA analyses are concerned, it will of course generally be desirable for the analysis teams to be formed by institutes that are not dependent on special interest groups. Under certain circumstances, dependent groups will deliberately neglect certain areas of impact and give one-sided priority to certain interests. However, neutrality, expertise, and the ability to organize larger projects seem to contradict one another to a certain extent. Independence and neutrality are probably most likely to be found in university groups. However, we know from American studies, for example, that when awarding TA studies "externally," public authorities give preference to non-university institutions over university institutions, with the probably justified reasoning that the latter do not have the necessary "management know-how" for the development of larger projects, even if their advantages in terms of intellectual capacity and neutrality are recognized.

Perhaps cooperation between university groups and non-university institutions would be a sensible solution. It would also be conceivable to bring together ad-hoc teams of experts from a larger number of institutions of all types for a specific assessment task. In both cases, however, considerable practical difficulties will have to be reckoned with.

The "*schemes*" for the approach to assessment studies proposed by various analysts to date are not particularly helpful for those who are faced with the task of carrying out a concrete technology assessment analysis and developing a strategy for it. The schemes are – inevitably – relatively crude and actually quite trivial. As far as the *checklists* are concerned, they can of course never be exhaustive – as is sometimes required – if they are to contain more than global categories. They can be a useful "starting aid," for example, in identifying areas of impact and options for action; however, it should not be overlooked that the existence of such prefabricated lists can also have a blocking effect on the imagination.

In recent years, fundamental criticism of the use of process schemes (as in the stage model outlined above) for the analysis of complex issues of a socio-technical nature has been repeatedly formulated within systems research, which tends to operate with very similar models. It is often disputed that the analytical process for such issues actually takes place in the described or a similar step-by-step manner. This criticism and its relevance for the implementation of technology assessment studies cannot be justified in detail here. However, it is clear, for example, that the collection of information cannot be a separate step in the technology assessment process, but takes place during the entire course of this process.

As mentioned above, most authors emphasize that the TA analysis process must be integrated into the policy-making process in order to be effective. However, it is generally not recognized clearly enough that a *mutual learning process* must take place on the part of the analyst and the decision-maker, in the course of which the analyst learns about the meaning and purpose of the study and the decision-maker sharpens his or her insight into the existing alternatives.

I would like to draw the following *general conclusion* from what I have said so far:

The analysis of the consequences resulting from the application of a technology does not constitute a scientific decision on whether a technology should be applied. Which impacts of a technology appear acceptable is not a scientific problem. The question of what impacts are *considered acceptable* and what distribution of these impacts across different groups of people is *considered desirable* is a political decision.

3. Consequences of the criticism presented

In any case, the implementation of technology assessment studies requires the conception of pragmatic strategies that are adequate to the respective issues – including the organization of a fruitful and realistic dialogue between experts, politicians and stakeholders, and the sensibly coordinated use of suitable instruments.

In my opinion, the attempt to construct a *standardized, generally applicable* scheme for the course of technology assessment processes is not very promising. It seems to me to be more important and urgent to reach a consensus on certain principles or guidelines that should be observed when planning and conducting technology assessment studies. The discussion of such principles forms the content of the following sections.

(a) Transparency of the TA process

Due to the large number of value judgments that are made in the course of the technology assessment process, this process must be made transparent at every step. All those involved in the technology assessment process must disclose the basis of their judgments to one another as clearly and completely as possible.

The main advantage of technology assessment studies over unanalyzed assumptions and fears – as with other methods that are also often referred to as "objective" (such as PPBS, cost-benefit analysis) – is that they *offer the opportunity* to disclose assumptions and value judgments and that the process leading to the result is verifiable and comprehensible. The assessment remains subjective. However, since an interpersonal understanding is reached, one can speak of an "objectified" procedure – to distinguish it from purely intuitive assessments – and thus does not conceal the fact that assessment studies tend to lead to different results with different basic convictions about the problem at hand, even with scientific means.

(b) Information for the public

The public must be informed of interim results and decisions and the reasons for them *during the course of* (important) technology assessment investigations in a form that also allows non-specialists to make an assessment. A more or less generalized final report on the results of the investigations is not sufficient.

(c) Ensuring maximum active, direct participation

Because "objective" technology assessment is not possible, participation in the assessment process must be ensured for those mainly affected by the consequences of the technology application. Participation opportunities should be demanded in particular for those groups of those affected who are not already able to influence the planning and decision-making process due to their limited economic power or difficulties in forming powerful interest groups.

The lack of genuine participation opportunities for the various interest groups increases the risk of manipulation, and one-sided favoring of certain interests. Without the participation of stakeholders, there is a risk that the analysis of the distribution of positive and negative impacts on the various groups will not be carried out carefully enough, both in terms of the existence, strength, and evaluation of the impacts, and in terms of possible redistributions of advantages and disadvantages (benefits and costs) depending, for example, on modifications to the technology under consideration or its application modalities, and that the results of such analyses, including any divergent views, will not be sufficiently publicized. A form of technology application that is favorable from the point of view of the analyst team and the client with regard to the overall ratio of costs and benefits and their distribution (among those affected) can thus appear to be the only sensible one, and in connection with the claimed "objectivity" or "neutrality" of technology assessment studies, the impression can easily arise that there are no other alternatives with different distributional effects and that those predominantly affected by the disadvantages must bear the burdens from the application of this – overall advantageous – technology "fatefully," as it were. This conceals the fact that the problem of which distribution of costs and benefits *will* result from the application of the technology is primarily solved by the political decision as to which distribution *should* result. A scientific study is no substitute for this political decision.

However, the practical implementation of the direct participation of stakeholders in the technology assessment process is associated with considerable organizational, information, and communication difficulties. Although a whole series of procedures for the direct participation of interest groups in planning processes have already been developed and tested, some of them with television and computer support, it must be expected that a high degree of active participation by those affected could delay important and urgent decisions regarding the application of technologies to a considerable extent. In addition, the costs of technology assessment studies are likely to increase considerably if one is not content with conventional opinion polls or hearings that are often scheduled far too late.

However, this – short-term – cost increase could be small in relation to the costs incurred in the longer term, for example, because a group which is not involved in the assessment, or especially the evaluation process, delays, restricts, or even prevents the use of the technology. Despite these difficulties, for the reasons discussed above it seems imperative to me that the issue of the direct participation of the main stakeholders in the technology assessment process is seriously addressed and that practicable procedures are sought that allow maximum active participation. The situation-specific knowledge regarding the concrete problems that arise in the context of technology assessment studies is not the monopoly of "experts," but is distributed across all those involved and affected. Citizens' resistance to "planning" by "experts" is rightly becoming ever stronger. Cases are no longer rare in which groups of affected people counter the reports of expert teams with their own analyses based on their specific interests and force their participation in planning processes through the public discussion of these counter-analyses.

As mentioned, there are already a number of approaches for the practical realization of direct participation. The Heidelberger Studiengruppe für Systemforschung (Heidelberg Study Group for Systems Research) has experimented with a planning and decision-making model whose core element is an "organized conflict" between the representatives of affected groups, which is broadcast via radio or television. Interested citizens can comment directly by telephone on controversial issues that arise in the course of the "organized conflict." The information received is immediately evaluated and the results are taken into account by the participants in the "organized conflict" in their arguments. Further elements of the system are: a database that provides the participants in the "organized conflict" with information on request to support their theses or to refute the theses of their "opponents," but from which interventions are also made in the event of false allegations; and a pre-selected representative panel from the population of the broadcasting area, whose members are obliged to participate by telephone and whose main function is to monitor the picture of the wishes and opinions of the population conveyed by the group of voluntary callers.

The reference to "forcing participation" on the part of certain groups of stakeholders refers to a certain basic form of technology assessment, the so-called "*advocacy approach*" ("advocate model" of TA). Here, different groups prepare assessments that reflect only *their own* interests. This approach makes opposing viewpoints on the analyzed technology clear, although the contradictory assessments are not directly comparable. The individual studies propose different measures, which of course cannot be coordinated with each other. By publishing the results and discussing them publicly, it may be possible to force the arguments of certain groups to be taken into account.

(d) Technology assessment as an argumentative process

The issues to be addressed in TA analyses are not purely technical or mathematical problems. Rather, they are complex problems with technical as well as economic, social, political, and ecological aspects. As a rule, these are problems for which no "wrong" or "right" solutions can be found, but only more or less "good" or "bad" ones, and the judgment on the solution to the problem depends on *who* has made it. At the beginning of the analysis, the TA analyst will usually only have a very preliminary understanding of the problem under investigation, about which he hopes to learn more and more as the project progresses.

The nature of the problems to be addressed leads to the insight that technology assessment analyses are to be understood as argumentative processes, i.e., as processes characterized by the fact that:

- new questions constantly arise in the course of their development and can constantly open up further (technological) alternatives and options for action, the consequences of which vary for different groups of those affected;
- every fact, every goal, every alternative, every option for action has its advantages and disadvantages, which are different from different points of view;
- different, more or less plausible arguments for and against different positions on the same issue exist and are put forward and discussed;
- etc.

"Argumentative" is understood here as being in contrast to the models derived from decision theory, which understand decision-making as the optimization of a measure of effectiveness and presuppose clear objectives on the part of the decision-makers, fully developed alternative courses of action, and the existence of that measure of effectiveness. These conditions cannot usually be met in planning processes in the political-social area, at least in the initial phases. The main difficulty for planning in this area is the problem-related formation of opinion, whereby the efforts to understand the problem, the search for possible solutions, and the search for objectives constantly alternate and overlap.

(e) Development of adequate procedures

Procedures must be developed and applied in specific cases that are suitable for organizing the technology assessment process as a transparent, participatory, and argumentative process.

As far as the individual tools used in technology assessment studies are concerned, the well-known methods of operations research, simulation, forecasting, decision theory, etc. can be of considerable benefit if they are used taking into account their characteristics and limitations. They must be specifically incorporated into the technology assessment process.

All methods and models used should be "open" in the sense that non-tangible, non-conventional, and situation-specific variables can be included.

There is some evidence that, in the current euphoria at the prospect of finally being able to obtain an effective instrument for a comprehensive technology policy that is also geared toward societal and ecological goals, some of the problems and difficulties associated with the planning and implementation of TA studies are being ignored or underestimated. Technology assessment, which in many respects is still in its infancy, thus runs the risk of being overrated in a similar way to other procedures and instruments of planning and decision preparation that have been propagated in recent years – only to be condemned all the more thoroughly afterwards. My comments should help to clarify some of the problems that I consider important in connection with TA studies, and possibly clear up some misunderstandings about the role and possibilities of TA.

Leonhard Hennen

Technology controversies: Technology assessment as a public discourse

1. Participation, discourse, and technology assessment

In the context of social debates about technology, methods of understanding and consensus-building have recently been increasingly used as a way of rationally resolving conflicts and controversies about modern technologies. Parallel, so to speak, to the approaches of recent technological sociology, which understands the genesis of technical systems and artefacts as the result of complex, non-formalized social negotiation processes and conflicts (e.g., Rip 1986; Bijker et al. 1987), formalized procedures of understanding or negotiating large-scale technological projects are thus being tested from a more practical political perspective. Such attempts are made, for example, in the form of the participation of those affected in the context of administrative planning, or in the use of the mediation procedure developed in the U.S. to resolve technical conflicts (Zilleßen et al. 1993; Hoffmann-Riem/Schmidt-Aßmann 1990; Carpenter/Kennedy 1988).

In the context of technology assessment (TA) projects, which focus less on current project-related conflicts on the ground (such as municipal planning projects) and more on general social controversies about the meaning, purpose, opportunities and risks of new technologies, the term "discourse" is being used more and more frequently, at least in the German debate. Reference can be made here, for example, to the TA project of the Social Science Research Center Berlin (WZB) on herbicide-resistant crops (van den Daele 1993b; Bora/Döbert 1993), the project "Biological Safety in the Use of Genetic Engineering" of the Office of Technology Assessment at the German Bundestag (Gloede et al. 1993), or the TA Academy of the state of Baden-Württemberg, which has set up its own "Discourse and the Public" department. The concept of "constructive TA" developed in the Netherlands, which endeavors to shape processes for the development and implementation of new technologies in a participatory manner, does not refer to the concept of discourse, but pursues comparable intentions with discursive concepts (Rip/van den Belt 1986). Such concepts are associated with the idea that an assessment of the consequences of technology or an evaluation of new technologies is hardly possible without taking into account a wide variety of social, more or less organized, demands and problem views. In this respect, the boom that the term "discourse" is currently experiencing in TA projects is an update to the element of participation, which has accompanied the concept of TA from the very beginning as an essential, albeit rarely realized, postulate (cf. Hennen 1993).

The idea of TA arose in the context of the growing crisis of state control over the supposedly uninfluenceable dynamics of innovation, with increasing technologization on the one hand, and on the other, the crisis of state legitimacy in view of the thematization of the negative consequences of "technological progress" by new social movements. This resulted in a twofold task for TA: Providing scientific policy advice with the aim of resolving the political control crisis (decision-related), and integrating the diverging evaluative and normative demands on technology policy in order to overcome the legitimacy crisis (public-related). This dual task has always played a prominent role in conceptual debates on TA. In a review of TA congresses in the 1970s and 1980s, Smits (1990) notes that the discussion at the first major international TA congress in The Hague in 1973 was characterized by two camps into which the "TA community" was divided: The representatives of a "reductionist approach," who saw TA as a scientific procedure for improving political decisions that should be kept free of politically judgmental arguments, and the representatives of a "holistic approach," who saw TA more as a participatory procedure of continuous communication between those affected about values, norms, and interests that enter into the evaluation of a technology. Participatory concepts of technology assessment are thus directed against a more "instrumental" understanding of TA as scientific policy advice (cf. Bechmann 1990, p. 144ff.). This opposition is characteristic of the development of scientific policy advice and policy analysis as a whole. An overview of the history of policy analysis in the U.S. shows the development from a rather positivist self-image to a self-image of policy analysis that takes greater account of the political-social context of science. The tension between technocratic tendencies and participatory potential, which is typical of policy analysis, always became particularly clear when policy analysis was concerned with the social and ecological implications of technical innovations (Torgersen 1986, p. 43).

The instrumental understanding of TA, which essentially sees TA as a communication process between scientists and decision-makers, revealed its weaknesses with the dwindling of a socially shared value basis for assessing scientific and technological development, and with the growing realization of the fundamental uncertainty of predictions about the consequences of technology. The necessity of linking up with public technology controversies thus became clear as an indispensable prerequisite for TA. On the one hand, TA requires the input of the knowledge of those affected in order to promote a "well-informed" political decision that takes all aspects of a problem into account. On the other hand, the interests and values of those "affected" must be taken into account if the political decision to be made is to have any hope of being "accepted" by society.

By taking up the term "discourse," the insight into the necessity of a participatory approach in the context of TA is updated. However, the recourse to the concept of discourse also more or less clearly formulates a claim that was previously made rather implicitly in connection with participatory procedures of technology assessment: The social debate about technology should be "rationalized," and controversies about technology should be "objectified," or stripped of their vested interests. Ideally, "discursive" TA is expected to achieve consensus on previously controversial issues by obliging those involved to engage in "argumentative," "objective" debate. In connection with such expectations of the performance of discourses, the question arises as to the rationality that is brought to bear in discourses, as well as the question of the rationalization potential that discourses can mobilize, i.e., their possible contribution to the preparation of better – in the sense of more socially reasonable – decisions. In the following, an attempt is made to substantiate the thesis that discursive procedures of technology assessment are to be understood as a reaction to public technology controversies and that their efficiency and rationality are based on this.[1] Just as technology controversies are to be understood as "informal technology assessment" (Rip 1986), TA is conversely to be understood as the formalization of public technology controversies.

Insofar as technology controversies are to be understood as public discourses on phenomena of a crisis of industrial modernity, TA processes – as an attempt to organize these discourses – cannot do without a mobilization of the rationality of the processes of understanding which are set in motion in public discourses on pending problems, reasonable solutions, and legitimate decisions. To develop this thesis, I first outline the central social development processes that form the background for current technology controversies (2). This is followed by a discussion of the concept of discourse, in which discursive rationality is identified

1 These considerations are based in part on a discussion on the subject of "TA and discourse" which took place in September 1992 at the Office of Technology Assessment at the German Bundestag, in which Gotthard Bechmann, Fritz Gloede, Leonhard Hennen, Christoph Lau, Joachim J. Schmitt, and Rene von Schomberg took part. I would like to thank Thomas Petermann for his critical review of the manuscript.

as an adequate response to the crisis of scientific-technical rationalization that emerges in technology controversies (3) and discursive procedures of technology assessment as procedures of formalizing public technology discourses (4). Finally, two central problems that TA discourses face are discussed, namely the question of the relation of TA procedures to scientific discourses and political decisions (5, 6). Finally, the question of the problem-solving capacity of discursive TA procedures is discussed (7).

This outline is intended as a contribution to the discussion of the concept and program of technology assessment. But, I would also like to attempt to link the more practically oriented TA discussion to more recent sociological theorizing and to situate the socio-political phenomenon of "TA" in terms of social theory.

2. Everyday life, science, politics: On the crisis of scientific-technological rationalization

The increase in performance and the multiplication of options for action that characterizes scientific and technological rationalization and is the basis for its success brings with it an increase in the consequences associated with actions. The shaping of the future is increasingly dependent on decisions that have to be made in the present without being able to fully foresee their consequences. Such diverse sociological diagnoses of the present as those by Beck (1986, 1993) and Luhmann (1986, 1992) can be reduced to this common denominator. The fundamental uncertainty or "ambivalence" (Bauman 1992) under which individual and social action is subject as a result of scientific and technological rationalization can be identified in problems of *everyday life,* the *scientific system*, and problems of *political decision-making*, which overall lead to a loss of confidence in the "technical feasibility of society" (Bonß 1993, p. 21). TA can be understood as a reaction to this crisis in the process of scientific and technological rationalization. It is part of society's attempts to overcome this crisis. What this consists of in detail is outlined below, with cursory reference to more recent approaches to social theory, in which technology controversies and the concept of risk play a central role.[2] The aim is not to provide a systematic theoretical development of the causes of the crisis of scientific and technological rationality, but merely to

2 Cf. Bechmann (1993) on the socio-theoretical career of the concept of risk.

point out key aspects of the new problem by taking up the central motifs of various recent social theory approaches.

From the perspective of the *everyday world*, processes of technical and scientific rationalization initially appear as an enormous expansion of the possibilities for action, and also the certainty of action, for the individual. The expansion of the scope for action consists in the detachment of individuals from traditional social ties and the dissolution of traditional world views. In addition, processes of scientific and technological rationalization are constantly creating new options for action in the form of success-guaranteed, i.e., safe and efficient technical artefacts and infrastructure systems. The process of mechanization thus introduces new socio-technical guarantors for ensuring certainty of action into modern everyday life – as a substitute, so to speak, for the traditional ties and patterns of interpretation that guarantee certainty of action (cf. Hennen 1992). However, the mechanization experienced by individuals as a relief for their actions comes at the price of an increasing dependence of the individual action situation on social conditions, i.e., conditions that cannot be controlled by the individual. This can be characterized as the typically modern, technically mediated form of "anonymous socialization" (cf. Hennen 1992, p. 212ff.). Anthony Giddens (1990, p. 22ff.) has characterized the effect of this form of socialization with the term "disembedding" as a temporal and spatial dissolution of the boundaries of action situations. In addition to the monetization of social relationships, i.e., the process of economic rationalization, Giddens describes "*expert systems*" as an essential "disembedding mechanism." "Expert systems" can be understood as technical-scientific artifacts and infrastructure systems, as well as the expert knowledge required for their operation or the socially trained role of the expert. The "disembedding mechanism" consists of individual or local action situations becoming increasingly dependent on and structured by spatially and temporally distant processes through the connection to "expert systems." To the extent that more and more conditions of action are socially produced and secured, the production of certainty of action is no longer within the competence of the individual – it must be guaranteed by society (including by science/technology) and therefore becomes a political issue. With increasing dependence on expert systems (or, in a broader sense, technology produced by expert knowledge) in everyday practice, *trust* in expert systems becomes a central resource for social integration.[3]

3 Cf. also Zygmunt Bauman (1992, p. 239ff.), who sees the function of the psychological expert or therapist in the creation of "identity" through the mediation of "objective knowledge" – i.e., social demands – with subjective preferences, whereby trust – here in the person of the expert – becomes the central factor in the success of this mediation.

However, the trust in anonymous "expert systems" that is necessary in the modern age to guarantee certainty of action is necessarily precarious. It must be maintained in the face of ultimate ignorance of how the systems work and without the mediation of (known) persons.[4] The existence of this trust is ultimately dependent on the (usually confirmed) everyday experience that "expert systems" provide action-stabilizing services for the lifeworld (Hennen 1992, p. 190ff.). However, when the scientific-technical system is faced with problems that it raises itself, but which it has no means of dealing with – and this is the case with the issues of safety and social compatibility that are the subject of modern technology controversies – the basis for trust necessarily dissolves. Laypeople are forced to extend their action-oriented "relevance system" (cf. Schütz 1972) – the framework of what is considered significant for their own actions – beyond the "world within reach" – their private everyday life – because "relevance" is imposed on them by the intended and unintended effects of the "expert systems." In this way, however, they cancel the delegation of the guarantee of certainty of action to "expert systems." The "expert systems" necessarily become the object of everyday pragmatic reflection, whereby the social relationship central to (technical) modernity – the complementary roles of expert and layperson – becomes problematic. The achievements of the scientific-technical system can no longer be taken for granted, without reflection, as a secure background for everyday actions (cf. Hennen 1992, p. 198ff.).

The new uncertainties of everyday life are the result of problems produced in the *scientific-technical system*. In terms of systems theory, the scientific system appears to be an extremely efficient system for increasing options for action by reducing environmental complexity through the coding of all questions along the lines of the "true/false" dichotomy. At the same time, however, it is blind to, or unable to "resonate" with, the consequences of its operations in the environment that cannot be processed along the lines of the internal code (Luhmann 1986). Since science and technology operate self-referentially, nothing can be determined a priori about the environmental adequacy of the constantly produced new options for action. It is only ever possible to recognize in retrospect what the environment tolerates. Thus, although science permanently expands the space of available options, "science [...] does not increase certainty, but rather uncertainty" (Luhmann 1990, p. 371). Science is then increasingly concerned with analyzing

4 Cf. also Luhmann's concept of system trust and the thesis of a lack of "internal guarantors" (the individual's own competence), which characterizes securities guaranteed by systems (Evers/Nowotny 1987).

the consequences, risks, and dangers of its own products. However, the more that science attempts to "clarify" risks, the more it emphasizes the provisional nature of scientific knowledge and becomes "self-reflexive" (Beck 1986, p. 254ff.). Scientific doubt is thus applied to science itself, and advances in science reveal the limitations of past truths. In this way, science loses part of its function of securing action in everyday life (see above), as well as its legitimizing and pragmatic function for political action (see below).

With the increasing penetration of science into social processes, the freedom that science has fought for in relation to other social subsystems is also becoming problematic. Large-scale technical systems become an experiment with society because large technical systems or so-called "risk technologies" cannot be tested in all their complexity under laboratory conditions. The implementation of the technology is at the same time a test of its functionality. This means that a "risk transformation" takes place: The risk of research hypotheses being untrue is transferred to society. However, this makes the research privilege – the independence from external control that science has fought for vis-à-vis the political system, problematic (Krohn/Weyer 1990). When research (including and especially basic research, cf., e.g., genetic engineering) is "directly" involved in social development, when "research hypotheses of science become future hypotheses of society" (ibid., p. 118), then the relationship between science and society is open to discussion, because then the social rationality of scientific knowledge also becomes questionable. Advances in knowledge in modern science are essentially based on experimental arrangements of knowledge production, in which science creates its own objects. However, through "decontextualization" – the isolation of research objects from their natural environment – modern science systematically ignores the reality components that arise from the interaction of the laboratory objects with environmental components. Science, its findings, as well as its (technical) products, must be "recontextualized," i.e., they must be evaluated with regard to the possible consequences of their reintroduction into complex environments (cf. Bonß et al. 1992). To this end, they may not only have to be confronted with other scientific disciplines – in the sense of an interdisciplinary "recontextualization" (cf. Hohlfeld 1993). The social rationality of scientific and technological achievements, their compatibility with lifeworld concepts of appropriateness, tolerability, and reasonableness are also up for discussion.

This means that "epistemic discourses" (cf. von Schomberg 1992), in which the sciences ascertain their own possibilities of knowledge and agree on "appropriate" theoretical paradigms and heuristics, become directly relevant to society beyond the boundaries of science. An epistemic discourse could be, for example, the question which is discussed in the debate on the risks of genetic engineering as to whether genetic manipulation can lead to the unintended development of pathogenic organisms from components that are considered harmless, and which could have dangerous long-term consequences for the environment or humans. Depending on the theoretical concept of the way in which individual genes interact with each other (in the context of the entire genome), the probability of such a risk must be assessed differently. However, the hypothetically plausible risk of the unintended emergence of pathogenic organisms can neither be ultimately proven nor ruled out. Ultimately, such scientific ambiguities can only be clarified scientifically. However, they have implications beyond science, because it is now up to politicians to decide which genetic engineering experiment or procedure can be approved as "safe enough."

The dynamics of the scientific-technical system, its tendency toward an unchecked increase in options, as well as the practical everyday uncertainties triggered by this, are also putting the *political system* under pressure. The new uncertainties of everyday life and the dwindling trust in "expert systems," which previously served as a functional equivalent for traditionally guaranteed certainties, reach the state in the form of new demands on the task of providing services of general interest, and in the form of difficulties in generating consensual decisions. With the assumption of the task of promoting science and technology, the state also becomes the addressee for the grievance of unintended consequences of scientific and technological development. However, the political system lacks, on the one hand, opportunities for control and, on the other, social consensus as a basis for legitimizing technology policy decisions.

The problems of the scientific system affect the state in its possibilities of social control, because the "reflexive scientification" also becomes a political problem with the increasing scientification of politics. The problematic relationship between science and politics becomes most apparent in the case of epistemic discourses, in which the sciences become involved when assessing risk and security issues (see above). Science does not reduce complexity and thus increase decision-making capacity, but rather increases complexity and imposes decisions on politics despite unresolved scientific controversies (von Schomberg 1992, p. 272). The "functional authority of science" is shaken. What science is supposed to do for politics – the guarantee of certainty of action under strong pressure to act by recourse to an established authority that guarantees the right decision (ibid., p. 260) – science does not do in this case. The increasing differentiation of the scientific system thus makes scientific discourse – or at least epistemic discourse – problematic for the political system. The potential consequences and complexity overtax the rationality of political action, so to speak. Rational decision-making and action requires control of the relevant parameters that determine the situation in which action is taken. However, this is insufficiently guaranteed. At the same time, the option of "non-action" is also excluded or risky (Luhmann 1991). The effects of the scientific-technical system require political action without providing the cognitive resources that would enable rational action.

On the other hand, the state cannot rely on a social background consensus regarding technology policy decisions. The individualization of life situations and styles as a result of the dissolution of traditional milieus (Beck 1986) creates changing and contradictory demands on state action. The dynamics of increasing scientific-technical options with a simultaneous loss of system trust in the rationality of the scientific-technical system overstrains the integrative power of the everyday lifeworld. The thematization of these lifeworld problems by new social movements (cf., e.g., Japp 1993) can be seen as a process of the dissolution of the ideology of progress, which previously served as the basis for the legitimation of technology policy decisions in the "old modern age."

With the dissolution of this last substitute for the foundations of meaning of religious world views that have been disenchanted in the course of modern rationalization (cf. Joas 1992, p. 358ff.), society now enters the phase of its "self-production" (Touraine 1984) – since in "reflexive modernity" (Beck) no "meta-social" guarantors of security are available anymore. Ultimately, this means a politicization of areas of life formerly removed from politics, and a dissolution of the boundaries of politics – not in the sense of state omnipotence, but rather a liberation of individuals, groups, and social movements for social debates that question and re-found political decisions (Beck 1993). This process of politicization of technical-scientific issues can be understood as an expression and motor of a social process of *de-differentiation*, a questioning of partial system-specific rationalities and sole competences. The loss of everyday self-evident facts and certainties turns formerly private questions of security into public questions. The technical-scientific system constantly generates problems that it cannot process itself ("trans-science questions"; Weinberg 1972). Decisions that were previously delegated to the political system as a matter of course become the subject of public discourse. In complete contrast to the assumptions of older concepts in the sociology of technology, which expected political decisions to be replaced by "factual rationality" as society became increasingly scientific (cf., e.g., Ellul 1954; Schelsky 1979 [1961]), the consequence of all this is not the end of the political in "technocracy," and the silencing of political debates by "factual constraints," but a (re-)politicization of technical-scientific discourses (Halfmann 1990).

3. Discourse as a medium of social integration

Social controversies about technology and science can be understood as a response to the cognitive and pragmatic ambiguities and uncertainties outlined above. Public, non-specialized discourses occur where subsystem-specific programs for dealing with problems fail and an unquestioned consensus on legitimate solutions to problems has dissolved. Social debates about technology can therefore be understood as attempts to create a new consensus about what is and what should be in the face of existing ambiguities and a lack of socially shared patterns of interpretation and preferences for action. Technology controversies call into question the validity of statements about hazards and potential consequences as well as the legitimacy of decisions and institutionalized decision-making procedures. Problems are discussed whose solution was previously delegated to specialized subsystems (science, politics), or that are newly raised by the specialized systems of problem solving but cannot be dealt with by them.

Technology controversies are thus part of a process of modern socialization, as addressed by Habermas (1981) in his theory of communicative action. For Habermas, lifeworld communication processes – alongside processes of systemic integration – function as a central dimension of socialization, in the sense of the production of socially shared patterns of interpretation and action. At the same time, he sees an enlightening potential bound up in them, which is released in the course of modern rationalization processes.

In processes of lifeworld interaction, validity claims are made with regard to descriptive, normative, and evaluative propositions (as well as expressions and explications) (Habermas 1981, Vol. 1, p. 66). The

> [...] truth of propositions, the correctness of moral norms of action, and the comprehensibility or well-formedness of symbolic expressions are, in their sense, universal validity claims that can be tested in discourses (ibid., p. 71).

In everyday lifeworld communication, world references come into play that are specialized at the level of social systems: Descriptive, normative, and evaluative validity claims are naively asserted in acts of lifeworld communication, i.e., they are generally not questioned. However, they remain – and this is decisive – "referred to discursive redemption" (Habermas 1992, p. 32). They can be problematized at any time, i.e., become the subject of discourse. The concept of discourse refers to

> [...] the central experience of the unavoidably unifying, consensus-building power of argumentative speech, in which various participants overcome their initially subjective views and, thanks to the commonality of rationally motivated convictions,

> simultaneously assure themselves of the unity of the objective world and the intersubjectivity of their life context (Habermas 1981, Vol. 1, p. 28).

The development of discursive or communicative rationality requires the counterfactual assumption of "domination-free communication," i.e., the assumption of an ideal speech situation in which all subjective and objective constraints that hinder an orientation toward nothing but the force of the better argument are eliminated. However, this is not to be understood as an ideal yet to be realized, but rather as a regulative idea that is always already at work in practical discourses against the resistance of existing power relations and unquestioned everyday self-evident facts.[5]

In this respect, discursivity unfolds in the course of *modernization.* To the extent that traditional, religious certifications of validity claims dissolve, validity claims become contingent and can no longer be justified in any other way than discursively. According to Habermas, this also puts "communicative reason" – the enlightening potential of communication processes – into action. With the release of spheres of value (Max Weber) – or the differentiation of specialized systems – the modern process of demystification and rationalization has not only led to an enormous increase in performance in the field of purposeful rational action, which is probably most blatantly expressed in scientific and technological progress, but has also "rationalized" the living world in the sense that the potential of communicative reason was first freed from the unquestioned self-evidentness of traditionally authenticated world views and power relations. Discourses dissolve such self-evident facts; in discourses, descriptive, normative, and evaluative judgments must be justified; claims to validity are set by the participants as quasi hypothetical in order to justify the claim to truth or correctness in the discourse, i.e., in the communication with others. The prerequisite for discourse is thus the willingness to problematize or virtualize validity claims.

> In this way, facts are transformed into circumstances, which may or may not be the case, and norms into recommendations and warnings, which may be correct or appropriate, but also incorrect or inappropriate (Habermas 1971, p. 25).

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5 This is the decisive contrast, but also the point of contact with Foucault's concept of discourse. For Habermas, the elements of the "order of discourse," with which Foucault (1977) describes discourse as a medium of exclusion, of asserting claims to validity against others, are the forces against which "reason" asserts itself as the telos of linguistic understanding. Ultimately, for Habermas, the hope of understanding between equals – based on linguistic theory – is suspended in discourse. For Foucault, every claim to validity ultimately implies the will to power, i.e., to the elimination of other claims to validity, which makes any hope of understanding illusory (cf. Habermas 1985).

However, the willingness to question outdated assumptions – including one's own – implies the chance of reaching an agreement on what is recognized as true or correct by everyone.

However, the integration of lifeworld action and social integration cannot be achieved through communication processes alone. Life practice is constantly required to make decisions "under conditions of ignorance and dissent," which do not allow any delay in enabling discursive clarification. In this respect, it is dependent on the establishment of routines for solving practical problems. Discourses must therefore not prevent "reproduction processes that are dependent on routine operations" (Giegel 1992, p. 75f.). Claims of understanding must therefore be mediated with claims of action, and social integration remains dependent not only on the resource of "understanding" but also on the integration of the sphere of purposeful rational action, i.e., on the guarantee of certainty of action through the success-guaranteed processing of action problems and the stabilization of behavioral expectations. In modern societies, however, the coordination of actions in the sphere of success-oriented, purposeful rational action is differentiated into efficient subsystems. Science, politics, and the economy are systems that have perfected purposeful rational action and constantly produce options for action and decisions. Ultimately, this means that discourses must relate to the rationality of the subsystems; they remain dependent on them for input and must also communicate their results to the systems.

Giegel (1992) sees the opportunity to mediate between lifeworld and system – understood here in the sense of discourse versus decision – in "intermediary negotiation systems," among others. Here, "insights gained through discourse are to be transported to the level of not agreement-oriented decision-making and strategic action" (ibid., p. 103). Giegel sees the specific opportunity of such negotiation systems in the fact that there is no direct intervention in the operational structures of the subsystems, i.e., their performance is not disrupted. They translate the demands of the lifeworld into the language of the systems and encourage the systems to self-reflect, thus increasing their capacity to perceive problems, so to speak, without impairing their mode of operation.

It makes sense to view technology assessment processes as such "intermediary negotiation systems". Technology assessment processes attempt to mediate public discourse on technology with systemic rationalities. They stand between the system and the living world, namely between public controversies about technology, and the scientific and political system. Discursive processes of TA must therefore clarify their relationship to scientific rationality on the one hand, and to institutionalized processes of political decision-making on the other. Following an outline of organizational problems of formalizing technology controversies in discursive TA processes, these questions are discussed below.

4. TA and discourse: TA as a formalization of public technology controversies

Problems and questions that are typically dealt with in TA processes refer almost automatically to the need for discursive clarification of validity claims. TA should answer analytical questions about the "laws" of scientific and technological development, and clarify cause-and-effect relationships; it should expand knowledge about reality – and even about the future. It should generate data. However, technology should be *evaluated* in TA processes. TA should produce statements on whether and how technology policy decisions or new technologies and technical systems jeopardize social values such as "health," "intact environment," "safety," etc. Claims and interests of different social groups regarding, for example, a fair distribution of opportunities and risks should be ascertained and balanced. However, since a social consensus on values can no longer be assumed in (reflexively) modern societies, the goals of social action are disputed, values such as "security" are not self-explanatory but must be operationalized, and risk perceptions differ depending on the cultural background (Douglas/Wildavsky 1982), TA must deal with normative questions such as "What should we do?" What is a desirable future? What can be considered a positive or negative consequence of technology? What are adequate means for legitimate ends?

TA also takes on a discursive character in that not only questions of normative correctness but also questions of objective truth can ultimately only be satisfactorily clarified through discourse. Particularly under conditions of "reflexive scientification," empirical statements about hazard potentials etc. also prove to be controversial, dependent on measurement methods and the disciplinary scientific paradigms used, and are prone to error (cf., e.g., Freudenburg 1992). The relationship between TA and discourse is therefore obvious: A procedure that aims to generate statements about future developments and evaluate technology on the basis of available objective – in the sense of intersubjectively "recognized" – knowledge and social norms, implies discursive discussion of the empirical and normative foundations of its statements.

Explicitly discursive technology assessment procedures, which emphasize the participatory or public nature of technology assessment, bring the latent discursiveness of TA to bear in concrete terms and make it the organizational basis of the procedure. They strive for an open exchange of all positions relevant to a technology policy issue and the participation of all potentially affected social stakeholders and interest groups.

In this respect, they tie in with public technology controversies, but transfer the “informal technology assessment” (Rip 1986), which gives expression to the “repoliticization of scientific-technical discourses” in the form of manifest conflicts and public controversies, into formalized processes of knowledge generation and consensus building with the participation of those affected. TA discourses aim to create an arena in which every argument can be given its due and in which every claim to validity must be justified or can be questioned. This is linked to the claim of a “rationalization” of informal debates. The aim is to ensure more socially sensible political decisions through better information, more comprehensive knowledge, and consideration of all relevant interests. To the extent that they want to create a free space in which nothing but the power of the better argument counts, and to the extent that they expect this to objectify or rationalize the debate, TA discourses (at least implicitly) refer to Habermas’ concept of discourse. They attempt to transpose the counterfactual assumption of an ideal speech situation into real communication conditions and thus expect the development of rationality, i.e., rely on “communicative reason” – albeit usually without recourse to the social-theoretical implications of Habermas’ concept of discourse.

Processes of discursive organization of TA attempt to minimize the restrictions that hinder the development of discursive rationality. This requires the elimination of “*access restrictions*,” i.e., no one may be excluded from the discourse as a matter of principle. Similarly, certain contributions or statements may not be excluded from the discourse (“*contribution restrictions*”). And thirdly, there must be no restrictions regarding the criticism of statements, i.e., the questioning of validity claims (“*criticism restrictions*”; cf. Schmid 1992, p. 116).

The realization of these conditions obviously encounters a number of practical problems, some of which are related to the external, not domination-free conditions under which a TA discourse takes place. For example, the linguistic competence of potential participants may not be equally distributed. The time and financial resources available to participants to work on a question or to mobilize knowledge and thus formulate or criticize validity claims also vary.

In addition, the boundary conditions necessary for an ideal speech situation collide with the practical requirements of conducting discourses, which result from the fact that TA discourses – precisely in order to be able to develop their rationalization potential as *organized* discourses – must be “situated” objectively, socially, and temporally, and thus “*closed*.”

- Unregulated public controversies are thematically open (*factual dimension*). However, this implies a number of disadvantages in addition to the basic permeability for all conceivable topics. A large number of topics and arguments are introduced without there being any guarantee that arguments have to be related to each other and questions answered, etc. The factual input is often random – technology controversies are not based on a systematic survey of available knowledge.
- Participation (*social dimension*) is unregulated, which means that in principle anyone who feels addressed can participate. However, it remains unclear who is legitimized to speak for whom. Nor does the possibility of participation in principle guarantee that certain groups cannot be de facto excluded because they have no access to "discourse arenas" (e.g., the media), provided that the boundary conditions are not free of domination.
- In principle, public discourses (*temporal dimension*) are never finished; they can be continued at any time. This implies the possibility of constantly citing new reasons for proving or rejecting validity claims. However, this also means that public discourses are indifferent to the necessity of practical decisions. In addition, the temporally unregulated structure implies that discourses can break off without having really dealt with the issues raised, and can be resumed without taking up what has already been discussed.

TA processes attempt to solve these problems of public discourse: The technology discourses are centered thematically. The procurement of knowledge is systematized. Differences in participation opportunities can be compensated for by providing financial or personnel support (counter-experts). However, some of the problems mentioned also remain latent – or are present in discourses as contradictions between the requirements of an ideal speech situation and the practical requirements of the organization. This includes, for example, the problem of representativeness: Who is legitimized to speak for whom if it is practically impossible to admit everyone who wishes to speak? The thematic centering of discourse, which promises rationalization effects, also implies a violation of the principle of minimizing contribution restrictions. This can lead to manifest problems in the implementation of discourses if participants are required to focus on different or contradictory topics. A typical TA problem in this context is, for example, the debate about whether the TA discourse should be "problem-induced" or "technology-induced," i.e., whether the examination of alternatives to a technology in question should be the subject of the discourse or not.[6] The necessary temporal limitation of the discourse also creates new questions that can burden the thematic discourse: When has enough knowledge been generated? When is the discourse broken off?

All of these questions concerning the social, temporal, and factual organization of the discourse can and usually are addressed by the discourse participants. They characterize the fundamental difficulty of reconciling the requirements of an ideal speech situation with the practical requirements of organizing discourse. If they cannot be clarified, they may lead to a refusal to participate or to the discontinuation of the discourse. In the interest of improving the practical implementation of TA discourses, these questions certainly require further discussion. Only two fundamental problems of the formalization of technology controversies will be discussed here, which are related to the factual/thematic and temporal structure of discourses: The role of science in TA discourses (ultimately a problem of contribution limitation), and the relation of TA discourses to political decision-making (a problem of the temporally and factually open structure of discourses).

5. On the relationship between scientific discourses and TA discourses

The question of the significance of scientific rationality in processes of technology policy decision-making has played a central role in the development of social science risk research ("risk assessment" and "risk communication"), particularly in the U.S. This development can be briefly characterized as a gradual abandonment of the belief in the superior rationality of quantitative engineering risk assessment over risk assessment by laypersons and increased consideration of the social context of the construction of risk assessments (cf. Dietz et al. 1993 for an overview). It has been shown that risk assessments – both by experts and laypersons – always include assumptions about the efficiency and trustworthiness of social institutions, which shape both the estimation of the level of risk and the determination of what is considered a risk (Wynne 1982, 1992). Both the rationalities of lay and expert risk assessment are inextricably linked to the unquestioned

6 See, for example, the statement of the Greens on the report of the Enquete Commission "Opportunities and Risks of Gene Technology" of the German Bundestag (Deutscher Bundestag 1987), or the discussion in the TA discourse on "genetically engineered herbicide-resistant crops" of the Social Science Research Center Berlin, which ultimately led to the environmental groups withdrawing from the process (van den Daele 1993b; Gill 1993). See also Sec. 5.

moral and political assumptions and attitudes of the respective actors. The point of this realization is that although this does not make engineering risk assessment superfluous, it is not sufficient for political consensual risk assessment alone. Risk assessment is primarily a political, not a scientific task:

> Since the very term risk is laden with political and moral implications, it should be open to *continued negotiation and redefinition,* as an essential part of *democratic life* (Wynne 1992, p. 283; original emphasis).

However, expert knowledge is not only relativized due to its attachment to values and "social images." Narrower epistemological justifications point to a crisis of scientific knowledge that manifests itself in risk assessment in particular. In the context of modern risk technologies, questions arise that can no longer be dealt with simply by applied science. Risk analysis is necessarily concerned with uncertainties and ambiguities of various kinds, i.e., in the case of risk analysis, scientific knowledge is confronted with situations "where typically, facts are uncertain, values in dispute, stakes high, and decisions urgent (Funtowicz/Ravetz 1992, p. 253f.). Decisions on whether and how to act must be made under conditions of systematically uncertain or unclear knowledge (see also Perrow 1989) and controversial normative (How safe is safe enough?), or ethical (What is socially acceptable?) evaluation criteria. The traditional relationship between "knowledge and politics" (Torgersen 1986) in political consulting is thus called into question.

> Whereas formerly we had the contrast between hard science and soft values, now we must take hard decisions between discrete alternatives, with only soft scientific inputs to them (Funtowicz/Ravetz 1992, p. 258f.).

The consequence of this is an "enrichment" of normal scientific practice toward "post-normal science" in two ways. Firstly, the circle of those involved in controlling the quality of knowledge and preparing decisions is extended beyond the scientific community ("extended peer communities"). Secondly, non-scientifically generated knowledge ("extended facts") – empirical knowledge of laypersons, qualitative dimensions of risk assessment – must also be included in the decision-making process (Funtowicz/Ravetz 1992; similarly Wynne 1992).[7]

Against the background of such debates and what has been said above about the crisis of scientific-technical rationalization, it seems not unproblem-

7 This is certainly hardly a reality in this radical form. However, when it comes to risk assessment issues, the practice of citizen participation by American authorities is certainly more advanced than in Germany. "Public hearings and citizen review panels are standard instruments used by authorities such as the Environmental Protection Agency" (cf. Fiorino 1990).

atic (which is quite obvious from a traditional, scientific self-image of TA) to organize discursive procedures of technology assessment primarily as a scientific discourse, because scientific discourse – since it is oriented toward truth – is assumed to have a higher factual rationality than political discourse. This will be explained here on the basis of some comments on conceptual considerations made in the context of a TA discourse on "genetically engineered herbicide-resistant crops" conducted by the Social Science Research Center Berlin (WZB) (van den Daele 1993a, 1993b; Bora/Döbert 1993). With the participation of representatives from science and industry as well as representatives of environmental groups, the risks of using genetically engineered herbicide-resistant crops in agriculture were to be discussed. The initiators of the WZB project intended to help "factual arguments" achieve a breakthrough and gave the "scientific-technical discourse" a central role in the process. This restricted the discourse thematically, and, tended to favor scientific arguments over political arguments.

First of all, the question arises as to the thematic significance of scientific discourse in the context of TA: What is the subject of TA discourse? There is no doubt that the subject matter of TA discourses is primarily to be seen in questions of science and technology. Undoubtedly, it is also about "information gathering" and not about replacing decisions to be made in the political system: It is about the "knowledge base of decisions" (van den Daele 1991), and in this respect not about the replacement of institutionalized "political discourses" by TA. The question, however, is what is to be regarded as relevant "knowledge" in the context of technology controversies. The discursive TA project undertaken by the Social Science Research Center Berlin attempted to limit the TA discourse to the discussion of "scientific questions." This meant, for example, that the question of examining alternatives to the use of herbicide-resistant crops in agriculture, which would have implied the – undoubtedly political – evaluation of the sense and benefits of using genetically modified crops against the background of a discussion on the environmental and social compatibility of different forms of agricultural production (intensive versus extensive soil cultivation), was thematiccally excluded. The TA discourse should be limited solely to the generation of data, the scientific "findings themselves," and thus the discourse should be concerned solely with the scientific assessment of the ecological and health risks posed by the technology in question (van den Daele 1993a, p. 11).

On the one hand, this (deliberately) neglected the fact that there is usually more at issue in technology controversies than risk issues. In my opinion, however, such an approach also fails to recognize that it is precisely in questions of risk that ambiguities in the data arise in principle, which ultimately cannot be resolved by recourse to "the findings themselves." Risks always involve assumptions about the extent and probability of the occurrence of a damaging event, which can be scientifically substantiated, but from which, as they are fraught with ambiguities, no clear instructions for action can be directly derived. The description of the task of a TA discourse with the words, "Before one asks whether a risk is acceptable, one must ask whether the risk exists" (van den Daele 1993a, p. 30), seems in its supposed triviality to completely ignore the importance of the "social context" – of values and "social commitments" – for the definition of "risk." In the case of hypothetical risks, such as the above-mentioned risk that a pathogenic organism is unintentionally created from harmless starting components through genetic manipulation, it is questionable how plausible the assumption of a possible causal chain leading to the occurrence of damage must be in order to derive the need for safety measures from it. The question "How safe is safe enough?", which is central to technology controversies, is a typical "trans-science question," i.e., a question to be answered politically – in accordance with practical reason. It is also difficult to exclude ethical questions ("How should we live?"), or moral questions about the fair distribution of opportunities and risks, which ultimately also means the (economic, political) interests of those involved.

Limiting the TA discourse to scientific topics implies, over and above the danger of excluding politically significant issues, the danger of closing the discourse to non-scientific arguments in the first place – i.e., "closed peer communities" instead of "extended peer communities." This is the inevitable consequence if one attempts to distinguish a "political discourse," which is at best analytically distinguishable and whose main function is "mobilization," from the "scientific-technical discourse," which is the actual content of TA, and if one assumes a priori that the latter is superior to lay discourses in terms of factual rationality (cf. Bora/Döbert 1993, p. 83f.). This is completely questionable if the distinction between scientific and political discourses is ultimately only based on the characteristics of actors. The scientific-technical discourse is simply represented by the so-called "representatives" of this discourse – i.e., scientists. The political discourse, on the other hand, which is considered deficient in terms of "factual rationality," is represented by the representatives of the new social movements. Such an approach runs the risk of linking the "factual orientation" to what the "representatives" of the scientific-technical discourse consider it to be. With such a hypostatization of scientific-technical rationality, TA discourses – in my opinion – come fatally close to older technocratic theoretical concepts, which saw the "factual rationality" of scientific-technical development as the decisive argument for a technical-scientific suspension of the political per se and for the rule of a technical-scientific elite. In this context of argumentation, the concept of discourse appears to be superfluous. Discourse could then only be understood as a conversation of "factual rationality" with itself in the form of scientific-technical functional elites. With recourse to Foucault's concept of discourse (1977), one could say that the "order of discourse" has excluded anything other than "technical" arguments from the outset. Doubts about the (factual) rationality of scientific-technical argumentation, as typically articulated by new social movements, would thus be excluded from the TA discourse a priori as "unobjective."[8]

Of course, questions of a scientific and technical nature – about how new technologies work, about chains of events that lead to the occurrence of damage, about data on expected immissions and emissions – remain a central topic of TA discourse. Even laypersons have to engage with the terminology and logic of scientific argumentation when clarifying validity claims, e.g., of empirical statements on the reliability and validity of data. The question is, however, whether the level of purely scientific discourse is necessarily abandoned when scientific statements and thus paradigms are disputed (epistemic discourse). In TA-relevant questions, there is not only a dispute about scientific methods and paradigms that could be continued ad infinitum in the scientific system – under conditions of an ideal speech situation. At the same time, there is – however constituted – pressure to make decisions (see also the following section). The dispute about the assessment of genetic engineering risks, for example, could ideally be continued in the scientific system until a decision is made on the basis of reliable knowledge, if it were not already politically necessary to decide whether or which genetic engineering experiments should be permitted. It is precisely at this point that the scientific (epistemic) discourse turns into a TA discourse. It therefore seems at least questionable if the subject matter of TA is reduced to the generation of knowledge – in the sense of scientific findings. TA discourses, if they want to remain compatible with public technology controversies, would have to be understood as events of practical reason – here in the sense of an undifferentiated lifeworld rationality – that primarily deal with scientific-technical problems.

8 The WZB's TA procedure was accused by the participating environmental groups of having been designed from the outset to favor scientific-technical arguments at the expense of more far-reaching arguments of the environmental groups, which ultimately led to the environmental groups dropping out of the procedure (cf. Gill 1993).

6. TA discourse and institutionalized procedures for democratic decision-making

TA discourses can be understood as "communication systems that organize themselves at the boundary between lifeworld and system" (Giegel). They must therefore not only clarify their relationship to scientific discourses, they must also determine their relationship to political decisions and to institutionalized forms of democratic decision-making. TA's characteristic location in the field of tension between science, the political system, and the public suggests that participatory technology assessment procedures in particular are associated with the idea that TA is designed to replace decisions made by the parliamentary system. This has been formulated as a danger on the part of established institutions and as an opportunity on the part of new social movements. It has been rightly countered that TA procedures are centrally related to political (technology policy) decisions, but cannot replace them (cf. Gloede 1991). In the following, the specific position of TA in relation to the political system will be explained with reference to discourse theory considerations. To this end, it is first necessary to revisit the problem of the relationship between everyday discourse and decision-making.

As has been shown, the fundamental openness of discourse not only offers an opportunity for understanding but also poses a fundamental problem: Reasons can constantly be replaced by new and better reasons, and discussions can in principle always be continued. Discourses therefore lack binding force. Discourses have virtually no inner telos that would put an end to them of its own accord. This would then lead to serious problems of social integration if action were not nevertheless constant, and strategic action were not successfully differentiated in specialized systems (Habermas 1992, p. 54 and passim).

The problem, however, is precisely the relationship between (lifeworld) processes of understanding and (systemic) decisions. This relationship can be understood as being mediated via "*constitutive discourses*." If one understands the lifeworld as a field of both communication-oriented action and strategic, success-oriented action, i.e., also as a life practice that is constantly required to make decisions under conditions of ignorance, one can speak of the lifeworld as a field of action, "[...] in which one constantly switches back and forth from discourse to strategic action" (Giegel 1992, p. 79). In processes of lifeworld communication, decisions are ultimately constantly being made as to when communication can be dispensed with and proven procedures of purposeful rational action or decision-making can be used. In this meta-discourse, the interface between system and lifeworld can be located, so to speak. Systems are to be understood as fields of action that are removed from the lifeworld discourse. However, they are at least potentially connected to lifeworld communication, insofar as they owe their existence or recognition to "constitutive discourses" (Giegel 1992), in which *rules of alternation between understanding and decision* are decided. Constitutive discourses separate discourses about rules and general preconditions of decisions from discourses about the actual decision. They thus ensure that decisions remain possible despite the fundamental incompleteness of discourses: "Discourse determines that under certain conditions discourse is dispensed with" (ibid., p. 83). Systems would then be "fields of strategic action constituted in an understanding-oriented way" (ibid., p. 84), but which have become independent of lifeworld discourses and have developed a complexity driven by specialization that is more complex than the meaning-making processes of the lifeworld.

In addition to the thematically centered discourses on risks, social consequences, etc., technology controversies are also constantly accompanied by a "constitutive discourse" on the question of who is legitimized to decide, when, and according to which rules. The debate about the legitimacy of decisions of the political system, which is usually an integral part of technology controversies, could be understood as such a discourse. To the extent that TA reacts to this, it stands in the field of tension of constitutive discourses, i.e., public debates on the legitimacy of political decisions and decision-making procedures. For discursively organized processes of technology assessment, this means that they must mediate the fundamentally open structure of the public discourse on technology with the necessity of political decision-making under uncertainty or even dissent. However, insofar as they are neither a substitute for public controversies nor a substitute for parliamentary decisions, they can only develop their function as "intermediary systems."

The relative independence from political decisions is a relief that makes TA suitable for preserving the creativity and openness of public technology controversies, and ultimately for developing the creative potential of the discourse. TA procedures offer the opportunity to take up all claims that are publicly discussed. Unlike in the political system, topics and validity claims are not selected according to, for example, electoral strategy. Furthermore, TA discourses make it possible to initially examine validity claims relatively free from strategic calculations of interest enforcement. The probability that the strength of the better argument alone will ultimately prevail increases with the degree to which the discourse is relieved of decisions. Ultimately, in situations relieved of the burden of decision-making, it is more likely that participants will be motivated to question their own, and seriously examine other claims to, validity.

Consultations that relate directly to political decisions are under pressure from existing differences in power and interests that want to assert themselves. They have to comply with bureaucratic requirements, administrative and legal constraints, etc., which prevent the potential for "socio-political and technological creativity" of the discourse from unfolding (cf. Gill 1993). The relative relief from decision-making that is given in TA discourses offers a certain guarantee that what Giegel (1992, p. 94f.) calls the "*organizational dilemma*" in the translation of lifeworld discourses into systemic decision-making rationality is alleviated: The successful transposition of lifeworld claims into decisions requires the organization of lifeworld discourses, their thematic and argumentative bundling, so to speak, with which, however, restrictions are necessarily created for the unfolding of discursive creativity.

However, the creative potential of discourse must be translated into decisions. TA cannot completely dispense with the claim to influence political decisions, as otherwise it would become functionless for the demands of the living world, such as those organized and articulated in new social movements. Non-binding discourses can, under certain circumstances, develop considerable problem-solving potential. However, their non-binding nature also puts them at risk of remaining politically meaningless. It is therefore necessary to agree on how binding the results of discursive TA processes must or may be for political decisions.

How TA discourses can be constitutively positioned in relation to parliamentary decisions cannot be discussed here. In terms of democratic theory, however, they can be understood as elements of a model of "deliberative politics," as outlined by Habermas (1992). "Deliberative politics" is understood as a democratic organization of opinion-forming and decision-making that emphasizes the active role of citizens in contrast to a liberal – state-centric – understanding of politics, without allowing politics to be absorbed into the community of collectively acting citizens in a republican – anti-state administration – way. Such a model sees the state as a democratically legitimized authority to which decisions are reserved, but which is linked back to the formation of public opinion and will, "which not only controls the exercise of political power, but also more or less programs it" (Habermas 1992, p. 365). In this model, state politics remains dependent on the public sphere not only as a "context of justification" but also as a "context of discovery" (ibid., p. 373ff.). With the latter, Habermas refers to the discursive potential of the public sphere – its openness to claims and questions of all kinds, its tendency to make traditional self-evident facts contingent.[9]

How TA is to be anchored as an institution of deliberative politics between the public and the state is ultimately to be clarified in "constitutive discourses," which in turn are to be conducted as public controversies, but must ultimately lead to parliamentary decisions. Such "constitutive discourses" have indeed taken place in several countries in connection with the question of establishing parliamentary TA institutions, with varying results (cf. Bryner 1992). However, which form of institutionalization is most compatible with a discursive understanding of TA and is appropriate for processes of "reflexive modernization" will certainly remain the subject of public and parliamentary debate. For example, the establishment of thematically centered policy forums prior to parliamentary decisions is conceivable (Zilleßen 1993), as is the establishment of parliamentary TA institutions with a strong public relations function or political support for social initiatives (associations, social movements) to set up TA discourses on specific topics. Which competencies are assigned to such institutions, and how their results are incorporated into political decisions, etc., is ultimately a question of "constitutive discourses" in the true sense of the word – it requires answers at the level of the legal constitution of modern societies. This is where the legal framework must be created in the parliamentary system that establishes the TA discourse and regulates its relationship to the political system. In this respect, the state must set and control the framework conditions for TA discourses (cf. Giegel 1992, p. 107).[10] The task of institutionalizing TA discourses thus points to a fundamental problem of modern organization of political decision-making, which must keep claims to validity open to criticism at all times and yet requires procedures for producing binding decisions. TA must therefore be integrated into a constitutional organization of political decisions, in which the law

> [...] functions as a mechanism [...] that relieves the overburdened communication efforts of those acting communicatively of the tasks of social integration, without in

9 For the role of the mass media public in technology discourses, rationality potentials such as thematic and participatory openness and a preference for general social values at the expense of particular values and norms are also emphasized from the perspective of media research (cf. Peters 1994). For a theoretical justification of a deliberative understanding of politics, see also the concept of "creative democracy" in Joas (1992).

10 Here, Giegel refers to proposals for social self-regulation of questions of technical design and standardization within the framework of association activities, the democratic organization of which would have to be guaranteed by the state (cf. Eichener/Voelzkow 1991).

principle reversing the restriction of the scope for communication (Habermas 1992, p. 57).

7. Benefits and limits of discourses on technology

Discursive TA processes – this thesis was pursued in the present discussions – can be understood as a formalization of public technology controversies, and are thus simultaneously *an expression* of a crisis of scientific-technical rationalization and a *reaction* to its consequences. Processes of discursive TA participate in the demystification of science insofar as they confront the emergence of science and technology with scientifically- and technologically-produced knowledge about latent and manifest consequences (reflexive scientification) and evaluate them against the background of political and everyday problems of action and decision-making. At the same time, they pose a challenge to the current political decision-making structures by confronting them with knowledge of the consequences and the security demands of everyday life.

However, they also claim to provide an *answer* to the new questions that arise. Insofar as public technology controversies as unregulated discourses lack factual, temporal, and social organization, organized TA discourses are linked to the hope of mobilizing the potential of social rationality – or communicative reason – bound up in technology controversies for technology policy decisions. TA cannot achieve this without reference to the structures of knowledge-generation and decision-making which are institutionalized in specialized subsystems. However, its ultimate goal must be to do justice to the ambivalence of scientific and technological modernization in the confrontation of systemic rationalities with public discourses and to increase the level of rationality of decisions. Whether TA is thus part of a process of "rationality reform," which Beck (1993, p. 192) sees as already underway, or whether this is merely a new institutional arrangement of the systemic and lifeworld rationalities released in the process of modernization, remains to be seen. In any case, it is unmistakable that TA, if it wants to respond to the challenges of "reflexive modernization," must tackle the mediation of lifeworld rationality with scientific rationality, and of the public sphere with the political system.

This claim is confronted with the critical objection that participation does not create decision-making rationality, since the problems of a lack of decision-making rationality in questions of shaping technological development or in decisions under uncertainty are not only due to a lack of representation of interests but also to "complex cognitive and coordination problems" (Wiesenthal 1989,

p. 139; cf. also Wiesenthal 1990 and van den Daele 1993a). Although participation offers an improved consideration of interests and values in political decisions, it is precisely this that blocks the chances of finding innovative solutions to problems or implementing them in society. The stronger assertion of particular interests blocks the opportunities to generate new problem views and perspectives for action. This requires a "relativization of particular rationalities" (Wiesenthal 1989, p. 140ff.). Ultimately, the criticism boils down to the thesis that lifeworld rationalities are undercomplex compared to the problem-solving capacity of social systems which are specialized in scientific, economic, etc. rationality:

- In participatory processes, the tendency to adapt the preferences pursued to the most feasible solution is encouraged because the pursuit of immediate interests is preferred to long-term ones.
- The decision-making problems caused by the fact that individuals often have contradictory preferences when it comes to technology policy issues (e.g., as residents of a planned industrial plant, as employees and consumers) cannot be resolved by the representation of those "affected."
- Moreover, it is quite rational for individuals to forego a contribution to the achievement of collective goods (free-rider phenomenon), which is why the chance that general interests are promoted at the expense of particular interests through participation procedures is low.

It should not be disputed here that participatory processes – whether in concrete planning projects or in technology assessment procedures – are fraught with problems resulting from the restricted rationality of the individuals or groups pursuing their particular interests. However, the criticism referred to above, which is based on the rational choice model of action, neglects the possibility of initiating social learning processes, which exists through the implicit obligation of those involved in discourse to reach an understanding.

First of all, the criticism does not sufficiently acknowledge the fact that the specialized rationalities of the subsystems – which are implicitly assumed to have a higher potential for decision-making rationality due to specialization – are precisely part of the problem. It is difficult to see how systemic rationalities can lead to rational decisions in the face of complex, system-produced, but cross-system problems. Environmental problems are known to be those that cannot be dealt with by systems due to their lack of resonance capacity based on specialization (Luhmann 1986). The argument directed against discursivity that relying on "negotiations" – as an alternative to the lost "authority" of science and politics – only increases the uncertainty of decisions by increasing the number of options and problem views, so that one can only come to an understanding but can no longer act (Luhmann 1992, p. 139ff.), is pragmatically unsatisfactory. Apart from the stoic waiting for problems to be solved through evolution, it offers no alternatives to social processes of understanding the problems at hand and the possibilities of dealing with them.

What is more decisive, however, is that the critique ignores the *creative potential* of discourses. This is rooted in the very characteristic that critics characterize as a shortcoming of discourse: The openness to topics and arguments and the non-commitment to preferences. Preferences or particular interests can be called into question in discourses because the normative claim to validity associated with them must be justified. Contradictory preferences become perceptible as contradictory. The possible consequences of unilaterally pursuing economic or ecological preferences, for example, can be discussed in TA discourses. The consequences of pursuing objective "a" at the expense of objective "b" can be made transparent. Finally, through their inherent tendency to question validity claims, discourses can mobilize social rationality beyond the one-dimensional, individual-utilitarian rationality of "homo oeconomicus" by equally considering and relating pragmatic aspects (questions of action coordination to achieve goals), normative aspects (questions of justice, the social distribution of opportunities and risks of decisions to be made), and ethical aspects of action situations (questions of the good life, of preferences).[11]

In fact, the problems of reflexive modernization require more than just improving the representativeness of decision-making processes. It requires the development of new problem views and preferences in the course of problem-solving action, i.e., creativity in the course of problem processing. What is required is the questioning of established goal orientations and the creative handling of the unavoidable ambivalence of the achievements of (technical) modernity (Bauman 1992). What is demanded in the critique of discursivity: "creation of ideas" or "institutional innovations" (Wiesenthal), is, however, inherent as potential in the discursive confrontation of different interests and rationalities. Discursive procedures of technology assessment question existing definitions of action situations and thus improve the chances of rational action by opening up the possibility of introducing additional knowledge and additional evaluation

11 Cf. the reference by Habermas (1992, p. 387ff.) to the distinction between three dimensions of social integration in Peters (1993): the "functional coordination of action," which requires a cognitive orientation toward events and conditions in the objective world, the "moral regulation of conflicts," and the "ethical safeguarding of identities and ways of life."

criteria into the technology policy decision-making situation. In this way, they enable precisely what criticism assumes to be necessary in view of new problems, but which cannot be achieved with the principle of participation: The relativization of original cost and benefit calculations and trade-offs taken for granted and proven by the "inclusion of further decision criteria" (Wiesenthal 1989, p. 153).

Of course, this creative potential of discourse can only unfold if the "boundary conditions" under which such discourse takes place allow it. In particular, the necessary motivation of the participants to set aside their own interests in favor of a focus on cooperative problem-solving should be considered here. In this respect, skepticism about participatory processes is justified. However, a lack of motivation for problem-solving-oriented action is to be assumed here less in fundamental contradictions between subjective rationality of action and collective goods than in the historical-structural conditions under which discourses on technology take place. The asymmetrical distribution of de facto decision-making power over technological innovation processes suggests a strategic approach by both opponents and proponents of a technology. Discourses, which initially do not change the distribution of resources for the assertion of interests, will always be suspected by new social movements of merely being conceived as events for the integration and silencing of protest. Conversely, it is unlikely that the proponents of a technology – usually the players in the scientific and technological innovation system – will expose themselves to the risk of being tied into a consensus that massively limits their power to define and act.

Consensus as the result of a TA discourse is extremely unlikely under the given structural conditions. In addition to the divergences of interest mentioned above, this naturally includes above all the problems of communication between the subsystems affected by technology policy issues and with the "living world". The resulting divergent views of problems and evaluations of technology represent the core of the crisis of scientific and technological rationalization. Nevertheless, technology controversies do not have to grow into endless conflicts. However, at least "rational dissent", in the sense of an understanding of what is controversial, should be expected from TA discourses, i.e., consensus at the "level of communicative understanding" (about what is controversial and the respective viewpoints represented), with existing dissent at the "level of collective acceptance" of what should apply in the case at hand (Miller 1992, p. 39). According to Max Miller, this makes it possible to transform infinite conflicts into conflicts that can be resolved if what is collectively valid (the background consensus necessary for any understanding) is sufficient to establish an understanding of differences and what is collectively recognized as valid. There are many indications in modern technology controversies that such a basis for understanding – e.g., a common understanding of what is recognized as a legitimate argument, a common “rationality” – is currently lacking; however, a democratic alternative to “negotiations” is not in sight. Following Miller’s argument, discourses on technology should be understood as the nucleus of a new structure, as an expression of the search for new forms and institutions of conflict resolution and decision-making, which can function as a procedural substitute for a no longer sufficient consensus on the “social rationality” to be assumed in relation to processes of mechanization – or as procedures for understanding the no longer self-evident “common good,” if one wishes to use the central term of another current debate on the state of modern societies (cf., e.g., Honneth 1993).

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Fritz Gloede

Technology policy, technology assessment, and participation

Technology assessment (TA) is on everyone's lips, participation was on everyone's lips, and participation in TA is a matter of course. The question, as Scharioth explained in 1983, was only "where," "when," "with whom," and "how"? (Scharioth 1983). However, a second "sociological" look, which many people take following Luhmann (e.g., Luhmann 1984), reveals that this self-evidence is not very instructive and conceals divergences.

I would like to make it plausible that the demand for participation in TA is context-bound and can therefore take on different meanings. I will try to illustrate this using the example of the TA project "Herbicide Resistance" [HR] (van den Daele 1994).

Finally, the question should then be raised as to which realization conditions a discursive participation concept is practically bound to.

1. Participation as a program

> If someone were able to reconcile industry operation requirements and public participation in such a way that everyone would be satisfied it would be worth an exceptional award for miraculous achievements (O.H. Wildgruber, in: OECD 1993).

Naschold described "publicity and participation in TA" as one of three fundamental problem areas that are "largely unresolved," "latent," and at the same time "highly explosive." Superficially, it is only about the function and recruitment of advisory boards, publication rights, and the public discussion of study results, the pluralistic representation of social groups, or the inclusion of decentralized groups in the implementation of studies. In reality, however, these are language games or *dilatory formula compromises* that conceal deeper social lines of conflict. The political system fears a challenge to central state structures from extra-parliamentary plebiscitary movements or a "radicalization of the network approach." The economy fears the trend toward "co-determination" for society as a whole and "forward-looking political technology design" – in other words, a regulatory revolution. Accordingly, the topic – also internationally – tends to be marginalized, usually not thoroughly discussed, and regulated restrictively in practice (Naschold 1987, p. 21ff.).

For this reason alone, it is inadvisable to reduce the issue of participation to the question of why the rhetorical consensus on participatory TA has not been put into practice and which pragmatic limitations may be responsible for this (e.g., lack of time and money, cf. Jochem 1988). On closer inspection, it becomes clear that the supposed consensus is already fragile in programmatic terms. Depending on the image of society and the "political target system" (Böhret/Franz 1985), different things are meant and intended when participation in TA is called for. It is very important, for example, whether this program point primarily:

- is about TA itself as a process of problem-oriented and consultation-based *research*,
- is about state *technology and industrial policy* as a decision-making and control process, or
- refers to "TA processes" as a model of *social learning* in the medium of the public sphere.

Many works on the program and practice of TA do not make such distinctions. This may be due not least to the multidimensionality or vagueness of the concept of participation. Used in the sense of "taking part," "participation" leaves it largely open as to who participates in what role or function and in what way.

In this context, I cannot go into the socio-historical changes in the concept of participation and democracy (cf. Rammstedt 1970). However, I would like to criticize a form of justification for participation in TA that collects all possible arguments with a normative background conviction without considering their different and sometimes contradictory contextual references (Lohmeyer 1984; Fiorino 1990). As we know, the formula "a lot helps a lot" does not always apply in everyday life either. To put it bluntly, one could argue that

- participatory TA does not make technology policy democratic, and
- democratic technology policy does not necessarily require participatory TA!

The difficulties with arguments such as Lohmeyer's only really become clear when two further lines of reasoning for participation are introduced in addition to the democratic requirement, namely:

- functional justifications (frame of reference: decision), and
- cognitive justifications (frame of reference: research).

Functional justifications for participation in TA are familiar in the TA debate. They are aimed at improving the possibilities for implementing the results of decisions, facilitating consensus on controversial issues, and ultimately generating public acceptance for technology development and technology policy decisions.

Beyond the question of its realizability, such a promise contradicts Lohmeyer's warnings against reducing TA to the procurement of acceptance, and his normative postulates of democracy.

The third line of reasoning, namely that participation could mean considerable information gains for TA (by involving "affected parties" as the experts on their own affectedness), also lies alongside the democratic premises. In this perspective, the "participants" become objects of research rather than being accorded subject status in the sense of decision-related participation (cf. Bechmann/Gloede 1986; Gloede 1987).

Well-meant intentions can thus lead to fragile and partially contradictory justifications for participatory TA, because the advocated participation refers to three participant roles at the same time: the role of the decision-maker, the role of the decision addressee, and the role of the object of decision-preparatory research.

2. Three justification contexts for participation

In view of these difficulties, I argue in favor of explicitly distinguishing between the justification contexts for participation in TA that I have indicated. These contexts of justification are related to general concepts of scientific policy advice.

- The first justification sees *participation in TA as a functional requirement* and focuses primarily on functions of cognitive decision-making preparation. Here, TA mediates between science and politics.
- The second context of justification sees *participation in TA as a democratic political demand* and corresponds with the idea of TA processes as socio-political arenas. Here, TA mediates between the public and politics.
- The third context of justification sees *participation in TA as an element of discursive mediation* of controversial cognitive and normative validity claims. TA as a model of "social learning processes" mediates here between science and the public.

2.1 Decision rationalization

The reference points for a *functional justification of participation* can be seen in the objectives of the classic TA concept.

Participation should contribute to the "completeness" and balance of the analysis; informing *the* public should contribute to the objectification of opinions; information *from the* public could contribute to early warning, and the involvement of those affected in the TA processes should increase the willingness to accept the decisions discussed in this way.

In short: Participation is related to the rationalization of (political) decisions and must be realized *in accordance with this requirement.* In this respect, it varies depending on the topic and situation; participation "rights" cannot be asserted. The selection of those to be involved can be subject to cognitive and political-strategic criteria in equal measure. All scientifically "irrelevant" contributions and/or all politically "irrelevant" decision addressees tend to be excluded. Under certain circumstances, however, this can be associated with competence problems (in the case of expert dissent) or legitimacy problems (in the case of normative dissent) (cf. Throgmorton 1991).

Which participation criteria are in the foreground for which phase of TA implementation (problem definition, problem processing, discussion of results) also depends on the preferred consultation models (Habermas 1964). A more "decisionist" concept is generally associated with a scientistic understanding of TA (cf. Gloede 1992) and will therefore primarily favor cognitive criteria for participation. The consideration of expert dissent is then rather unlikely, since scientific uncertainty is either to be resolved by research or made clear by limiting scientific validity claims. In contrast, political-strategic participation criteria are left to the considerations of the decision-makers.

A more "technocratic" concept is likely to shift the absorption of uncertainty more into the area of scientific problem definition and processing, and instead define political-strategic participation criteria very restrictively. There is little room for normative dissent where practical constraints prevail.

Finally, a more "pragmatic" concept would have to take little account of the distinction between scientific and political-strategic participation criteria and could be realized, for example, in the formation of hybrid communities of experts and decision-makers whose composition takes equal account of both sets of criteria.

2.2 Democratization

The points of reference for a *democratic-political justification of participation* must be sought in those normative premises and political preferences whose representation and implementation in decision-making is sought in TA processes. This involves both the identification of legitimate normative concerns and the realization of appropriate procedures for social decision-making.

Participation in TA should guarantee the opening up of technological and socio-political alternatives and at the same time ensure the democratic participation of the population or social groups previously excluded from decision-making. From this perspective, the demand for participation is usually closely linked to the expectation that the results of democratic TA processes are "consistently" translated into political decisions.

This justification for participatory TA thus corresponds to the demand for participation in decision-making – not only in the traditional political sphere. Accordingly, it must be based on democratic norms that can vary between a more policy-centered and an extended "social" understanding of democracy. This results in considerable differences with regard to the political-social participation criteria. In this respect, this context of justification generally faces the problem of justifying its participation criteria and procedures vis-à-vis the prevailing forms of democratic participation and, in particular, those of representative democracy (cf. Guggenberger/Offe 1984). Such justifications can take both "elitist" and "plebiscitary" directions.

"Elitist" justifications for supplementation or expansion correspond with a scientific normativism (cf. Gloede 1992) and tend to assert the consideration of concerns that limit the validity of the democratic majority rule, but which are essential for a substantial orientation toward the common good. This line of justification of participatory TA therefore usually also has rationalist implications. The difference from functionally-based TA participation is perhaps that a "social rationality" should take the place of a "technical rationality" (cf. Gill 1991). Critically, one could speak of a concept of technocracy extended by the "social."[1]

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1 An objection to this interpretation of a normative concept of social or especially constitutional compatibility has been that it is rather an analysis of the normative or constitutional implications, which in this respect only aims to make a contribution to the democratic discourse, but in no way intends to directly determine political action (Roßnagel 1993, p. 200ff.). Even if the analysis of normative implications thus wants to withdraw into the general framework of technology assessment, the concept of constitutional (in)compatibility must remain ambiguous. Violations of values and norms in this

"Plebiscitary" justifications for supplementing or expanding democratic participation, on the other hand, correspond to political normativism and are therefore entirely compatible with a decisionist definition of the relationship between science and politics. In general, they are based on a critique of representative-democratic institutions that asymmetrically ignore societal interests. With regard to participatory TA, concern in this context is directed toward the participation of non-organized interests and concerns, which have so far been accorded neither articulation nor representation (due to a lack of conflict capacity) (cf. the institutionalization concept of the "Greens" in: Deutscher Bundestag 1989).

The scientific participation criteria, on the other hand, appear to be of secondary importance in a democratic context. In contrast to criticizable objectivity postulates of traditional TA, the focus here is rather on a concept of advocacy TA, according to which all socially legitimate concerns legitimately seek their cognitive underpinning. In this respect, the safeguarding of TA participation must primarily focus on the accessibility of expertise as a resource (cf. Schevitz 1992).

2.3 Social learning processes

A comparable openness toward different concepts of deliberation cannot be assumed for the *discursive justification of participation*. Insofar as it is based equally on questionable cognitive *and* normative validity claims, it not only excludes scientistic or normativist understandings of TA. It is also incompatible with decisionist or technocratic conceptions of science and decision-making.

When controversial normative preferences and political positions wrestle argumentatively over "correct" decisions and "robust" assessments (cf. Rip 1987) within the horizon of scientifically contested knowledge, scientistic and normativist claims are balanced, as it were. The normative integration of scientification requires participation according to socio-political criteria, while scientific dissent requires participation according to cognitive criteria.

The TA process – it could be pointed out – becomes a "domination-free" discourse in a double sense: All social interests, normative demands, and scientific views have the same opportunity to participate, but the decision-making reference of TA appears considerably loosened.

However, the "latency" of the decision reference of discursive TA (van den Daele 1991, p. 40f.) has reasons other than those found in the case of a strategic

dimension still seem to force political or legal decisions rather than putting them up for discussion (cf. also the criticism in van den Daele 1993, p. 220ff.).

TA concept, which is also not directly decision-forming in its orientation toward the "knowledge base of decisions." Discursive TA aims to generate arguments that are oriented toward standards of social justice, political legitimacy, and scientific competence. Since consensus on equally legitimate and competent conclusions will not necessarily be achievable, or will not be achievable within the time frames required for practical decision-making, the results of TA discourses can rarely satisfy criteria of "practicability" (Throgmorton 1991). The initial conditions for discursive TA processes, namely the social and scientific openness to participation, also have a restrictive effect with regard to "practicability." This is because the practical consideration of argumentative positions that were previously socially or politically marginalized already implies a shift in power and domination relations. To expect this from discursive debates would not only mean indulging in idealistic or rationalistic ideas (cf. also Gill 1993a).

For even if a consensus were reached, there would be no guarantee that this consensus of the participants in the discourse would successfully pass through democratic procedures. What's more, a consensus that could in principle be reached through discourse would ultimately suspend democratic decision-making by making it superfluous.

Conversely, it can be concluded from this that a discursive justification of participation against the background of desired social learning processes is fundamentally compatible with different ideas of democracy.

The implications of the discursive TA concept for participation criteria are thus also more clearly outlined. Similar to a functional justification for TA participation, this raises the question of the relevance criteria for participation. For although the discourse concept excludes political-strategic considerations regarding the participation of "powerful" social actors and "influential" scientific positions (cf. Ueberhorst 1990), this does not result in any positive relevance criteria. The same applies to the exclusion of democratic criteria of quantitative representation. Equal opportunities for the discursive exchange of arguments means not only disregarding the different social power of controversial positions but also their different political supporters in the population. This also does not result in any positive criteria for the selection of the positions and concerns to be included.

Finally, a discursive determination of selection criteria for discourse participation would not be a viable perspective either, but a circle of justification. The discursive justification of participation must therefore refer to non-discursive participation criteria. Ultimately, the ability to articulate positions must be empirically presupposed and it must be relied upon that the problem-specific selection made does not encounter social contradiction.

It should have become clear that functional, democratic-political and discursive justifications for participation in TA have significantly different implications for participation goals, participation criteria, and, in some cases, for participation procedures. In addition, they are open to varying degrees to common consultation concepts (relationship between science and decision-making) and concepts of socio-political consideration of interests (relationship between the public and politics).

However, the systematic incompatibility of participation contexts does not exclude the possibility that participatory TA processes of different types may practically coexist in society. A practical coexistence can be assumed because the types of TA mentioned are related to different problems that are perceived with different frequency:

- strategic TA projects with functionally based participation are aimed at the internal rationalization of decisions by organized actors or social subsystems;
- democratic TA processes aim to extend the legitimacy of socio-politically far-reaching decision-making;
- discursive TA processes with qualitative participation criteria are aimed at restoring fragile social integration as a prerequisite for democratic decision-making, not at decision-making itself.

However, discursive attempts to generate argumentative consensus do not necessarily have to end with a "consensus on the matter." An understanding of areas of consensus and dissent and their reasons, i.e., the creation of a "rational dissent" (Miller 1992), can also serve as a driver of social learning processes and, as a "second-order consensus," can be a sufficient basis for the re-establishment of decision-making ability.

Empirically, strategic TA processes are the rule, whereas democratic or discursive TA processes are the exception (see Sec. 4). However, an elementary condition for the success of *all* processes is likely to be a prior agreement among the participants on the underlying problem situation and thus on the desired character of the TA process.

The following discussion of the TA project on herbicide resistance shows the dissonance that can arise if this condition is not met.

3. The TA project "Cultivation of crops with genetically engineered herbicide resistance"

> The so-called consensus theory is an invention of people who are all gifted polemicists. They combine their desire for general agreement with the threat of declaring the unwilling to be evil or imbecile. Since then, we have had to be doubly careful when they majestically call for consensus. [...] What happens anyway should not just be accepted. What had been tacitly assumed, the so-called acceptance, is now expressly requested (Konrad Adam, FAZ of May 24, 1991).

In contrast to the social debate on genetic engineering, which goes beyond technology-specific aspects to include general problems of industrialization and technological development, the debate on appropriate state regulation of the use of genetic engineering focuses on legally-required risk prevention and risk precautions. The biological risks of genetic engineering and measures to ensure biological safety are of central importance for the protection of fundamental legal interests such as life, health, public safety, and the environment.

The discrepancy between the extensive expectations and fears expressed in the societal debate on genetic engineering on the one hand, and the extensive limitation of state technology control to safety precautions on the other, has led to increased expectations regarding the implementation of technology assessments on genetic engineering.

In view of the current state of the debate against the backdrop of the advancing use of genetic engineering, it has been postulated on various occasions that the time of fundamental controversies is over. The original polarization between fundamental supporters and opponents has now receded behind application-related differentiations, and it is now more important to carry out concrete TA studies on specific fields of use. The TA project on herbicide resistance in genetically modified crops (HR project), which was launched at the Berlin Social Science Center (WZB) in 1991, was thus in tune with the times, so to speak. It seemed to be both an expression of and a driving force behind an increasing objectification of the controversy, which has now been going on for almost 20 years.

However, the disputes surrounding the 1993 amendment of the German Genetic Engineering Law (Gentechnikgesetz, GenTG) make the diagnosis of objectification appear somewhat premature. Both supporters and opponents of genetic engineering and its "deregulation" expressed a considerable degree of emotionality and moralization.

Shortly after the GenTG came into force, an article in the newspaper "Frankfurter Allgemeine Zeitung" (FAZ) stated that the "dispute about playing with genes" had become less heated, but the contradiction remained. The course of the HR project also confirms this.

At first glance, the HR project was designed as a discursive TA. Neither a scientistic limitation to the generation of scientific expertise nor a normative representation of controversial decision-making claims was intended (van den Daele 1994; cf. also van den Daele 1991, p. 40f.). The planned TA procedure was to be a "discourse arena," so to speak, "in which the range of social conflicts surrounding genetic engineering is reflected" (van den Daele 1991, p. 39). The participation problem was perceived accordingly. Instead of democratic-political criteria, recourse was made to discourse-theoretical participation criteria; an attempt was made to qualitatively represent the argumentative positions in the concrete field of conflict, both in socio-political and scientific terms. It had already been recognized in advance that selection criteria based on discourse theory could hardly be justified discursively and could at best be partially corrected in a discursive TA process itself (van den Daele 1991, p. 42). As the practical implementation of the HR project showed, the selection criteria were relatively uncontroversial. After all, the basic principles of the planned procedure design also met discursive requirements: This was because the participants in the HR project were to be able to influence the formulation of the questions and the rules for their processing (van den Daele et al. 1990).

In addition to conducting the discourse on HR technology itself, a key objective of the project was its accompanying investigation by the WZB. Paths were to be sought to find a way between mere adaptation to a natural innovation race and an unproductive blockade of further development. The investigation into "how problem perceptions, argumentation, and conflict patterns change under the influence of the TA process" (van den Daele et al. 1990) was therefore already set along a pathway.

The accompanying research was guided by the hypothesis that factual rationality in dealing with HR [herbicide resistant] plants was most likely to be achieved via the social dimension (discursive procedures). Scientific ambivalences had to be "bridged socially, i.e., by consensus" (ibid., p. 14).

The withdrawal of the environmental groups (AbL et al. 1993) during the final conference should not necessarily be interpreted as a failure in the context of procedural "rationality gains," but rather in the context of the intended "impact" on the initial social conflicts (van den Daele 1994).

First conclusions on the functioning of discursive TA procedures have previously been drawn with a not inconsiderable amount of sociological conceptualization (Bora 1993; Bora/Döbert 1993). Their formal status is that of a sober examination of initial hypotheses. Their political core, however, seems to be disappointment about the political failure of a strategy (van den Daele 1994). In contrast, the thesis here is that the implementation of the HR project was characterized by a confrontation between two irreconcilable TA expectations, for which "discursive" approaches could only represent an unstable bridge.

With recourse to the typification developed so far, it could be argued that the project as a whole was characterized by the *conflict between a strategic and a democratic TA concept*, which not coincidentally coincides with the fronts in the genetic engineering conflict itself.

The spokespersons of the environmental groups clearly articulated themselves as representatives of a democratic TA concept (Gill 1991, 1993a; Kiper 1993a, 1993b). Here, "participatory TA" was to have an explicit influence on technology design, i.e., on decision-making. According to this guideline, it was already considered at the beginning of the procedure whether the required participation effort could be reconciled with the expected political yield (Gill 1991) – a legitimate tactical calculation, which was also related to the special participation requirements of the represented organization.

The *participants from industry and public authorities* will also initially have been faced with the question of why they should enter into such a procedure and which interests they should take into account. Such considerations inevitably take place regardless of whether the procedure in question is an event for political and administrative decision-makers or a discursive TA program remote from decision-making (cf. Giegel 1992, p. 78f.). These groups of participants can be assumed to be representatives of a strategic TA concept on the basis of a classification made by Bora and Döbert with regard to the "discourse" typology they constructed. According to this, the participants from industry and public authorities are largely to be regarded as supporters of HR technology who at the same time advocate technical-scientific and/or procedural standards of cooperation in the TA process, with the aim of cognitive preparation of political decisions (Bora/Döbert 1993, p. 90). None of these participants are supporters of a democratic TA concept directly related to decisions. How could it be otherwise?

Interference in the economic or official "freedom of action" would, as van den Daele also sees it, deprive the TA process of its "business basis." Moreover, the non-binding nature of participation was signaled by the fact that the representatives of the authorities were not officially 'sent'. Against the background of current genetic engineering law, however, the desired restriction to "information orientation" not only has restrictive consequences for the function of the TA procedure to "serve as a forum for technopolitical conflict" (van den Daele 1994,

p. 116). It must itself be regarded as a political preference. The existing structures of technology regulation are thus not only unavailable for decision-making, but ultimately cannot be addressed discursively either. In this light, the orientation toward a "scientific type of discourse" proves to be just as political as the "political type of discourse."

While the *organizers of the HR project* initially appeared as representatives of a discursive understanding of TA, and this had in many respects become structure-forming, it must now be shown that the organizers were already entangled programmatically in contradictions between a strategic and a discursive concept, the practical elimination of which took place in favor of a strategic orientation.

I would like to make this assertion plausible on three levels:

- at the level of the problem perception, on which the HR project was based and which ultimately shaped the expectations of the TA process,
- at the level of the process design itself,
- at the level of the accompanying process monitoring.

3.1 Organization of social learning processes or "rationalization" of decisions made?

Insofar as there is an explicit perception of the problem in the context of the HR project, this perception appears ambivalent. On the one hand, reference is made to the central genetic engineering conflict in society, which should be clarified and structured with the help of TA procedures. The opportunity for social learning processes inherent in this should be utilized. Apart from the question of who explains and who learns, this perspective could be described as an orientation toward a latent "constitutional-political" function of discursive TA processes. They reflect background conflicts about fundamental questions of the relationship to technological development and nature, which are not only decided by "regulation," but also by changes in awareness and values (van den Daele 1991, p. 45).

According to van den Daele, the addressee of discursive TA is not the decision-maker directly, but the opinion-forming public. It is obvious to recognize "social integration" as an existential problem in this problem-description and functional definition of TA. Endangered social integration threatens to undermine decision-making ability per se. The aim of establishing consensus through discursive TA processes then concerns the restoration of the ability to decide between alternatives.

However, this functional definition of the HR project is now contrasted with the accentuation of TA as information procurement for the rationalization of (political) decisions (van den Daele 1994, p. 115ff.). Such a functional description is fully compatible with the prevailing "strategic framework concept" of TA and the corresponding functional participation criteria. It is rightly stated that "information orientation" in this context has been the "political business basis for the relative consensus" that "has led to the institutionalization of TA" (van den Daele 1994, p. 115). Concerns about TA institutionalization were based in fact on the risk of thereby creating "constitutional political" forums for fundamental social conflicts (cf. Naschold 1987; Rautenberg 1989).

Precisely because the Enquete Commission on "Genetic Engineering" (1984–1987; see Enquete-Kommission et al. 1987) and, following it (if not in compliance with all of its recommendations), the genetic engineering legislation, had now demonstrated decisions and thus the ability to make decisions, the organizers of the HR project should have asked themselves which social actors still shared the perception of a fundamental conflict in need of discussion. After all, the path "between a natural innovation race and an unproductive blockade" of genetic engineering use had practically already been taken. What else could rationalization and legitimization of decisions mean?

Significantly, however, a strategic TA concept, which would be appropriate at this point, is not consistently explicated. Neither in the project application nor in the reports on the project published to date is it apparent which political decision alternatives or which regulatory requirements the HR project was to be geared toward. It seems that this standard question of a traditionally decision-related TA procedure was largely left open in favor of the rather diffuse question of whether there was any need for political action at all. It is understandable that this is denied by those who do not see the "special" risks of transgenic crops.

It is therefore hardly surprising that the HR project developed into a virtual review of "application documents" in legally-regulated approval procedures. From this perspective, the "recognizable problems" could be reduced to "approval issues" – the question of whether the concept of an "additive" risk assessment on which this administrative approach was based could be appropriate (cf. Gloede et al. 1993) was and remained controversial as a reflection of the original conflict of principles.

There could therefore hardly be any talk of an overarching mapping of the social genetic engineering conflict, which also extends to moral aspects and in particular to weighing-up the presumed "opportunities and risks." "TA implicitly accepted the self-running course of technical change as a starting point" (van den Daele 1994, p. 127). It thus more or less followed the basic conviction of at least one of the applicants, according to which resistance to new technology is the "inconsequential accompaniment to technical progress" (van den Daele 1988).

If the HR project could thus claim neither "constitutional policy" nor decision-related functions, and the information procurement organized in it was largely similar to that in approval procedures, it would not seem inappropriate to see its actual purpose in the testing of a hypothesis, namely the hypothesis that TA is suitable for "conflict management," i.e., that through scientific discussion in conjunction with procedural constraints it is able to "objectify" the initial conflict and "rationalize" decisions that have already been made. It is then consistent, despite the elementary information orientation of the project, to ultimately call it a "political (!) experiment." In *this* context, participation must be seen less as discourse-related and more as functionally justified.

Finally, with regard to conflict resolution and gaining acceptance through involvement in proceedings, the suspicion of a "modernization of the rhetoric of appeasement" (Gill 1991) can no longer be simply dismissed.

3.2 Problem-induced or technology-induced TA?

The previous discussion of problem perception and the corresponding TA function is reflected at the level of the project concept itself. In an event on technology assessment held at the Institute for Genetic Biology Research (Berlin) at the end of 1989, van den Daele emphasized that a "problem-induced" examination of alternatives to the genetic engineering HR strategy in agricultural weed control was undeniably legitimate (van den Daele 1990). It certainly does not follow from this that "technology-induced" TA is illegitimate. It is not a question of distinguishing between legitimacy and illegitimacy, but of problem adequacy. Apart from the fact that, in this light, "technology-induced" TA also presents itself in a specific sense as problem-induced TA (cf. Gloede 1992), van den Daele rightly notes that the comparison of alternatives between industrialized intensive agriculture and organic farming demanded by the environmental groups (cf. Gill 1991) would have meant a considerable extension of the problem, affecting fundamental regulatory and economic structures. The evaluation aspects and standards of comparison to be used would also have been different. However, this would have allowed the HR project to exemplarily take up the entire complexity of the genetic engineering controversy and to fill the "constitutional-political" dimension of discursive TA without risk under conditions of decision remoteness – an opportunity that is generally not given to strategic TA projects that are closer to decision-making. Measured against this, references to financial restrictions or to analyses of "agricultural development paths" carried out elsewhere (van den Daele 1994, p. 115) must appear rather meagre. Finally, it should be noted that, also at the procedural level, a considerable restriction formed the starting point: In contrast to even "ideal concepts" of strategic TA, participation in the process does not extend comprehensively to the problem definition.

3.3 Normative or empirical consensus hypothesis?

One initial assumption of the HR project is that, in the face of cognitive uncertainty and scientific dissent, consensus in the social dimension is required as a bridging factor to enable decision-making. Where this consensus is no longer unquestionably present, it could possibly be established by implementing suitable procedures (van den Daele et al. 1990). At first glance, this consensus hypothesis on the performance of discursive procedures stands in striking contrast to the castigation of "consensus theory as a German ideology" (Döbert 1992) found elsewhere. In contrast to the efforts of a universal pragmatic discourse theory, which, as in the work of Habermas, theoretically assumes elementary consensus as a prerequisite for discursive communication about what is right and just, "factual rationality" plays a prominent role in the procedural theory of the HR project. To a certain extent, this was the medium in which politically polarized conflicts are made to "disappear" in the course of the TA process (Bora/Döbert 1993, p. 93). The constraints of the "truth-oriented discourse" had also become so strong empirically that it was not possible to adhere to the "political discourse" (ibid., p. 95).

Without being able to go into detail here on the conceptualizations of the relationship between truth, morality, and procedural participation, which are certainly not entirely consistent with the project (cf. van den Daele 1991, p. 18ff.), the "emphasis on the factual dimension of procedures" (ibid., p. 21) must nevertheless be surprising. This hypothesis appears paradoxical or leads to a circular reasoning. If it is the *limits* of factual rationality that are to be bridged by procedurally mediated consensus in the social dimension, it can hardly be this "factual rationality," which in turn represents the *medium* for creating social consensus in the procedure.

In the light of the now clear course of the proceedings, it becomes apparent that the observation of the proceedings and its hypotheses operate with a changing frame of reference. Insofar as the initial controversy about the HR project amounted to political dissent, this could by no means be made to disappear by the constraints of the truth discourse. "Conflict resolution presupposes [at least, F.G.] that one agrees on what the case is" (van den Daele 1991, p. 19).

Since, in view of the preliminary decision in favor of a "technology-induced" TA, there was already no agreement on the problem that should constitute "the case" for the project, the prospect of a consensus-building influence on the initial conflict was already largely blocked.

The consensus on the given framework conditions, topics, and discussion procedures that could be observed in the further course of the process was also neither about the "matter" nor the "morals." Rather, it can be assumed that the participants were also able to make sense of even the narrowly defined procedure for different reasons. This "meaning" probably consisted of the expectation of being able to use the scientific controversy conducted here on specific terrain as a strategic resource with a view to the ongoing public conflict. This is supported in particular by the dispute over the final "reconstruction" of the discourse on the part of the organizers (van den Daele 1994, p. 134f.). For in the context of the public controversy, it certainly seems relevant whether the result of the project is a "confirmation" or a "refutation" of the additive or synergistic risk hypothesis – just as it cannot be indifferent whether, according to "the" project, the ecological and agricultural policy opportunities of the HR strategy are confirmed or "refuted."

Of course, it would be unsatisfactory if the outcome of controversies that were conducted in a discursive manner was nothing other than the positions announced before the proceedings. However, whether the observation of developments in the argumentation is accepted by the participants and whether it even allows further conclusions to be drawn cannot be decided by the observers alone. If their interpretations are not shared, they must be accused of exerting "consensus pressure." This approach appears to be covered neither by the course of the proceedings nor by the organizers' excellent position in terms of discourse theory. Reservations must apply here all the more because the organizers played a privileged role, especially in practice: "Although the WZB working group had no formal mandate to steer the TA process, it did have de facto influence" (van den Daele 1994, p. 123).

Instead of following their own insight that no one in the proceedings has the position of a neutral judge, and accordingly leaving the assessment of the results of the proceedings to a subsequent public discourse, the organizers nevertheless claimed to represent their reconstructions and conclusions as exclusively "cognitive assessments" of what was "the case" (van den Daele 1994, p. 135). The burden of justifying the contradiction was then placed on the participants. Apparently, it is not reflected that the observers of the proceedings – in their own cause, so to speak – are just as little entitled to judge whether the objection is argumentatively appropriate to the "increasing pressure of justification."

In this respect, it seems that the consensus hypothesis based on "factual rationality" has taken on a normative function. Much less has been done to prove that "factual rationality" is actually capable of what was initially assumed: namely to pull itself out of the "swamp" of political controversies and epistemic discourses by its own bootstraps.

The normativization of the consensus-building function of the procedure is supported not least by the disappointment expressed that "the hard-won channels of participation may have been blocked again." It is also time to ask whether valuable resources for political mobilization are not being tied up in a dispute that is being lost internationally and in which the arguments of the critics are becoming weaker and weaker (van den Daele 1994). This probably reflects less the current state of a discourse than the state of a development characterized by competition for innovation. Whether the arguments on hypothetical risks have become "weaker and weaker" is something that no one is currently able to say conclusively for both fundamental and empirical reasons (on the inadequate quality of the accompanying research on the release of HR plants, see Kareiva 1993).

Thus, it seems obvious to me that the organizers – with their political orientation toward "rationalizing" decisions which have already been made on internationally unstoppable developments, with their thematic orientation toward approval-relevant questions of risk assessment, and with their sociological fixation on the consensus-building potential of "factually rational" discourses – practiced a strategic TA concept that in this case could serve less the cognitive preparation of political-administrative decisions than the attempt to generate acceptance. It was precisely this attempt that ended in disappointment.

Conversely, this does not mean that the environmental groups "won." Gill had already stated during the kick-off conference in Loccum in 1991 that the HR project, which was under consensus pressure, could ultimately only end with a political defeat of organized criticism of genetic engineering. The actual course of events now resembles his variant 3a: In line with Gill's description, the fundamental positions of industry and the research bureaucracy prevailed. As a commentary on the critics' withdrawal from the process, it was then to be expected that they "had just realized" that they "had no arguments on the basis of rationality" (Gill 1991, p. 19). Such a potential for sanctions was assumed by the organizers with reference to procedural constraints and was practiced after the environmental associations withdrew (cf. van den Daele 1994).

In Gill's anticipatory calculation, the premise that industry and the authorities have completely different power-political resources than the environmental associations is certainly correct. While the former held the decision-making authority in their hands, the critics relied exclusively on their legitimacy and credibility vis-à-vis the organized grassroots and the public. Accordingly, both compromise-oriented "haggling" and the confirmation of the other side under the influence of those procedural constraints could only lead to a weakening of legitimizing resources. At best, variant 1 ("the critics get their way") would not be such a bad outcome, but would "change little" in terms of the practical decisions on the release of HR plants (Gill 1991).

In fact, the environmental groups were unable to assert themselves either with regard to decisions or with regard to the conception of the HR project. Although Gill had already openly stated during the kick-off conference in 1991 that the environmental groups themselves apparently no longer considered a "research moratorium" possible (ibid, p. 19), the environmental groups' statement of withdrawal criticized, among other things, that

> [...] the release of HR plants in Germany was started without regard to the still outstanding results and Ciba-Geigy withdrew its initial statement that it did not want to participate in the HR strategy (AbL et al. 1993, p. 13).

And although the demand for a problem-related examination of alternatives (Gill 1991, p. 20f.) had already been largely rejected in 1991, the environmental groups still made this point a key argument in their exit declaration in 1993 (AbL et al. 1993, p. 12).

The other points in the exit declaration (one-sided focus on "factual rationality," imbalance of resources) also point to the dilemmas of a democratic political TA perspective.

I would like to briefly outline these dilemmas on three levels:

- at the level of political-strategic calculations,
- at the level of the concept of "rationality,"
- at the level of practical procedural implications.

3.4 All-round "willingness to learn" or social democratization and a "round table"?

On the part of the organizers of the HR project, ambiguity could be identified between genetic engineering dissent in need of social clarification and a need for (subsequent) decision rationalization (Sec. 3.1). On the part of the environmental groups critical of genetic engineering, this corresponds to the ambiguity between the search for effective decision-making instruments to prevent genetic engineering and a willingness to participate in discursive learning processes (cf. Gill 1993b).

Behind this lies a fundamental strategic dilemma in the criticism of genetic engineering. In view of the adoption of the GenTG and the increasing international use of genetic engineering, the practical question arose as to whether the general rejection of genetic engineering could still be sensibly maintained or whether it was necessary to specify the criticism in the various areas of use. Answers to this question lead to a systematic and a practical dilemma. Systematically, the discussion of specific areas of application ends in considerations in which the predominance of a social benefit cannot be ruled out in individual cases – for example, in the area of medical use. In practical terms, the diversification of criticism can lead to a fragmentation of forces and also no longer provide the public with a uniform picture (cf. Göttinger AK 1991).

Despite these risks of at least tactical differentiation of contexts of use, genetic engineering critics find it difficult to avoid such differentiation. On the one hand, this differentiation of genetic engineering assessment is already present in the public (cf. Gloede et al. 1993). Secondly, the criticism itself is by no means limited to safety concerns, but is centrally based on weighing up hypothetical risks and dubious benefits.

This dilemmatic situation meant that participation in the HR project was associated with ambivalent expectations. On the one hand, it was indeed expected to be able to provide exemplary proof of the irresponsibility or undesirability of this line of technology in order to influence the particularly critically assessed release plans, despite the decisions that had been made. This expectation is associated with talk of "participatory TA as a method of democratic technology design" (Kiper 1993b). The keyword "round table" (cf. Ökologische Briefe 1991; van den Daele 1994), suggestively thrown into the arena by the organizers, reinforced such expectations.

On the other hand, participation in the HR project was perceived as an opportunity to cognitively review and, if necessary, substantiate one's own assumptions and reservations about HR technology – for example, through a wealth of expert opinions on questions that would otherwise hardly have been dealt with in this form. In particular, the scientific ambition of the counter-experts was seen by Gill as a motive "to learn something new rather than to state the fundamentals" (Gill 1991, p. 19). The later questioning of the environmental groups also reveals such an interest: information gain, interest in a discursive TA concept with the possibility of exerting discursive (!) influence on the other participants (Gill 1993b, p. 28).

However, the ambiguity outlined here consistently appears – particularly in the case of the representative of the environmental groups on the coordination committee of the HR project – as an expectation without contradiction. Apart from a certain overestimation of one's own abilities, which as late as 1993 was still taking credit for the actual implementation of a moratorium on releases ("initially"!) (Kiper 1993a, p. 311), the *tension between discourse and decision* is systematically and practically overplayed. This goes hand-in-hand with a further lack of clarity regarding the mode of "influence" of environmental protection groups on shaping technology and the future.

As far as influencing the formation of public opinion on genetic engineering is meant (ibid., p. 310), there is agreement with a discursive TA concept. In addition, however, two further forms of influence are suggested, which are neither adequately distinguished from the former nor from each other. The form labeled as a "round table" would probably be understood as *mediation* (see also Ökologische Briefe 1991, p. 15). Mediations are informal forms of participation of social actors in concrete decision-making processes. The extension of participation to include actors who are not formally authorized to make decisions is due to their conflict capacity (e.g., blockade power; cf. also van den Daele 1991, p. 32ff.). Democratic participation, however justified, should be strictly distinguished from this form of influence. However, Gill had correctly stated during the kick-off conference in Loccum that neither a power-political decision-making situation nor democratic participation was associated with the HR project. "It would by no means be democratically legitimate if we wanted to decide on such fundamental issues [...] in a small circle" (Gill 1991, p. 19f.).

However, neither discourse nor mediation, let alone democracy, are compatible with those expectations of the HR project that were aimed directly at enforcing the true and the good in a normative manner. The fact that it was Gill in particular who made himself the spokesperson for such orientations reveals the second dimension of the political-strategic ambivalence on the part of the environmental groups. In a nutshell, the normativist expectation can be formulated as follows:

(1) Meaningful TA only has to ask the right questions, give the right answers, and then consistently translate these into political decisions, and
(2) genetic engineering critics are already in possession of the right questions and the right answers – but do not have access to a decision.

The fundamental rejection of genetic engineering is as "trivial as it is true" (Gill 1991, p. 19) – all the more so as "empirical proof of our warnings [...] should not even be attempted" (ibid., p. 20). With a view to the fundamentals, any discursive TA becomes superfluous here. In retrospect, Kiper claims that the HR project confirmed the critics' assumptions and thus the "intuitive superiority of political discourse" (Kiper 1993a, p. 311). The background to such a view is probably the self-perception of environmental groups as keepers of the common good, who are opposed by industry, authorities, and established scientists as representatives of particular interests (Gill 1993b, p. 42; cf. also p. 3). In combination with a critique of the "superficiality of the concept of scientific rationality," these are the normativist premises of a claim to implement the true and just standpoint.

Despite criticism of the pressure for consensus from the organizers of the HR project, a consensus postulate is thus paradoxically placed *before* the implementation of the discourse, which is equivalent to the former.

This is not compatible with mediation procedures for the simple reason that such procedures are necessarily geared toward practical compromises that are limited in scope (see also Gill 1991). And such a consensus postulate could not be compatible with democratic decision-making, even if it had actually been confirmed in the course of the discourse. In concrete terms, a decision between the alternatives of "organic farming" and "pesticide strategy" could no longer be legitimized.

Under the impression of the discussions about the HR project, Gill has since modified his position. Today, he sees the call for TA to be more strongly related to decision-making or a legally enshrined obligation to consider as problematic. Such directly decision-related TA processes could hardly free themselves from the real existing boundary conditions and power relations. In addition, openness and mutual willingness to learn in order to develop creative technology policy options would only be possible if the TA processes were relieved of immediate decision-making pressure (Gill 1993a, p. 39). If one also assumes that TA discourses must not be subject to the expectation or even the compulsion of consensus, then the loss of legitimacy of environmental groups through "integration" in such procedures, which Gill apparently still fears, appears to be considerably mitigated (cf. Gill 1991, 1993a, p. 39ff.). Openness and willingness to learn on the part of *all* participants cannot be achieved without the risk of delegitimizing previous positions. Whether and to what extent this has repercussions in the power-political dimension will be the subject of political-strategic considerations on all sides. As there can be no meaningful obligation to participate in such discourses, it seems unavoidable that the intended purposes, the effort involved, and the possible returns will continue to be weighed in the future.

3.5 Scientific discourse or rationality of the "lifeworld"?

One facet of the ambivalences outlined above, which is not reflected in the political and strategic aspects, should be mentioned briefly.

Basic normativist convictions imply a belief in the superiority of common sense. The "intuitive superiority of political discourse" (Kiper 1993a) over a restricted technical-scientific factual rationality is not only claimed with regard to *normative* aspects of "social rationality" and justice. It should also extend to the correctness of intuitions on social, political, ecological, and economic issues, the scientific assessment of which ultimately only provides confirmation. However, the criticism of an empirical-analytical conception of "factual rationality" conceals two things:

- The expansion of the scientific concept of rationality to include normative preliminary decisions and conceptualizations in no way eliminates the difference between science and its social environment, between scientific argumentation in discursive TA processes and "lifeworld" or political discourse in the public sphere.
- The limited nature of technical and scientific expertise in the narrower sense with regard to social issues does not make it superfluous.

In this respect, van den Daele is initially right:

> If science were essentially nothing but politics, it would be worthless as a means of political criticism. Then one could (and should) vote right away (van den Daele 1994, p. 142).

However, as little as it can be concluded from this that science determines "what is the case" in a value-free manner, the corrective function of the "factual reference" can also hardly be disputed by critical scientists. Critics of genetic engineering who normativistically fail to recognize this aspect of critical expertise thus practically deny its decisive role in the development of all major technology controversies. The subsumption of institutions such as the Öko-Institut under the heading of "environmental groups" would then be consistent (Gill 1993a). However, it should be noted that this subsumption follows the discursive classification normally used by the criticized technology advocates.

The unease felt by many supporters of a lifeworld rationality about the discrepancy between science and politics or between knowledge and will is probably a social reflection of problems that are perceived as increasingly complex and their fragmented scientific treatment. In this respect, the members of social movements probably resemble the representatives of the political system more than they think possible. However, functional and disciplinary differentiation in dealing with social problems seems almost impossible to ignore. The question is therefore rather how to deal practically with the plurality of social interests and academic dissent.

If, for example, the biological discourse on the risks of releasing genetically modified crops were to end in an argumentative "stalemate" between the additive and the synergistic concepts of risk assessment, as an expert from the Öko-Institut believes (Fankfurter Rundschau, 19 June 1993), this could not only express the undecidability of the epistemic discourse between molecular biology and ecology (cf. Schomberg 1992). Above all, the question would necessarily follow as to what practical research and regulatory consequences should be drawn from this politically and socially (cf. Gloede et al. 1993). One such consequence would be the required reversal of the burden of proof – but this demand can no longer be justified "scientifically."

A completely different problem, which is also familiar to the analysis of scientific policy advice, is the unavoidable difficulty of translating scientific analyses or even the results of scientifically inconclusive discourses into a language that is understandable in everyday and political terms (Paschen et al. 1991). In a strategic and probably also in a discursive TA concept, the translation process would have to take place in the phases of problem definition and interpretation of results that precede and follow the scientific processing phase. It is possible that the HR project also exhibited deficits in this comparatively trivial dimension and/or was accompanied by excessive demands on the "laypersons" involved. At any rate, this is indicated by the survey of the environmental groups (Gill 1993b, p. 35). This problem now draws attention to further procedural dilemmas.

3.6 Resource asymmetry in TA discourses or excessive demands on interested citizens and associations?

At first glance, it seems contradictory, particularly in terms of procedural practice, that the representatives of the environmental groups on the one hand demanded a "problem-induced" TA concept in the sense of an examination of alternatives on the basis of scenarios, but on the other complained about an almost unmanageable "flood of information" (Kiper 1993a; Gill 1993a) and a procedure that took too long. Even if one assumes that the complaint about the flood of information is related to an inadequate preliminary clarification of the problem definition and considers that the complaint about the excessively long duration is to be understood in terms of the desired relevance of the results for decision-making (cf. Gill 1993b), the procedural dilemma remains. The more complex the initial problem is perceived to be and the more its implementation in discursive discussion is considered necessary, the more time-consuming the TA procedure must inevitably become in factual, temporal, and social terms. And even if relief from political decision-making pressure is guaranteed by discourse orientation (cf. Gill 1993a, p. 39), the problem of equal opportunities and equal resources, as discussed by the environmental groups, still arises (AbL et al. 1993). References to the approximately equal distribution of financial resources between supporters and opponents of HR technology (van den Daele 1994, p. 122) are likely to overlook this problem somewhat. Formal equality under conditions of social inequality confirms the latter rather than eliminating it.

On the other hand, the underlying inequality appears to be only partially compensable and only to a very limited extent within the framework of a single TA procedure. It is virtually impossible to achieve a balance between organizations structured according to the division of labor and equipped with considerable resources (large industrial companies, state administration), and functionally less differentiated, far less well-equipped environmental organizations (cf. Gill 1993b). For the latter, the commitment of their resources to TA procedures is almost inevitably at the expense of other tasks; the division of labor between participation in TA discourses or other dialogue offerings and public relations work can be considered *between* rather than within associations (Gill 1993a, p. 40). Comprehensive financial compensation (Gill 1993b) can only remedy this imbalance to a limited extent and also raises the question of the potentially problematic political consequences of professionalization promoted in this way. On the other hand, professionalization is also to some extent unavoidable for the grassroots and public-oriented environmental movement. The fact that the structural promotion of critical expertise is therefore a prerequisite for participation in TA discourses beyond the HR project (cf. Gloede 1994) is hardly controversial. Even parliamentary TA processes of a more strategic nature can hardly fulfill their function without recourse to a plurality of scientific institutes and concepts.

4. Outlook

In summary, I would like to clarify once again the possibility of mediation with regard to the expectations of the TA discourses outlined above, and at the same time ask about the conditions for their realization.

Discursive TA processes are a necessary but not sufficient condition for democratic technology governance in society, especially when the contingency and future orientation of decisions are at the forefront. At best, they are initiated when problems requiring a decision are accompanied by pronounced public dissent.

Such TA processes should attempt to compare *the disputed development and action options in a problem-oriented manner*. They cannot be carried out without preconditions, but must be open-ended. There can be no obligation to reach a consensus.

Their relationship to social and political decisions is communicated via broad public discourse and social conflicts. The *question of a democratization of technology policy* or social technology development can be the subject of such TA and public discussion, but does not coincide with them.

Participation in discursive TA cannot be justified in terms of democratic policy, but only on the basis of the tasks and conditions of discursive processes. Among other things, this means that the participants in discursive TA processes do not have to represent social opinions and interests *quantitatively*, but *qualitatively* or *argumentatively*.

This participation should take place at all three stages of the TA process:

- at the problem definition stage (bounding or scoping);
- at the problem processing stage (parallel expert opinions; controversial scientific discourse);
- at the stage of discussing and using the results (publicity and publication requirement).

There are basically two ways of organizing this process:

- through the expansion of a "*TA network*," i.e., through the pluralistic institutionalization of TA capacities among various social and political actors, who thus participate in public discourse with their own scientific and deliberative capacity (cf. Catenhusen 1988);
- by setting up one or more *central TA institutions*, or by initiating such projects in which plural interests and arguments are brought together in TA processes from the outset. *One* option for realizing this perspective is the

“foundation model” proposed by the Green Party in the Enquete Commission on Technology Assessment (Deutscher Bundestag 1989).

These perspectives are not necessarily mutually exclusive. In any case, in both cases the problem of formal and material equality of opportunity would have to be solved with regard to the consideration of those social arguments and interests that tend to be marginalized by the institutionalized mode of taking interests into account. No patent remedies for this have yet been presented. Catenhusen, for example, calls for state support for interests that are less capable of organization and conflict, as well as for “alternative” expertise (e.g., eco-institutes). The limits of this proposal are obvious. On the one hand, such state funding presupposes to a certain extent the ability to articulate the interests that it seeks to create. And on the other hand, the state funding bodies themselves would have to jump over the selective shadow they cast over the addressees to be funded. However, other proposals pose similar problems.

In addition to participation in – rather rare – discursive TA processes, there will continue to be functionally justified participation in strategic TA, which varies from case to case and depends on its possible contribution to the internal rationalization of the respective client. Here too, there is a latent contradiction between TA’s proximity to the public and its proximity to decision-making. In my opinion, this can also be shown by comparing European forms of institutionalization of TA (cf. Gloede 1994).

On the other hand, in the case of highly politicized conflicts and public criticism with the power to impose sanctions (example: nuclear energy), the organization of a TA process itself can take on the character of a political negotiation. Participatory TA then takes on a *direct* mediative or democratic function – even if only as far as the decision-making powers of politics vis-à-vis society extend.

Such directly political functions can generate neither strategic nor discursive TA on their own – they are and remain dependent on resonance in the public sphere, both as a prerequisite and as a consequence.

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Recognition and acknowledgement: A consideration of the limits to the idea of "early warning"

Preliminary remarks

The German Federal Minister of Research and Technology divides his work on technology assessment (TA) into four areas: Early detection, impact and precautionary research, specific technology assessment analyses, and infrastructure and international cooperation (BMFT 1987, p. 11). A series of national research, such as the project group at the Gesellschaft für Strahlen- und Umweltforschung (Society for Radiation and Environmental Research), which started in 1985 and continued with ecosystem monitoring programs and the development of bioprobes (BMFT 1989, p. 7ff.), also served the early detection of environmental problems in particular. The concept or concern of "early warning" (as it used to be called) is the subject of the following considerations. The focus is not only on early detection as such, but also on its cognitive, normative, and procedural problems, as they arise analogously in the concept of technology assessment in its function as an "early warning system," as an instrument for *timely* detection and assessment.

1. State action and early warning

With the emergence of large-scale technologies as part of the industrial modernization process, the state has increasingly become the driving force and subject of scientific and technological development. Without state planning and decisions, without the pre-financing of research work, the covering of risks, and without the expansion of the economic infrastructure, the development of nuclear technology, for example, would likely not have come about (Keck 1984; Radkau 1989). The technical infrastructure systems in transportation and communication are also often actively built and operated by the state (Mayntz/Hughes 1988). At the same time, however, the state has also assumed responsibility for the associated risks and dangers (Murswiek 1988).

One consequence of this development is the increasing politicization of scientific and technological development. Decisions that used to be made by individual entrepreneurs and scientists have in many cases become political decisions, so that responsibility for the consequences of technological innovations, in particular for their technical and social disruptive potential, is also attributed to the political system. Due to the confrontation with the undesirable consequences and global risks associated with the introduction of new technologies, political action today operates in a field of social debate in which its legitimacy is called into question. In fact, there have been fierce social debates in the field of technology policy in recent years. These have contributed to the dissolution of the population's positive basic consensus with regard to technological progress and have caused a significant loss of legitimacy for politics.

There are many reasons for the politicization of technological development and the fragmentation of the basic social consensus on the future directions of development of industrial society. Factors of social change also play a role here, which are only conditionally related to technical-scientific development, such as an emerging new value consciousness (Klages 1988). It is certain that a major reason for the loss of legitimacy of politics can be seen in its interplay with scientific and technological development, which is difficult for the general public to understand. The use of science and technology increases the interdependence and consequences of decisions and changes to such an extent that it is difficult to grasp all of their future effects. Examples of this are the safety problems at nuclear power plants and chemical production facilities, the impact on the climate, the problems of determining tolerance thresholds in ecological systems, or the consequences of genetic research and genetic engineering. In all these cases, experiments are being conducted with technical possibilities whose exact consequences no one can determine, but for which politicians must develop a solid basis for decision-making and evaluation.

To the extent that research and technology policy becomes a central component of state activity (OECD 1985, p. 68; cf. Hilpert 1989), state action is faced with a dilemma. The task of creating framework conditions for long-term economic and technological growth tends to conflict with the state's task of averting and preventing danger. From the perspective of constitutional law, it has occasionally been lamented that the original and indispensable state task of averting danger is "in retreat" compared to the "performance and control functions" of the modern state (Martens 1982, p. 29).

While the structural policy task involves, among other things, promoting technologies to application maturity that are not developed by the private sector either for cost reasons or because of the high risks involved, the task of hazard prevention involves eliminating existing hazards and preventing future ones.

The political-administrative system thus takes on a dual role. On the one hand, it has become an essential initiator of technological progress; on the other hand, it is supposed to take precautions against the risks and possible negative consequences of the very technologies it promotes (Saladin 1984).

This situation is also reflected in national research policy. In the German federal research report 1984 (Bundesforschungsbericht), for example, the general objectives of research and technology policy included not only the promotion of scientific knowledge and technical innovation but also the conservation of resources and the environment, as well as the improvement of living and working conditions (BMFT 1984, p. 14). In this report, the German Federal Government states that it sees "the opportunities of technological development in conjunction with the risks." It must succeed in "exploiting the opportunities offered by technology and reducing possible disadvantages to the lowest possible and at least acceptable level in an orderly process of risk assessment, political opinion-forming and decision-making" (BMFT 1984, p. 18).

In order to achieve these goals, the German Federal Government relies, among other things, on "systematic technology impact and potential assessment" and "early warning" (BMFT 1984, ibid.). In its report "Status und Perspektiven der Großforschungseinrichtungen" [Status and perspectives of large research institutions], it goes into more detail on the aspect of early warning. There it reaffirms its intention to build up an "early warning network" for the early identification of potential danger areas and risks (but also technological opportunities) by drawing on the scientific and technical potential of large research facilities in order to be able to take appropriate measures in good time (Bundesregierung 1984a, p. 30). In the meantime, appropriate steps have also been taken to coordinate existing knowledge toward such an objective and to develop new types of scientific observation instruments (BMFT 1987, p. 15; BMFT 1990, p. 5ff.).

The formula of "early detection of technology-related dangers and risks" is to a certain extent the link in the centrifugal movement of the diverging roles of the state administration: Technology is to be massively promoted, but at the same time the problems, side effects, and long-term consequences of these promoted technological developments are to be recognized in good time in order to limit or completely avoid the corresponding risks.

However, containment and avoidance require the will of the political administration to abandon developments if necessary, or at least to modify them and promote alternative technologies.

If one analyzes the term "early recognition," it has two components of meaning: A cognitive one (*early recognition* of problems) and a normative one (*timely recognition* of developing problems that call for political action). Although mixed in the specific case, the analytical distinction between these two functions of early recognition – which can also be applied to TA – is helpful: On the one hand, it is a problem of knowledge, of stimulating research, of more precise or even just more sensitive observation, of discovering connections; but on the other hand, it is a problem of recognizing problem situations, i.e., of accepting that action must be taken without the respective problem situation having already developed into an irrefutable political and social problem.

From a *cognitive point of view*, early detection implies that its task cannot be limited to the identification of already emerging individual risk areas or suspicious toxic substances. The singular risk, the monocausal analysis of cause-and-effect chains cannot be its primary object, even if it absolutely must be based on the relevant research that has already been carried out.

The specificity of early detection obviously lies in those dangers and risks that have a "systematic" quality in terms of their causes and/or effects.

In terms of the constellation of causes, these are dangers that can arise from the exposure of ecological systems to small quantities of substances that were previously considered harmless (the "sleepers" so to speak, among the consequences of technology), or synergistic effects that have not been researched. In terms of the effects, we are talking about potential damage to (interdependent) systems (biotopes, political systems, social structures) that do not occur as a result of a single factor.

It follows, as will be shown, that normative aspects (e.g., selection and relevance criteria) are incorporated into the organization of the cognitive process of early detection at each stage (problem identification, problem conceptualization, information selection and analysis, interpretation, and result evaluation).

From a *normative point of view*, early detection implies that hazards and risks are identified and qualified early enough to define "alternative courses of action" and prepare "decision-making" (BMFT 1984, p. 30), which leads to their containment and prevention. Since – as mentioned – relevant research activities (including long-term forecasts) already exist, a key political and institutional aspect is obviously to coordinate existing and, if necessary, newly created capacities in the field of technology research with the explicit objective of "early warning" and to orient them toward scientific policy advice.

However, this raises a specific political problem. Early or timely recognition of technology-related dangers and risks also means that it takes place at a time when these dangers have not yet manifested themselves, i.e., they have not yet created an immediate need for political action. Where possible, prophylaxis should replace therapy.

In view of the cognitive, political, and institutional characteristics of early warning, however, it is obvious that this form of scientific policy advice is less able to replace political decisions and actions than other forms. Early warning will – as has been and continues to be the case with TA – be scientifically and politically controversial. The new demands it places on science and politics will be analyzed in the next two sections.

2. Possibilities and limits of scientific methods for early warning

The German Federal Government's 1984 report on the status and perspectives of large research institutions, in which the intention to set up an "early warning network" is stated, gives the impression that the primary aim is to align, reorganize, and restructure existing knowledge and scientific infrastructure toward the goal of "early warning" (Bundesregierung 1984a, p. 30f.).

Although the diagnosis and prognosis of technology-related risks to humans and the environment cannot be the sole task of individual scientific disciplines and is therefore already the subject of wide-ranging research in the economic and social sciences, as well as in the field of practically-oriented project research (risk and safety research, environmental impact research, systems analysis, and technology assessment), the impression is that it is the "exact" natural sciences in particular that are expected to provide the most unequivocal findings possible on cause-and-effect relationships in this field. Such "hard" findings are intended to prepare the ground for decision-making.

And there is more: The Bundesforschungsbericht VII [Federal Research Report VII] states that "reliable technical-scientific" statements are the prerequisite for environmental policy action, e.g., statements that "clarify ecological relationships and causal causes/effect chains" (Bundesregierung 1984b, p. 128).

The example of the large-scale experiment at the time of the report on the effects of a speed limit for road traffic on air pollution illustrates this attitude of "acting only after unquestionable scientific knowledge." A more recent example is the German Federal Government's argument that a ban on the use of atrazine is only justifiable if valid and representative results from so-called lysimeter studies are available.

In order to avoid the misunderstanding that politics and the administration alone are being blamed for an overly naïve view of science, it should be clearly stated that the high expectations of science, and the overestimation of its possibilities, are for the most part aroused and nurtured by scientists themselves, and are still often shared today in an equally naïve manner. In our opinion, one of these overestimations is the enduring idea of the possibilities of predicting the development of complex systems.

Current research into the causes of forest dieback and comparable ecological problems clearly shows that the natural sciences are confronted with the interactions between humans and the environment in much the same way as the social and economic sciences are confronted with the complex system interrelationships of their subject areas (Süddeutsche Zeitung, 11.11.1983). These are open systems that are influenced by rare, unpredictable events; systems with non-linear relationships between multiple factors.

Classical natural science often finds it difficult to reach conclusions here because certain standards apply to the recognition of classical scientific work, such as experimental repeatability, proof of causal linkage, statistical proof of significance, freedom from contradiction, and evaluation by the scientific community.

It would also be unrealistic to believe that the consequences of technology can be largely predicted through more intensive scientific research before the technology has even been implemented. In the vast majority of cases, early warning will probably amount to recognizing the emerging consequences before they have taken on an "epidemic" character.

From the temporal aspect – early warning after implementation or prior to implementation – the methodological problems of early warning are to be structured according to two basic approaches:

- problem recognition through the observation of symptoms, i.e., changes compared to the past, which are assigned a "disease value," or which are classified as problematic in some way (Sec. 2.1);
- problem identification by combining and integrating individual knowledge and experience, analogy building, modeling, and simulation to create a forward-looking scenario of the possible effects of one or more technologies (Sec. 2.2).

2.1 Identifying problems by observing symptoms

Damage – e.g., to certain ecosystems or health impairments – is often perceived, the causes of which are unknown at the time of perception and which could not have been causally deduced from the observer's knowledge of the affected system. The problem becomes noticeable through the "conspicuousness of its symptoms," i.e.:

- Changes must already have occurred that are so far advanced that sufficiently conspicuous symptoms become visible.
- There must be an observer who classifies the symptoms as conspicuous, atypical, or pathological.

The symptom-oriented approach is *retrospective* and *analytical* with regard to the identification of risk areas, because it is based on effects that have already occurred, which should be recognized at the earliest possible point in time and analyzed for their causes. Popular examples of problem identification based on symptoms whose causal classification is largely unknown – indeed whose existence is doubted by some scientists in the contexts discussed – are "forest damage," "acidification of lakes," "pseudo-croup," an increase in allergies, or increased mortality during smog episodes.

These examples from the field of ecology illustrate the fundamental problems and possibilities of early detection using a symptom-oriented approach. The case studies are characterized by the following:

- These are relatively cause-unspecific symptoms and phenomena. What is new about the phenomenon of "forest damage," for example, is not necessarily the symptoms themselves, but the possibly novel causes, the frequency, and the spread of their occurrence. The same applies to pseudo-croup and the increase in allergies.
- It is difficult to recognize an epidemic development in good time if the "normal" frequency and the variation in occurrence are not known, especially in the case of cause-unspecific symptoms. One example of this is the so-called "marine bloom," which occurs naturally but is also discussed in connection with marine pollution. This is a short-term explosion in the growth of certain marine algae. Although observations of this phenomenon have been available for a relatively long time and a number of factors for its occurrence are known, there are still so many unknown influences that it is almost impossible to predict when a marine bloom will occur.

- The problems under discussion here are aptly described in the ecological or medical field as complex diseases. This means that many influences and circumstances are involved in the development of the disease, which can often vary from case to case. For example, "itai-itai disease" is most likely not a consequence of high cadmium exposure alone, but must also be caused by poor nutritional status.[1] However, this example also shows that unexpected problems can arise very quickly, for example in connection with certain heavy metal exposures, if influencing factors such as nutritional status etc. change.
- Attempts to clarify the genesis of the observed symptoms often lead to influencing factors, which in turn are very complex and little known (such as the correlation between the input of pollutants into the soil and changes in the microflora and fauna, and thus also certain symbiotic systems of higher plants).
- Statistical investigation methods, primarily correlation analyses (epidemiology), provide indications of potential correlations, but no causal evidence. In the case of air pollutants, for example, several pollutant components correlate with respiratory diseases. To date, it has not been possible to make individual pollutants unequivocally responsible for the observed effects.

However, the role of the observer with regard to early detection should by no means be limited to those with specialist training.

This is particularly true where previously unknown consequences or symptoms are triggered by previously unknown causes. Negative consequences may be perceived more readily by those affected than by experts. However, those affected often do not have the relevant specialist knowledge to be able to go beyond the diffuse feeling that something is conspicuous and not "in order" and provide evidence of actual damage that is recognized by science and politics. However, case studies show that "lay judgement about technical hazards reveal a sensibility to social and political values that experts' models would not acknowledge" (Fiorino 1990, p. 227).

In practice, therefore, the question arises not only of an observer, but also of a corresponding procedure for assessing observations. This is where science has a decisive "filtering" function. Those with the appropriate professional training are better able to recognize whether the observed symptoms should be assigned a "disease value."

1 *Editors' note*: For further information, see: https://en.wikipedia.org/wiki/Itai-itai_disease (accessed 25.04.2025).

In order to gain more knowledge about the process of uncovering problems, the role of individual social groups in discovering negative consequences, in general recognition, and ultimately in coping with the consequences, a well-founded investigation of the processes using current and past cases would be useful. Case studies of this kind on "forest damage" and "pseudo-croup" could probably provide important information about the role of individual social groups in this process.

A systematic search for potential undesirable consequences of technologies is possible if certain search criteria can be found. This task largely falls within the remit of science. Criteria for a systematic search require knowledge of the properties of emitted substances, for example, or knowledge of the observed systems, which can be used to distinguish "normal conditions" from "abnormal conditions." Knowledge of frequencies, geographical distribution, sensitive areas, and temporal variation is particularly important for the systematic observation of disease symptoms.[2]

2.2 Problem identification through system-oriented approaches

In contrast to retrospective-analytical problem identification, the system-oriented approach is *prospective* and *synthesizing*. Formally, two approaches are possible: *Targeted experimentation to observe the reactions of the systems* and thus gain *direct* knowledge about the negative effects of technologies and products, and the *combination and integration of individual findings, model development, and simulation*.

Targeted experimentation to observe the reactions of the systems

The path of gaining direct knowledge about the negative effects of technologies through experiments with natural systems is only feasible in exceptional cases. Although the advantage of leaving the system in its natural environment is obvious, experiments under realistic conditions might have to expose the system to the very dangers that need to be prevented. Further difficulties arise from the

2 Cadastres are already being planned or installed with this aim in mind (usually referred to as "impact cadastres"). Experience to date has shown that area-wide cadastres are problematic due to their high cost, the often too low resolution for an early warning system, and the resulting "smearing" of regionally limited effects. For "point-based cadastres," knowledge of sensitive systems or highly polluted and therefore potentially endangered areas is required. In any case, "point-based cadastres" are useful as "probes" alongside area-wide cadastres.

often long periods of time over which realistic experiments would have to be carried out and – for example in studies on the effect of small doses of pollutants – from the large number of studies required to achieve an acceptable level of significance.

Another problem with experiments on natural systems is usually the large number of interfering factors, which are often the reason why the causal relationships cannot be clarified despite careful planning and execution of the experiments. If we consider, for example, the possible effects of emissions from waste incineration plants etc. on ecosystems, it is not possible today to say with certainty what the composition of the emissions is. A permutation of multifactorial impacts and their mostly multifactorial effects often already shows the hopelessness of an exclusively experimental approach to the direct identification of potential hazards.

Of course, measurements are absolutely necessary in order to clarify the impacting factors, e.g., the type and quantity of certain environmental noxae in soil, water, and air, to investigate the spread and deposition of pollutants and their transition rates into the endangered systems. This experimental inventory, e.g., in the form of "substance-related screening" or "exposure-related monitoring," and research into the processes leading to the mechanisms of system damage must be an integral part of an early detection system. However, even with intensive research, complete knowledge cannot be expected, not least because ecological, social, and economic systems are not constant over time. Even under natural conditions, for example, species die out without the influence of humans and technology, and equilibrium conditions change in such a way that individual systems "tip over."

In order to investigate specific influences under defined conditions, which is impossible in natural systems, parts of the system can be investigated under laboratory conditions. It must then be taken into account that certain control loops, symbiotic systems, synergetic or anergic factors are excluded by "cutting out" the natural environment. If, on the one hand, the certainty of knowledge with regard to the system under artificial conditions is increased, the certainty as to whether the natural system will react in the same way as the system isolated in the laboratory is reduced. However, experiments in a closed laboratory open up the possibility of exposing the isolated system to conditions that might already pose a risk in natural systems.

Combination and integration of individual knowledge, modeling, and simulation

In addition to TA studies, this approach is also characterized by the studies of the Club of Rome (Meadows et al. 1973) or "Global 2000" (Barney 1980; Deutscher Bundestag 1988). The approach of these studies is characterized by the cognitive or numerical derivation (construction) of conceivable future states of complex systems on the basis of current knowledge.

The problems and advantages of the non-experimental approach are outlined below using the example of modeling and the simulation of model systems on computer systems. However, these explanations largely apply to all non-experimental system studies. Experimental simulation, for example of flow conditions on city models in a wind tunnel, is not explicitly dealt with here.

The most frequently used method of numerical simulation of complex systems, such as Meadows' world model or the various CO_2 models, can be described as follows: Starting from the real system, a model is constructed that is intended to represent the behavior of the real system with sufficient accuracy. In order to achieve this goal, the knowledge about interrelationships in the system, previous developments, the current state, external influences, etc. – in short, the current state of knowledge – must be compiled and documented. When constructing the model from the mosaic pieces of existing knowledge, the gaps in knowledge crystallize particularly clearly.

In mathematical formulation, models usually consist of systems of differential equations. Based on certain predefined initial and boundary conditions, which are often hidden behind the concept of scenarios, the system of equations is integrated. With this simulation technique, different system states can be examined, so to speak in "fast motion," for the effect of various influences as well as for sensitivity to these influences. Simulation is therefore primarily a technique for researching the dynamics of couplings and feedback in the systems and therefore, in principle, offers the possibility of analyzing correlations and development trends under the conditions set by the "model designer."

Ideally, a complete, tested, and validated numerical model would be an excellent early warning instrument. During the first development phase of numerical model simulation, which was accompanied by much euphoria, many scientists envisioned the design of such forecasting systems. In the meantime, the possibilities of this method for forecasting the future of complex systems following serious quantitative mispredictions (e.g., about energy requirements) have been assessed more realistically and critically by many scientists.

Despite this, high expectations are still being placed on mathematical modeling and computer simulations of complex systems in some circles, both within and outside the scientific community.

To be clear: If, looking back from today's experience, we have to correct some expectations, this is not a reproach against the attempts to forecast future world developments, provided they were carried out and evaluated seriously as simulations of thought constructions and computer experiments. On the contrary: These experiments were necessary in order to sound out the scope of the newly developed possibilities of studying complex systems with the aid of computer technology.

However, criticism is warranted if nothing more is revealed behind the veil of apparent scientificity and apparent rationality than fictions and preconceived opinions.[3]

The impression is often given that a process once translated into computer language can, according to Steinbuch (1974), for example,

> [...] be examined analytically – in a sense – in its structure and stringency, and on the other hand – synthetically – with regard to its consequences under the most diverse conditions.

This may be correct *in principle*; but practice in dealing with large program systems and databases, especially if these are also networked via computer systems, shows rather the opposite. It is quite impossible even for the scientifically trained "everyman" to gain insight into and an overview of external program systems.

When Steinbuch (1974, p. 44) and others attribute to "future" computers a "superiority over the human brain with regard to all rational mental processes," they have unfortunately overlooked the fact that these machines not only increase intelligence, but – "incorrectly programmed" – also increase stupidity.

We must ask, on what foundations these optimistic visions of science stand – or rather – stood.

If we summarize the basis of Steinbuch's opinion that in future humans will only have to specify a value system and that the optimal solution to problems will then increasingly be a matter for computers, which are far superior to the human

3 Every "insider" knows how densely the veil of impenetrability can be woven, especially with today's instruments of mathematical models in conjunction with computer technology. It is not wrong when it is claimed that ignorance, incompetence, and mediocrity are the easiest things to hide behind computer programs today.

brain in terms of rational and intellectual functions, then these foundations are the following:

- The truth criterion of a "regularly correct forecast" based on repeated experiments,
- Rationality of the procedure and the resulting ability to criticize, whereby rationality is assigned very specific characteristics (explained information and procedures),
- The assumption of a constancy in natural processes that can be generated experimentally.

This foundation is none other than that on which the classical natural sciences based their successes. However, measured against the problems for which the early warning system is to be designed, those dealt with very primitive systems.

One example is gas dynamics. The laws of gas dynamics were discovered by studying the behavior of gases, which were easy to study when confined in containers. Naively, one could now believe that a consistent application of these laws in conjunction with other physical laws identified in the same way, such as the law of radiation, would enable a long-term and correct forecast of weather events in the gaseous sphere of our planet. If we now compare the weather forecasts for a prediction time of one week or longer with the development of the real system, the probability of a correct forecast is not too far removed from chance.[4]

The mathematical model formulations of complex technical and scientific systems and their simulation on computer systems are fraught with problems such as gaps in knowledge, uncertain assumptions about the size and correlation of parameters, and results that are difficult to interpret in models of high intrinsic complexity. In the uncertainty of their results, these natural science approaches do not differ from analogous social science attempts to analyze social systems. Furthermore, the actual purpose of scientific policy advice becomes questionable:

> The more differentiated forecasts [based on model calculations; the authors] become, the less suitable they are for justifying political decisions (Teichler 1985, p. 216; see also Luhmann 1969, p. 14).

4 This also applies to long-term forecasts in other areas. There is a biting, but not inaccurate, opinion circulating in relevant scientific circles about the attempts to forecast energy demand: They all have one important thing in common, namely that none of them are accurate.

This could give the impression that the sciences are hardly in a position to contribute to early warning. This is not our intention and is certainly wrong. It is merely to point out that the naive view of the classical natural sciences is not suitable for solving the problem in view of the systems with which an early warning concept for the negative consequences of mechanization has to deal.

If we summarize the previous considerations, we can state the following:

- The scientific methods available for the early detection of developments in large, real, dynamic systems often do not allow for unquestionable findings about causal relationships. The traditional standards of scientific certainty can hardly be met (EWERS 1988). As in the case of long-term technology assessment, for example, we would have to speak of "possible consequences," of which, for the most part, neither the manifestation can be described exactly nor the course of events predicted with certainty (Bechmann/Wingert 1981a).
- Inevitably, normative decisions (selection of indicators and measurement methods, model constructions, and data selection) are involved in the analytical procedures and the interpretation of results, which are difficult to reconcile with simple notions of neutrality and value-free scientific work (Teichler 1985; Wynne 1983).
- Due to the characteristics of the systems under consideration – such as historically developed uniqueness, irreversible change in the event of interventions, unmanageable variety of potential development possibilities – proven scientific "truth criteria" such as the "regularly experimentally confirmed prognosis," the reproducibility of the results of the same experiments, the possibility of proving statistical significance, or verifiability by the community – fail in their investigation.

Accordingly, expectations on the part of the political administration with regard to "well-founded scientific evidence," which are also repeatedly stirred up by industry (Dickson 1981, p. 58), can usually only be disappointed, especially in the field of early warning of technology-related dangers.

However, the *political processing of* relevant expertise is likely to pose even greater difficulties for a practically effective early warning.

3. Early warning as a political problem

Eduard Pestel's pessimistic prognosis that

> [...] it will probably be decades before politicians base their decisions on scientific findings and are prepared to take into account in their decisions catastrophes which, if they act or fail to act, will only threaten in the distant future (Wissenschaft, Wirtschaft, Politik 1984, p. 3[5])

is possibly based on intimate knowledge of the inner workings of power. However, by suggesting that successful early warning fails for the time being due to the subjective inability and unwillingness of individual representatives of the political-administrative system to learn, it fails to recognize the structural conditions and limits for taking scientific findings into account – whether they are of "hard" or "soft" evidence (Ravetz 1984, p. 11).

Even if "exact" findings are available – for example on dose-response relationships in the case of chemicals or pharmaceuticals – administrative consequences are by no means self-evident. Rather, the determination of "safe" limit values for substances and emissions is the product of political decision-making. Their justification is not scientifically possible, "since there is no scientifically comprehensible trade-off between health and freedom, between social security and nature conservation and similar values" (von Lersner 1983, p. 138f.). Embedded in social conflicts of interest (Weidner/Knoepfel 1979, p. 161), the process of political-administrative problem processing decides "what is dangerous" (von Lersner 1983, p. 133). This became clear, for example, in the public disputes about the "Hazardous Substances Ordinance" ("Grenzwerte für giftige Stoffe politisch gesetzt", Frankfurter Rundschau, 18.4.1985) and about radioactive contamination after Chernobyl.

In addition, numerous problem areas and potential hazards are already known today that no longer require early warning. We can think of the common problematization of causal relationships (energy production, industrial production, agriculture, waste management, car traffic, and households), "prominent" toxic substances (formaldehyde, dioxins, PCBs, atrazine) as well as threatening levels of damage to elementary ecological systems (soil poisoning, water quality, ecological death in the North Sea, forest dieback, reduction of biodiversity). Also, much damage to human health associated with critical environmental conditions is no longer waiting to be discovered through early detection (environmentally

5 *Editors' note*: No bibliographic details were provided in the original publication.

induced increase in allergies, cancer incidence, respiratory diseases, workplace-specific diseases) (Koch 1985; Umweltbundesamt 1984).

In most of these problem cases, there were complaints that politicians "do nothing or too little" (Koch 1985, p. 6). The population seems to share this view. According to a survey conducted by the Ipos Institute in 1985 on behalf of the German Federal Ministry of the Interior, only 18 % of all respondents "believe in successes in environmental protection since the Bundestag elections in March 1983" (Frankfurter Rundschau, 16.8.1985). According to an opinion poll of the Institut für Desmoskopie Allensbach, 28 % of respondents trusted the Minister of the Environment to solve the tasks set, while 72 % had confidence in Greenpeace in this respect (Handelsblatt, 17.10.1989). In the view of many experts, the measures taken by the political administration are usually not far-reaching enough. This can be illustrated by the example of forest dieback and the policies pursued in this context (Large Combustion Plant Ordinance, Technical Instructions on Air Quality Control (TA-Luft), speed limits, catalytic converter cars) (Bechmann et al. 1985, p. 409).

This makes the question of the structures and mechanisms of the ultimately decisive political and administrative processing of warnings about the consequences of technology all the more urgent.

3.1 General selection services of the political system

Only a few studies have systematically reconstructed cases of failure to provide early warning or failure to recognize dangers (Crenson 1971). However, from existing studies on the functioning of the political-administrative system, as has become clear in various policy areas[6] (Russ-Mohl 1982, p. 3ff.; von Prittwitz

6 Von Prittwitz explains the development of environmental policy from "different factor complexes," namely "the state of action capacities and environmental pollution. However, each set of factors is of unequal importance. Effective environmental policy can only develop if sufficiently large technical-economic and political-institutional capacities for action are available. If these are lacking, even the most severe environmental impacts will not lead to an effective response. Environmental pollution, environmental crises, or disasters are only possible triggers or amplifiers of environmental policy action on the basis of sufficient capacity for action. If this is the case, the calculations of goal-oriented environmental policy generally gain in importance. Environmental policy therefore often intensifies as the capacity to act increases or as problems are overcome; it therefore primarily expresses the state of the capacity to act and has a more pro-cyclical than anti-cyclical character" (von Prittwitz 1990, p. 114f.).

1990, p. 103ff.), some general insights can be gained that are relevant for the "recognition" of technology-related hazards.

Every differentiated social subsystem, including the political subsystem, has the basic problem of securing its existence in relation to the social environment and its demands by reducing and processing its complexity in accordance with its functional requirements (Rucht 1982, p. 37). Accordingly, the political-administrative system can be characterized by *general selection mechanisms* that distinguish it from the other subsystems. With regard to social problems, Russ-Mohl rightly states:

> There are many problems [...]. Very few overcome the threshold of repression and non-decision and thus become a *political* issue (Russ-Mohl 1982, p. 6; emphasis added by the authors).

The attention and thematization criteria of the political system[7] are particularly relevant to the question of early "recognition" of impending dangers. They are what make a named problem in need of a decision in the first place.

Luhmann includes:

- the perceived threat to overriding social values;
- crises that jeopardize the functioning and existence of the political system;
- the socio-political status of the person addressing a problem;
- symptoms of political success that seem to be associated with the adoption of an issue;
- already occurring "pain or civilizational pain surrogates" (e.g., loss of income) in connection with a problem situation (Luhmann 1970, p. 13).

The process of an issue entering the political arena is further accelerated by events such as the exacerbation of problems as a result of cumulative effects or protests by those affected by the problem (Russ-Mohl 1982, p. 6; Mayntz 1983, p. 335).

These rules of attention refer to the structure and "ratio" of the political-administrative system, whose elementary communication medium for the production of binding decisions is "power" (maintaining and gaining power), while the

7 It is not enough for a problem to have already attracted public attention for it to become the subject of political processing. Many problems are recognized relatively early on – after the effective "attention rules" of the political system, "decision rules" come into force, which decide on the type and manner of the measures ultimately taken (Luhmann 1970, p. 11).

communication medium "truth" of the scientific system or "factual rationality" plays a rather subordinate role in its processing (Mayntz 1983, p. 334).

It must therefore be possible to translate problems into the frame of reference of gaining and maintaining power for individual politicians, parties, or the entire political system. The decision-making rules and the question of the implementation of measures to be adopted are also determined by the rationale of the political system. In addition to the decision-makers' interest in their own political survival, Mayntz points to the criteria of the "feasibility" of problem solutions as well as the material and financial restrictions. Political feasibility means the support of measures and their implementation by relevant actors in the political arena or "acceptance" by the population; financial feasibility is ultimately based on the political influence of the respective interested parties and their ability to present the measures to be implemented as particularly urgent (Mayntz 1983, p. 334).

The analysis of the general selection mechanisms and the ratio of the political system therefore leads to the following conclusion: What also applies to technology assessment applies to the chance of scientific expertise being taken into account: The improvement of its cognitive quality (methodology, validity), which is certainly desirable, is far less decisive than its compatibility with political criteria and processes. "Technology assessment [or early warning; the authors] therefore requires advocates with sufficient power within the decision-making system" (Mayntz 1983, p. 339).

3.2 Social and institutional boundaries

The general selection mechanisms outlined would now have to be specified in more detail for given political systems.

At this point, we will only draw attention to some of these *specific selection achievements*, insofar as they can be related to the consideration of technology-related dangers for people and the environment in Western industrial societies.

Following Offe, a distinction can be made between the structural, ideal, and procedural levels (Offe 1972, p. 79ff.; cf. Bachrach/Baratz 1977, p. 87ff.):

- *Structural selection services* are provided by the overarching historical, socio-structural, and economic framework conditions of a political system, which are reflected in its basic constitutional and institutional provisions. In this way, a preliminary decision is made as to which issues and matters can become the subject of state policy at all, and which premises and scope for action apply. In the area of environmental policy, for example, the structural selection achievements in the public debate on the relationship between economy and ecology become visible. In principle, ecological issues can only be raised in the political arena and considered with proposals for solutions to the extent that they are compatible with market economy conditions and means (Offe 1972, p. 83).

- *Ideational selection services* are provided by the prevailing socio-cultural and political system of norms and further restrict the structurally available scope for action of the political system. Such selective norms range from the slowly changing dominant value orientations of society, established political preference structures, and legally standardized norms to the frequently discussed "sensitivity" of social actors to specific problem situations. For example, it was the "lack of sensitivity to the ecological hazard potential" that characterized the Hamburg Senate in the opinion of a parliamentary committee of inquiry, despite the existence of legal possibilities for action and control in the case of the Georgswerder hazardous waste landfill (Der Spiegel, 4.3.1985).[8] Of greater importance in this context may be the criteria according to which the necessary balancing processes between conflicting economic, social, and environmental policy objectives are carried out with regard to an early assessment of technology-related hazards and the costs of averting them. To date, for example, it cannot be assumed that the costs of eliminating environmental damage are systematically included at the macroeconomic (or even business management) level (Simonis 1988).
- Finally, *procedural selection services* are provided by the formal and informal procedures of policy formulation and their implementation, which in turn predetermine the possible content or the possible outcome of the processing of early findings on technology-related risks. In this way, certain interests and content are given greater chances of being implemented, while other topics or social actors tend to be excluded from these procedures. With regard to "collective bargaining" between associations and state authorities, it has often been complained that "nature" has no lobby.

  The same applies to socially underprivileged groups, or groups with little capacity for conflict, who are often burdened with the costs of crises and state crisis policy (Russ-Mohl 1982, p. 25). Their interests are usually difficult to organize; they lack material, human, and information resources and expe-

8 For further information, see: https://www.internationale-bauausstellungen.de/en/history/2006-2013-iba-hamburg-leap-across-the-elbe/energy-hill-georgswerder-a-landfill-becomes-an-energy-hill/ (accessed 16.04.2025).

> rience in dealing with political procedures. In contrast, the "interests of those who cause [problems; the authors] are usually (and especially when they are producer interests) represented in the political system through clientele relationships," and "this circumstance can (even without lobbying efforts explicitly related to the problem) already be sufficient cause for denial or neglect of the problem and non-decision on the part of politicians" (Russ-Mohl 1982, p. 5).

The analysis of the specific selection mechanisms shows that: In the political system, early warning of technology-related dangers must reckon on the one hand with the influential dominance of interests and values that are linked to industrial progress and the market economy, and on the other hand with a tendency to repress interests and values that have a low capacity for organization and conflict. Environmental protection and the improvement of "quality of life" for broad sections of the population must still be counted among the latter (Frederichs et al. 1983, p. 17ff.).

From two sides, the selection mechanisms of the political system obviously pose particular difficulties for early warning, with far-reaching consequences:

- As explained above, the expected expertise is generally even more "uncertain" than the already established scientific policy advice. In this respect, it is even more dependent than the latter on a promising transmission into the political arena – and that means: On "advocates" who can mobilize political power for their recommendations.
- Since the subject matter of early warning concerns dangers and damage that have not yet occurred (on a large scale) and/or do not (or cannot) affect any dominant interests in the political system, early warning has a particularly low chance of finding such advocates and generating a willingness to act.[9]

Accordingly, it is much more likely, and paradoxically a background experience for the call for early warning, that the aforementioned structures in the political system do not initially give rise to any real willingness to deal with an indicated problem situation. Scientific expertise tends to be received according to the extent

9 In this context, one could also point out that heeding warnings is politically a thankless business. In any case, it causes high costs and does not necessarily pay off in the case of a "successful alarm" (Clausen/Dombrowsky 1984, p. 302), as it destroys the proof of the soundness of the warning at the same time as it eliminates the danger. For the audience interested in the politician, a professionally correct warning can then no longer be distinguished from a false prophecy.

to which it helps to "objectively" justify the rejection of recommendations and demands (Mayntz 1983, p. 337). If this reaction is no longer sufficient, "symbolic politics" is used to give the impression to those affected and the public that the political administration "has things under control" (Mayntz 1983, p. 335; Russ-Mohl 1982, p. 7; cf. Bechmann et al. 1985, p. 409).

It can therefore be assumed that all attempts to improve the cognitive performance of early warning must remain practically futile if the chances of its transmission into the political arena cannot be improved. But given the specific selection criteria, how is expertise supposed to find influential advocates in the political-administrative system at an early stage?

4. Opening up the political system to science and the public

Initially, it seems obvious to look for advocates who already play a more or less important role in the political decision-making process. In concrete terms, the known cognitive, normative, and functional problems in communication between experts issuing warnings and political actors present themselves as obstacles. Recommendations encounter difficulties in understanding, reservations on the part of political actors with regard to value premises, and perceived impairments of their sole decision-making authority (Mayntz 1983, p. 336ff.). However, dealing with trans-scientific issues in particular requires the organization of a communication context not only in terms of content, but also institutionally, in which the classic distribution of roles between the politician as decision-maker and the scientist as advisor is gradually abandoned. Van den Daele et al. have coined the term "hybrid community" for this new network between politics and science. The selection and discussion of the relevance of different research approaches, the strategy to be pursued, and the evaluation of the results must be jointly discussed and represented. In doing so, the representatives of politics and administration must engage with internal scientific problems and link their decision-making premises to scientific discourses (van den Daele et al. 1979). Such hybrid communities can already be found to some extent in various areas of project-oriented research. The Enquete Commission in the German parliament also represents such a case. The formation of a hybrid community oriented toward early warning would be supported by the fact that the politicians involved in it would certainly represent the resulting warnings in the political system with greater commitment and dedication.

A second consideration for finding suitable advocates for early warning in the political system lies at the level of organizational and procedural institutionalization. With regard to the comparable problem of raising the chances of technology assessment being taken into account, it would appear to make procedural sense to prescribe early warning by law, and at least its acknowledgement in the process of political decision-making (Mayntz 1983, p. 340f.). However, this perspective fails to recognize that the individual actors also make or are subject to the general and specific selections that are responsible for the fundamental dilemma of early warning. In other words, an institutional allocation of early warning capacity to the highly influential ministerial bureaucracy in Germany in no way guarantees that the latter will exert its influence on expected warnings. Precisely by keeping expertise out of political-parliamentary controversies (Mayntz 1983, p. 341), the danger of its dethematization would grow under the given circumstances.

At the same time, this highlights the fundamental limitation inherent in all proposals to seek advocates for early warning only among the actors already dominant in the political system, or to reduce the problem to the communicative, procedural, and institutional relationships between science and politics.

A relaxation of the specific selection mechanisms for the recognition of technology-related dangers can only be expected, taking into account the rationale of the political system, if systematically excluded interests, values, and actors are given easier access to the debates in the political arena. Conditions must also be created in the relationship between the political system and the public that promote the willingness to recognize and deal with dangers.

Similar to technology policy decisions, the perception and political treatment of early warning should also be understood as a social conflict and consensus-building process. Accordingly, the public should be involved in the initiation, implementation, and evaluation of early warning expertise (Paschen 1983, p. 425ff.; cf. OECD 1979, p. 114):

- In the early warning initiation phase, public participation can help to identify problem areas and issues for early warning. This is the only way to ensure that social needs and interests are taken into account at an early stage and on a broad basis.
- In the implementation phase, public participation should, within certain limits, promise the development of additional knowledge resources (cf. Sec. 2). Such experiences have been made not only in the context of technology assessments, but also in various areas of government planning (Hucke et al. 1984, p. 214ff.; Türke 1981, p. 1). The inclusion of representatives of the public

in advisory and control bodies of early warning-oriented research should also be considered (Mayntz 1983, p. 343).

- In the phase of discussion, evaluation, and administrative processing of results, public participation improves the chance that warnings and identified hazards will be recognized by more social actors and broader sections of the population, and may prompt action.
- In this way, early warning would be more likely to meet the political system's criteria for thematization. At the same time, instances within the political system itself are likely to be found more quickly, which, in view of the political benefits that can now be expected, will become advocates for the warning.
- Finally, by making the early warning results the subject of a broader public debate, the possibility of finding support for the measures to be taken and their administrative implementation also increases. It is well known that political measures in the field of environmental protection are particularly dependent on such public support.

If these considerations are systematically applied to the modification of those selection mechanisms of the political system that hinder effective early warning, then public participation could have two main effects:

On the one hand, it would lead to an expansion of the values, interests, and political preferences taken into account (ideal selection), and on the other hand, it could generate a willingness to act via the lever of the political actors' need for support and legitimization (procedural selection). In this context, it is not least important that the scope for action of administrative actors would be increased in relation to the often dominant social interests in the political system with reference to the attitudes and demands of the public (Hucke et al. 1984, p. 219).

Although it must be conceded that the political decision-making process and administrative control through public participation in early warning expose themselves to greater expectations, there is no guarantee of successful social consensus building on dangers and countermeasures to be taken (Bechmann/Wingert 1981a, p. 324; cf. Paschen 1983, p. 364). Just like the dissolution of the rigid boundaries between science and politics through problem-oriented hybrid communities as carriers of early warning, the opening of the political-administrative system to the public also contains risks. However, this appears to be the price that must inevitably be paid if the risks of a lack of early warning or incrementalist management of technological consequences are to be avoided.

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4.
TA as a theoretical approach – the action-theoretical and system-analytical dimension

Herbert Paschen, Thomas Petermann

Technology assessment: A strategic framework for the analysis and evaluation of technologies

Preliminary remarks

In 1966, the Subcommittee on Science, Research, and Development of the House of Representatives of the U.S. Congress published a report on the side effects of technological innovations, which included a call for the establishment of an "early warning system" to detect negative and positive consequences of technological applications (United States Congress 1966). The term "technology assessment" was probably used officially for the first time in this report. Since then, the methodology, practice, and institutionalization of technology assessment have become more specific and differentiated in terms of objectives, basic concepts, methodological instruments and institutionalization options (Porter et al. 1980). A series of exemplary TA case studies was carried out – in many cases on behalf of the National Science Foundation (Jones 1973) – and with the Office of Technology Assessment of Congress established by the Technology Assessment Act of 1972, a TA institution was created that has remained unique in terms of its size and institutional structure to this day.

After a short time, the "technology assessment movement" spread to other countries, especially to the industrially highly developed countries, and increasingly influenced the research and technology policy debate there (Coates/Fabian 1982; Böhret/Franz 1982; Leyten/Smits 1987; Smits 1987).

1. Basic concerns of the TA concept

In the Federal Republic of Germany, the term "Technologiefolgen-Abschätzung" or "Technikfolgen-Abschätzung" has now become widely accepted as a translation of technology assessment, at least among "TA practitioners." This choice of words is not a particularly happy one, because it could encourage the opinion that it is merely a matter of determining – as quantitatively as possible – the individual consequences of technology applications, and in particular not of evaluating them as a prerequisite for an overall assessment of the technology or technology application under consideration and for comparison with alternatives. However, such an idea would be completely inaccurate: technology assessment goes far beyond the identification and quantification of singular consequential aspects of the use of technology. Roughly speaking, TA aims to:

- Systematically research and evaluate the conditions and (potential) effects of the introduction and (widespread) use of techniques,
- Identify and analyze areas of social conflict that can arise through the use of technology, and
- Identify and review possible courses of action for improving the technology under consideration or its application modalities (policy analysis).[1]

In terms of its origin and concept, TA is therefore an analysis and evaluation approach with regard to the prerequisites and potential consequences of the social use of technologies. Criticism of its technology-centeredness on the one hand and the "consequences" fixation on the other are therefore certainly futile at the conceptual level. The long-standing *practice* of TA, however, will have to face the accusation that it has neglected the social conditions of technology use in particular, and that by ignoring alternative design options, alternative technologies or non-technical solution concepts, it has itself caused the criticism of technology determinism.

In the German-language literature, technology assessment is often referred to as a "procedure." This is misleading insofar as there is no binding, routine and generally applicable procedure for TA studies, nor can there be in view of the variety of specific issues relating to the very different technologies with which TA analysts are confronted.[2] Rather, TA should be understood as a "strategic framework concept." This concept can be related to others with a similar general objective – increasing the "awareness of consequences" of political and economic

1 In order to prevent the possible misunderstanding described above, the term "technology evaluation" (Technikbewertung) or "technology impact evaluation" (Technikfolgenbewertung) is sometimes preferred – but this causes irritation of a different kind.

2 Vary T. Coates formulates this as follows: "Technology Assessment [...] now is recognized as not one research algorithm or model but as a varied palette of analytical and speculative techniques used in support of public formulation and strategic planning" (Coates 1983). For Joseph F. Coates, who worked for a long time at the National Science Foundation and the Office of Technology Assessment of the U.S. Congress, TA is "more an art form which must be actively created and framed to fit the individual issue or problem being assessed" (Coates 1974).

action – such as so-called "accompanying technology research."[3] Both technology assessment and accompanying technology research (Bechmann/Wingert 1981) aim to address and solve the problem of controlling the consequences of actions. They differ in their basic strategic conception, roughly outlined here, as follows:

- TA should present the available knowledge (with evidence of knowledge gaps) about the realization conditions and effects of technologies in as anticipatory a manner as possible, in a generally comprehensive overall balance and in a decision-oriented manner. The approach is "cross-sectional," so to speak.
- The idea of accompanying research, on the other hand, is primarily to shape the process of realizing an innovation in accordance with criticisms after the fundamental decisions on the use of the technology have already been made. The approach is "longitudinal", so to speak.

From a comparative perspective, the concept of the environmental impact assessment (EIA) can also be considered.

Both TA and EIA are a form of timely action and decision planning in view of possible consequences. Both are also prevention-oriented, aim to analyze consequences as comprehensively as possible and are committed to the idea of participation. The differences between the two approaches lie in the following aspects, among others:

> TA is a medium for consultation between science and politics in the course of preparing political discussion processes and measures. The participation of affected and interested groups is a non-binding component of the overall process.
>
> EIA is integrated into the formal administrative procedure and serves to expand the planning concept and the criteria of the planning administration with the aim of environmental precaution. The type, scope and legal quality of participation is prescribed in a procedurally binding manner.

The implementation of concrete TA studies requires the detailed, case-related fulfillment of the framework concept, i.e., the development of a pragmatic strategy adequate to the respective question (e.g., Coenen et al. 1988, p. 3ff.). In this context, "flow charts" and "checklists," as offered in the TA literature (Jones 1971),

3 Other examples include evaluation research, which is essentially an ex-post impact analysis designed to provide information on the effectiveness of measures taken, as well as indications for subsequent impact management and improved future planning and decisions, and risk assessment (identification, estimation and evaluation of risks).

can only provide a limited amount of initial help in the conception phase of TA projects.

2. Pros and cons in the debate on TA

There are many good arguments which, as one might think at first glance, should make TA appear to be a generally plausible and attractive proposition, the realization of which promises considerable benefits for society as a whole. These arguments relate above all to the recognizably increasing threat to many areas of society and the natural environment from the unforeseen side- or delayed effects of technologies with considerable "primary benefits," to the growing complexity and magnitude of new technologies with increasingly difficult to understand and possibly irreversible "impact chains," and to the irrefutable need to conserve increasingly scarce natural resources (Krupp 1990). The fact that the public debate on technology assessment has nevertheless been controversial from the outset can initially be explained by the different interests of the social groups concerned.

For example, industry, but also government agencies, have frequently expressed the fear that a broad application of the technology assessment concept would inhibit technical progress – and thus also economic growth – and ultimately lead to a "technology arrestment" (Coates 1971; Green 1972): Innovators would be deterred, technical developments and applications would be hindered and blocked, and by detailing long-term, usually quite improbable consequences, TA would create a climate of fear and only create the problems that would cause sections of the population to refuse to accept it. The practice of technology assessment to date does not confirm this fear, at least in that only in exceptional cases have technology projects been completely blocked due to technology assessment analyses; on the contrary, there is much to suggest that such analyses tend to promote the process of technical progress, for example by encouraging the development and use of improved technical variants and alternatives. The aim of TA is not to hinder, but to "shape" socio-technical systems in a reflective manner. In fact, one of the main tasks of TA is to draw attention to the potential risks of using technologies that are usually ignored in conventional planning and evaluation procedures, e.g., investment calculations or market analyses. This is based on the conviction that ignoring or concealing possible disadvantages and dangers of a technology ultimately has a far more negative impact on public acceptance than disclosing potential threats at an early stage, which will be uncovered sooner or later.

What the term "impact assessment" may suggest semantically is not actually its aim: the concept is not designed to eliminate and compensate for problem-generating development and use of technology. Rather, it is about the *ex-ante* opportunity to set a course that *avoids* problems. However, in view of the decentralized, pluralistic structure of technology producers, this can only be done by the state and politicians within the framework and with the intensity of intervention that can be considered enforceable and acceptable from a regulatory point of view.

While critics, especially from industry (Meier 1987; see also Rautenberg 1989), see TA as a kind of "obstruction strategy," other interest groups often make the opposite accusation, namely that technology assessment is nothing more than a subtle "enforcement strategy" for technical developments and projects (Coates 1973; Büllingen 1984). It is precisely this accusation that underlines the fundamental importance of some of the demands that have been made with regard to the organization of TA processes (Paschen et al. 1978), namely:

- to make such processes transparent and verifiable at every step due to the large number of assumptions and value judgments to be made,
- to ensure the active participation of the groups most affected by the use of technology, because the lack of genuine opportunities for such groups to participate increases the risk of manipulation and the one-sided favoring of particular interests,
- to inform the public about interim results and decisions as well as their justification during the course of (important) TA investigations.

In this context, the accusation raised in some developing countries that efforts to harness the TA concept for the purposes of development policy should be seen as an attempt by highly industrialized countries to perpetuate their dominance in the field of state-of-the-art large-scale technologies should not go unmentioned. This accusation probably has its origins in the fact that in the discussion about the application of the TA concept for the interests of developing countries there is a close connection between technology assessment and the problem of selecting "appropriate" technologies, and the latter are only "second choice" technologies in the eyes of some politicians from developing countries (United Nations 1979; Boroush et al. 1980).

The character of TA as an element of decision-making processes gives rise to a further point of contention. In order to be effective in the sense of implementing the results of an analysis in political and – depending on the addressee – also corporate measures, the TA function must be integrated into the decision-making process in an appropriate manner, i.e., it must be organized and institutionalized to some extent. In the Federal Republic of Germany in particular, this problem of institutionalization has been a controversial ongoing topic in the "technology assessment debate", especially in connection with the demand for the creation of a TA institution at the German Bundestag.

However, if science – in the form of TA – is placed as an element of political (or even economic) decision-making processes, the question of the ultimately decisive opinion leadership and decision-making authority in such collaborations arises almost as a matter of course. We now know from rich experience that competitive relationships develop in the joint processing of a problem area. In general terms, these are such that, due to the very different characteristics and functions that distinguish science on the one hand and politics and business on the other, efficient communication between science and the application system is extremely difficult to achieve, as there are "hardly any clear point-by-point correlations: neither in terms of time nor in terms of subject matter, nor with regard to partners and role contexts" (Luhmann 1977, p. 30).

Although, in our opinion, there is no alternative to undergoing the efforts of this communication and cooperation, Luhmann's assessment that it makes little sense "to expect communicative interaction to resolve differences through consensus in the true and the good" (Luhmann 1977, p. 31; cf. Petermann 1988) is nevertheless important.

The quality of TA practice to date is also controversial. A very pointed criticism of practical TA work is contained in a study presented by the OECD in 1978, in which 15 case studies were analyzed that had been made available to the OECD Secretariat by the member countries as representative of work in the field of technology assessment (OECD 1978). Although these case studies were completed in 1974 or earlier, the OECD's findings are still largely valid today (Jochem 1989, 1990; OECD 1983):

- Only very few of the studies reviewed undertook a systematic identification of impacts and a "homogeneous assessment" of all impact areas. The selection of impact areas is highly intuitive, often determined by personal preferences or access to useful data.
- Very few studies would take into account the interests and problems of those affected by the use of technology.
- Only inadequate attempts are made to forecast possible future changes in the environment in which technology is used, i.e., in social, political and economic trends.

A set of "methodological guidelines" developed by the OECD itself and published in 1975 (OECD 1975), served as a benchmark for evaluation, describing a kind of "ideal" of technology assessment. Apart from the fact that studies from the early days of technology assessment can hardly be expected to meet the expectations of "TA purists," the fundamental question must be asked as to whether TA analyses as a complete implementation of desirable maxims represent a practically feasible possibility at all. This question is explored further in the following sections.

Excessive demands on TA practice, i.e., the processing of TA assignments resulting directly from the "ideal concept," are described and discussed, and problems associated with this concept in the implementation of TA results in the world of action of the addressees are also considered.

3. The "ideal concept"

Such an ideal concept of TA is based on a series of postulates,[4] which have already been mentioned. These postulates will be presented in more detail in this section.

- *TA analyses should anticipate the realization conditions and potential consequences of the use of technologies and thus serve as an "early warning" (postulate 1).*
  From the very beginning, the main concern of technology assessment has been to identify and weigh up the realization conditions and potential consequences of the introduction and application of new technologies, or technologies still under development, or the increased or modified application of known technologies[5] before a situation is created (e.g., through extensive investments) in which the freedom of decision regarding the use of these technologies is already severely impaired ("constraints"). "Early warning" or "early detection" is, as it were, the programmatic core of at least the so-called "technology-induced" TA studies, in which a specific technology – still under development or testing, or already in use – forms the starting point for the

4 Cf., for example, Coates 1974; Deutscher Bundestag 1986; Kawamura et al. 1979; OECD 1975; OECD 1978; Paschen et al. 1978; Porter et al. 1980.

5 Many advocates of technology assessment also consider "social technologies" – such as various forms of organization, standards, co-determination models and forms of taxation – which can have far-reaching effects in many areas of society, to be part of the scope of technology assessment.

various analysis steps:[6] Negative consequences are to be avoided from the outset, or at least limited.

- *The range of impacts to be identified, assessed, and evaluated in TA analyses should be "comprehensive" (postulate 2).*
  It is required that particular emphasis be placed on the analysis of

  - unintended (side) effects of the use of technologies,
  - indirect effects, which often occur with a long delay (second and higher order effects),
  - cumulative and synergetic effects,
  - institutional and social consequences (effects on social structures, socio-cultural values, socio-political systems, etc.),
  - (re)effects of social developments on technological developments (consideration of the social environment of the use of technology),
  - impact categories that cannot be quantified (or at least not in a meaningful way),
  - without neglecting the planned, primary, economic-technical, directly quantifiable effects.
  - *The technology to be assessed should also not be considered in isolation.*
  - This means that
  - important technical variants (system alternatives) of the technology under consideration, and
  - technologies complementary to the "main technology" (example: uranium enrichment plants as a complementary technology to nuclear power plants),
  - should be included in the investigation.
  - In addition, the short- and long-term interactions between the technology to be assessed and competing technologies must be taken into account. In all cases – depending on the time horizon of the study – future

6 *"Technology-induced" TA analyses* deal with the problem of the use of a technology with regard to the consequences for the environment and society in the context of a wide range of proven or potential applications. In contrast, *"problem-induced" TA studies* aim to analyze alternative solutions to an acute or foreseeable (economic, ecological, resource-related, social) problem. These are often problems that are (co-) caused by technologies in an "interplay" that is often difficult to understand – or where there is at least a suspicion of this: It is always about problems where there is an expectation that technology can make a significant contribution to solving them. This distinction should be handled with caution – even for analytical purposes. Technology-induced TA is hardly conceivable without a systematic reference to problems and needs.

technical developments in the area under consideration must be taken into account as far as possible.

- *TA analyses should be "decision-oriented" (postulate 3).* In other words, they are intended to increase the level of reflection and rationality of decision-makers by incorporating problem-oriented knowledge about technical developments and programs into decision-making processes. The aim is not only to contribute to the preparation of decisions that have already been recognized as more or less urgent, but also, for example, to clarify whether there is a need for decision-making with regard to a new or developing technology, or with regard to an emerging economic, ecological, resource-related, or social problem.
  Closely related to the postulate of "decision orientation" is the requirement that TA studies – over and above impact analysis and assessment – *should identify and review alternative measures or packages of measures (options for action)* in a "constructive" part, through which the technologies under consideration or their application modalities can be improved in such a way that overall fewer negative and/or stronger positive effects can be expected. Whether the explicit formulation of recommendations for the implementation of *very specific* measures is still one of the tasks of a TA team is judged differently; this certainly depends not least on the interests of the respective client and the self-image of the TA analysts. Examples of such options for action (Coates 1971) are:

  - Implementation of a monitoring or surveillance program parallel to the introduction of the technology (in the event of great uncertainty about the effects of a technology application and the resulting areas of social conflict);
  - Staging of evaluation measures or accompanying research, creation of committees with a monitoring, approval or control function;
  - Legal measures to prevent or tax incentives to promote specific applications of a technology;
  - Changes in institutional structures associated with the introduction of the analyzed technology;
  - In extreme cases: abandonment of a project or a technology, if necessary testing of completely different solutions than those originally planned (so-called macro-alternatives).

- *Technology assessment should be "participatory," not "elitist" (postulate 4).* This means that, despite the major organizational and communication problems, the aim is to achieve broad participation by the social groups affected by the consequences of technology use.

Some of the reasons given for this demand are:

- The utilization of the situation-specific knowledge of those affected is an indispensable prerequisite for realistic TA analyses.
- Some effects of a technology application are often only taken seriously when a group of people affected insists on them being discussed.
- The danger of manipulation by specific interests can best be countered by the active participation of many affected individuals and groups.
- More recently, there has also been a widespread expectation that consensus between proponents and critics of a particular way of using technology could be achieved or developed through participatory procedures within a TA process.

• The results of TA analyses are highly dependent on the subjective assessments of TA analysts and their clients; value judgments must be made at every stage of the TA analysis process. The increasing realization of the decisive role that interests and standards play in TA as a "value-sensitive" procedure (Deutscher Bundestag 1986) results in the *demand for transparency, traceability and verifiability of TA processes: Assumptions and value judgments and their justification should be disclosed (postulate 5).*

4. Problematization of the "ideal concept"

The "ideal concept" described above, with its plethora of demands, leads in most cases to TA practice being overwhelmed. This is particularly true when it comes to the (technology- and problem-induced) impact assessment and evaluation of far-reaching technologies (e.g., energy technologies, transportation technologies, information technologies, new biotechnologies). Such technologies do not have the "machine character" of an artifact, but are networked with other technical and social systems and are diffuse in a way that makes anticipatory analysis extremely difficult. Programmatic overload is also obvious if one takes the view that an assessment and evaluation process for a far-reaching technology or a serious acute or foreseeable social problem can be "completed" by a *single* study comprehensively designed according to the requirements of the "ideal concept."

Aspects of this problem are illustrated below using the example of postulates 1 and 2. The aim is also to provide indications of conceivable ways out of the difficulties in applying the "ideal concept."

With the firm claim to analyze the dangers and risks that may be associated with the development and use of technologies *at the earliest possible stage (postulate 1),* TA has taken on enormous theoretical, methodological and data problems. A TA study carried out with regard to this claim would require information to be available on the future "need" or demand for the technology or on the future scope of technology use, on "reinforcing" or "disruptive" developments in the environment of the expanding technology, on its further development and its alternatives, on the long-term ecological and social effects of technology use, and on future values as a prerequisite for weighting and evaluating subsequent effects.

These and similar problems in the development of plausible statements about possible futures appear difficult to solve, if not impossible – especially if one expects such statements to have the status of exact, determinative "forecasts." For example, some consequences are only assessed as harmful over the course of time with increasing use of the technology and *growing awareness of the problem.* Particularly in the diffusion phase, new problems can always arise that are "unforeseeable." It is not surprising that there are those who declare that TA has failed as an attempt to create an "early warning system."

Many TA analysts now *see* technology assessment as a *"normative instrument"* whose task is to design plausible – or even desirable – alternative futures (scenarios) and to describe pathways (options, measures) and analyze them in terms of the conditions and consequences with which these futures can be achieved.

One possible manifestation of such an approach is a TA study by the Department of Applied Systems Analysis at the Karlsruhe Nuclear Research Centre, which looked at the technical possibilities, implementation conditions and consequences of increased use of hard coal for oil substitution in the Federal Republic of Germany (Coenen 1985). The study was based on the assumption that a proportion of mineral oil *should* be replaced by German hard coal. Accordingly, alternative scenarios were designed in which this goal is achieved, using different technical methods (electricity generation, combustion, gasification and liquefaction). The various options were then analyzed and evaluated with regard to various prerequisites and consequences. The result is well-founded answers to questions such as: If option or strategy X is chosen, what consequences can be expected – given defined framework conditions – and what preconditions must be met?

Of course, even with approaches that are "normative" in this sense, the "forecasting burden" of technology assessment remains high. The assumptions made must be based on "forward-looking" information, i.e., they must not be completely arbitrary. Above all, however, the problem remains of estimating (and evaluating) the possible future consequences resulting from the assumptions or the options based on them, in a situation of largely unexplored cause-and-effect relationships. There is an urgent need to intensify impact research, particularly in the area of the ecological and social effects of the use of technology, in order to improve the information base for balancing and evaluating TA analyses.

It is now widely accepted among TA analysts that a significant reduction in the prognostic burden can only be achieved if TA investigations are not conceived as a "one-off affair," but as a sequence of repeated analyses and assessments – as a *process*, so to speak – at least when it comes to the development and use of very far-reaching techniques. After an initial "TA round," further analyses should be carried out as necessary during the development and application of a technology in order to check whether an originally positive assessment may no longer be justified, and which – originally unrecognized or misjudged – negative consequences are becoming more significant. A continuous technology assessment in the sense of "monitoring" developments and development opportunities is also conceivable. Such an approach enables better adaptation to political decision-making processes. The idea that political decisions on technologies are finally made at a specific point in time on the basis of a one-off comprehensive assessment is quite unrealistic.

However, the "process approach" also harbors risks that need to be considered. For example:

- The "strategic structure" of the TA study can be jeopardized (one gets lost in an increasingly impenetrable thicket of detailed information and in the analysis of ever new options);
- There is a risk of losing the overall context, especially if the process-like implementation also implies splitting into partial studies;
- Fundamental decision-making options can be lost in the sense that perhaps only relatively insignificant modifications to the technology under consideration or its application modalities are possible. The concept of flexibility or reversibility plays a role here; it is very much a question of the extent to which it is realistic to assume that the process of introduction and diffusion is reversible in the case of large technical systems or other long-range technologies, for example.

The – not even complete – list of requirements drawn up to concretize *postulate 2* should make it clear that "comprehensive" technology assessments in this sense will usually be unfeasible for practical reasons alone (time and resources required). Fixating on such generally unfulfillable maximum requirements can only be detrimental to the use of TA in concrete decision-making processes.

In this context, a comment made by John H. Gibbons, Director of the Office of Technology Assessment at the U.S. Congress, at a symposium held in 1982 on the "Role of Technology Assessment in the Decision-Making Process" (Umweltbundesamt 1983) is revealing. With regard to the interest of the addressees of TA studies in "comprehensive" analyses, Gibbons says that such studies – assuming they were methodologically possible and could be carried out by the OTA – would find few takers among the political decision-makers for whom the OTA works. The U.S. Congress prepares its decisions in subcommittees; these need TA analyses that focus on a specific area but do not ignore the broader implications of the problem in question. The OTA always tries to keep the "customer" – his needs and constraints – in mind.

As informative as such references may be for the design and communication of TA and for improving the interaction between TA users and TA producers, it is important to warn against the latter orienting themselves exclusively to political and other user requirements and reducing the demands of the TA concept too much. If the criterion of *comprehensive* analysis of a complex object of knowledge were to be abandoned without further ado, TA could easily lose its guiding effect and run the risk of losing its profile.

Nevertheless, pragmatic variants must be sought. One way out of the difficulties associated with postulate 2 is offered by the concept of *complementary* partial analyses, which can be imagined as follows:

Step 1: Problem analysis ("Mini-TA") with the following characteristics:

- less "depth" than a comprehensively designed TA analysis,
- partly only qualitative consideration,
- obtaining a preliminary overview of important impact areas and implementation problems,
- identification of "dominant" areas and those particularly "in need of analysis."

Step 2: Assignment of "partial" TA studies for the areas assessed as dominant.

Step 3: Implementation of such partial studies by institutes that have special expertise (e.g., better access to data).

Step 4: Assessment of the results; examination of whether further studies need to be carried out; integration into an "overall picture."

The individual partial analyses carried out on a specific topic must of course be coordinated and agreed in terms of content from the awarding of the contract to the evaluation, which also requires a degree of institutional support. If coordination and harmonization do not work then there is a risk, for example, that important "trade-offs" remain unrecognized (e.g., between the economy and ecology).

On the implementation side, the broad use of this concept requires a "network" of interdisciplinary working groups that cover the various areas of technology and can be commissioned to carry out (partial) TA analyses. Ensuring institutional continuity, but above all the scientific independence and neutrality of such TA groups, is a prerequisite for the high quality of TA studies and for the credibility of TA results as an information basis for decision-making processes. The demand for continuity of TA groups is of course not intended to rule out the possibility of forming temporary ad hoc groups, e.g., parliamentary commissions of inquiry, for specific TA problems.

Such a decentralized network should involve not only expert groups from the "established" research institutions, but also institutions that see themselves as "alternative" and/or pursue new and unconventional topics and methods.

If we now transfer the idea of complementary partial analyses from the level of individual TA processes to that of TA activities as a whole, this opens up the possibility of developing a strategy for the practical support of TA potential:

The informative value and practical effectiveness of individual TA projects could be increased by integrating them into a network of parallel TA projects – on a specific technology or a specific problem. In this way, complementary theoretical approaches and methods and the linking of selectively unearthed insights in a network of TA processes could constitute a broader spectrum of insights, and an approximation to the fundamentally far-reaching cognitive interest of the TA concept could be achieved. If such a network is not only synchronous, but also diachronic, these positive aspects can be further strengthened (Deutscher Bundestag 1986, p. 12).

The development of such a structured practice of TA activities with the aim of broadening the information base on socio-technical processes, increasing the informative value of analyses, and enriching the range of possible options, would have to be institutionally and procedurally underpinned by the establishment and expansion of the network of capacities in research and advisory institutions already outlined, which are familiar with the specific procedures and information requirements of technology policy decision-making processes (Paschen et al. 1981, p. 65).

5. The problem of implementing TA results

The implementation or application of new knowledge is a constant problem for any kind of application-oriented research. Implementation deficits have always been deplored:

- between science and industry (innovation deficits, technology transfer problems),
- in the scientific system itself between basic research, applied research and development, but also between the individual scientific disciplines,
- between science and the political system in the broadest sense (legislature, executive, social interest groups).

This is no different with TA, although this type of research tends to focus less on the explanation of phenomena and more on the provision of knowledge for action, and must strive to include decision-making contexts in the analysis and thus overcome the barriers between the scientific system and the political system or the economic system (cf. postulate 3).

One reason for the implementation deficits of TA studies may initially lie in the *complexity* of the object of knowledge. The correspondingly necessary comprehensive analysis of diverse consequences can significantly strain the user's willingness to perceive and therefore lead to selective perception. The – ideally interdisciplinary – analysis of complex impact dimensions may only generate a moderate response and limited understanding on the part of the addressee – due to sectoral expertise and, as a rule, specialized disciplinary training.

In addition, at the macro level, decision-making processes in politics are generally driven simultaneously by a large number of fragmented units organized according to the division of labor, such as ministries, departments, committees, etc.

One of the main reasons for implementation deficits is probably that – as the discussion of postulates 1 and 2 in the previous section has shown – the results of such studies are highly *hypothetical in nature* and are particularly fraught *with uncertainties* due to the concept.

Although the treatment of uncertain future developments by TA is valued and desired by potential users, the associated *deficits in certain knowledge* reduce the acceptance of the results. No TA process, no matter how sophisticated its mathematical forecasting models, can rule out uncertainties in statements about the future. This uncertainty, which is primarily due to the nature of the object of knowledge to which TA refers, entails a lack of certainty, which can lead to great skepticism in the reception of the results (Mayntz 1980, p. 313; Hammond et al. 1983, p. 294ff.).

In view of the dilemmas in the analysis and assessment of consequences, which can hardly be resolved, the appropriate path to more open-minded communication about possible futures with uncertain knowledge would not be a mere call for more research and greater certainty in decision-making. Rather, a modification of the "political decision-making culture" (Ewers 1990, p. 156) should be sought while partially renouncing the standards of scientific certainty of knowledge.

Another closely related reason for implementation problems, is that *normative aspects and value-sensitive strategic considerations* decisively determine the framework of every TA study and the implementation of the individual analysis steps (cf. postulate 5). However, the respective normative settings do not necessarily have to be shared by all potential users of the TA analysis. Even if it were possible to make them sufficiently and comprehensibly transparent, it could not be ruled out that they collide with those of the users. Confronted with different interests, values and preference structures in society, TA analyses run the risk – due to their normative character – of being perceived as possible triggers or amplifiers of conflict processes in socio-political disputes. It is possible that the controversy over values and norms then overlays the discussion of the analytical components of the TA process in a dysfunctional way (a discourse on this is actually desirable).

The *discrepancy between scientific (substantive) and political rationality* can be seen as another important reason why the actual contribution of TA – as well as other types of policy advice research – to shaping political decisions usually falls short of expectations (or fears) (Weiss 1978; Mayntz 1986).

This discrepancy – as the difference between two "ideal types" – can initially be described as one between two different world views.

Scientific approaches, in particular in social science, attempt to "explain the world" and operate with basic theoretical assumptions and a specific set of methods that capture reality in categories that tend to be alien to the approaches and questions of practice. This difference[7] can also be understood as a competition between "lay images" and scientific world views, between everyday knowledge and scientific knowledge, which leads, for example, to controversies about which problem situations are considered worthy of investigation and in what order, and how they should be treated (Nowotny 1975, p. 449ff.).

Furthermore, even with a reflected application orientation of scientific analysis, a difference remains between the *thematization of* political options for action through technology assessment and *political action* as a search for consensus and the securing of power. Politics as a practice is subject to specific constraints such as the imperative to gain and maintain power, the need for tactical negotiation processes and compromise building, and the pressure to decide and act within a tight timeframe. All of this results in a narrow perception of the knowledge provided and its often tactically motivated use.

> Policy-makers for their part are interested not only in the application of research evidence to public decisions but also in representing interests and values, reconciling differences, and reaching compromises that maintain the stability of the system. Theirs is political rationality rather than scientific rationality. They may neglect research in their service of other functions, but, from their point of view, the use of research is not necessarily the highest good (Weiss 1978, p. 61).

Accordingly, politics must

> [...] refrain from such enlightenment [...] whose *consequences of action* would overstretch the institutional framework of politics and invalidate the interpretations and premises built into this framework" (Offe 1977, p. 323; emphasis added by the authors).

6. Concluding remarks

If the areas characterized in this way cooperate with each other, communication difficulties and a tendency toward conflict cannot be ruled out. However, the

7 The discrepancy between the two world views also manifests itself as a problem of mediation: If scientific knowledge and practical knowledge of action were identical in terms of their structures and elements, only theoretical propositions would have to be transformed into prescriptive propositions for the purpose of transferring science into practice. Since the two forms of knowledge are not identical, this solution perspective is fundamentally obstructed (Neidhart 1970, p. 332).

conclusion cannot be that TA has to adapt to the patterns of perceptions and possibilities for action in politics through "mimetic" efforts.

Attempts to resolve difficulties and improve the consultation process, which is jointly supported by science and politics, will only be successful if the difference between the two players is fundamentally recognized and respected. Nor should it be assumed that the (alleged) substantive rationality of science should be ascribed a higher dignity. A functional interlinking of analysis and evaluation processes will lead to a better integration of both sides in this process, if the respective (relative) autonomy and profile as well as the advantages of specialization are retained – and used in a reflected manner.

From this perspective, however, it is not enough to improve *procedures.* Rather, it is also necessary to further penetrate the relationship between science and policy theoretically, and at the same time to broaden the empirical basis for its assessment and for targeted improvements. Evaluations of the use of TA should be systematically continued and continuously supplemented. It is true here – as for advisory relationships in general – that they have by no means been sufficiently researched. This applies to scientific and epistemological as well as organizational-sociological and socio-psychological aspects of the utilization process, whose lack of "intensive observation" (Rosenmayr 1977, p. 36) is *one* cause of implementation difficulties (Petermann 1986).

Influenced by multiple context variables, the advisory situation in TA processes is an unstable structure. In order not to stop at a mere organizational "intermingling of science and politics" (Ronge/Schmieg 1973, p. 57), but at least to achieve an "institutionalization of reliable environmental sensitivity" (Scharpf 1973, p. 80), the conditions of advisory situations must be consciously analyzed and constantly improved. It should be noted, however, that the fundamental difference between science and politics cannot – and should not – be eliminated.

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Meinolf Dierkes, Katrin Hähner

Concept development of technology assessment: Review and outlook

1. The social background: From enthusiasm for technology to technology ambivalence

As in all highly industrialized countries, there was a relatively broad and firmly anchored consensus in the Federal Republic of Germany until the end of the 1960s in the assessment of scientific and technological progress. A clearly positive attitude toward technical and scientific developments prevailed among large sections of the population, as they were seen as a reliable guarantee for economic growth as well as personal and social welfare (Andersen 1997). The state was expected to create the conditions for closing the existing or expected technological gap with other industrialized nations – above all the United States – as quickly as possible through a proactive research and technology policy. A socially relevant technology acceptance problem did not exist (Dierkes/von Thienen 1977, p. 2; Dierkes 1984, 1989a, p. 67ff., p. 69ff.).

This situation changed fundamentally from the late 1960s to the early 1970s, and the enthusiasm for technology that had prevailed increasingly gave way to a distanced and critical attitude. There were two main reasons for this:

- Firstly, more and more people were confronted with indirect, unintended, and long-term secondary and tertiary effects of new technologies, both at the micro level of their working environment and at the macro level of their living environment. Scientific and technological progress and the welfare of society as a whole therefore no longer automatically went hand-in-hand but, in the opinion of a growing proportion of the population, conflicted at more and more points.
- Secondly, traditional and new social movements focused on people's concerns and worries and intensified them through broad media coverage. Acceptance of technology could no longer simply be taken for granted, but became a socially relevant problem (Dierkes/von Thienen 1977, p. 3ff.; Dierkes 1984, 1989a, p. 69ff., 1989b, p. 67ff.).

At first glance, it seemed that fear or even hostility toward technology was spreading. However, a series of surveys quickly showed that neither technology nor scientific and technological progress per se was fundamentally questioned. The negative attitude was not primarily related to the technology itself, but rather to the neither intended nor foreseen social, political, economic, ecological, and cultural consequences resulting from its use. Although these concrete, unintended consequences became the starting and crystallization points for controversial discussions and/or differentiated forms of protest, the increasing unease was rooted more deeply than just in one or another spectacular individual cases (Dierkes 1985, 1986a, p. 24, 1989b, p. 68). Rather, the assumption that scientific and technological progress and social progress were in a linear, directly proportional relationship to each other, which had guided actions and decisions for a long time, was fundamentally shaken.

While the problem of technology acceptance superficially appeared to be a loss of trust in scientific and technological progress, a closer look at the phenomenon clearly showed that at its core this was more about a loss of trust in the social mechanism whose task it was to promote and control this progress and steer it in the socially desired direction. The increasingly obvious differences between technical goals and social and ecological outcomes were not simply attributed to technology in the technology acceptance discourse, but were instead seen as part of the dysfunctionality of this mechanism.

The institutions found themselves in a crisis, which became particularly evident in two symptoms: A lack of awareness of the problem, and a growing displacement of the problem. Firstly, the growing distrust of many citizens toward the increasingly serious risks of technological progress was only gradually recognized by the majority of state institutions and companies. Secondly, there was a growing tendency to shift decision-making processes for the concrete use and application of new technologies from the legislative, executive, and administrative levels to the judiciary, where they inevitably accumulated, as they could be resolved neither competently nor quickly due to their complexity and intricacy (Dierkes 1974a, p. 24; Dierkes/von Thienen 1977, p. 3ff.; Lohmar 1977). From the very beginning, technology acceptance was therefore not only a problem in the social sphere, but above all a problem of the social sphere. Against this background, the question inevitably arose as to how social science technology research could provide the basic knowledge required to deal with the acceptance crisis.

The social science debate on the social problems of technological change, conceptualized as questions about technology, reached an initial peak in the early to mid-1980s in German-speaking countries.

2. Societal technology control as compensation for inadequate self-control

However, the ensuing efforts to develop comprehensive and coherent concepts for technology control also raise the question of why steering and corrective interventions in technical development are necessary at all, and why progress is not simply left to a market or a political selection process. On closer inspection, however, the difficulties of such a selection mechanism quickly become clear. Since there are no markets in the traditional sense for many of the new technologies that are subsidized by the state or predominantly used in the public sector, there are no feedback mechanisms that can adequately control technological progress with regard to society's quality of life. However, it is precisely the most diverse quality-of-life-reducing effects of technologization that are generally the starting point for the demand for society-related control of technology. Feedback through the mechanism of political elections works imperfectly with regard to state-funded research and development (R&D), as technology policy issues only play a subordinate role in electoral decisions. However, a change is to be expected here, as a further increase in political pressure can be expected under the impression of the diverse negative environmental effects and under the influence of citizens' initiatives, and environmental and consumer protection groups, especially if these groups succeed in joining forces across national borders within the framework of Europeanization.

In addition, the development of new technologies, even when it took place with state support, was for a long time – and to a large extent still is today – essentially oriented toward the criterion of private sector profitability and the market mechanism as an assessment process (Dierkes/Bauer 1973; Dierkes 1974b). Apart from a few exceptions, macroeconomic aspects were and are hardly taken into account. Insofar as side effects of new products or processes were included in the decision-making considerations – mostly due to legal regulations – this was largely limited to selective, direct, and predominantly technical aspects. With regard to society's objectives, however, microeconomic profitability is too limited a criterion for such decisions. Furthermore, the participants in the market process, primarily the consumers, are not, or only to a modest extent, in a position to function efficiently in the role of "assessor" of a new technology, as they generally lack any systematic information, especially about the side effects already mentioned (National Academy of Science 1969; Geschka/Schwerdtner 1974), and often the buyers are not those who suffer the burdens of the side effects.

In addition, due to the long duration of innovation processes, market success as a decision criterion for the overall economic desirability of specific technical progress only provides the corresponding "feedback" at a very late stage. Extensive productive resources may then have to be regarded as misdirected, or the technical development is ultimately "brought to market" under the pressure of the R&D expenditure already made with the help of marketing instruments.

As the traditional decision-making criteria and calculations are therefore significantly flawed, both with regard to decisions made by the private sector and by the state regarding the type, scope, and direction of technological progress, it is advisable to look for an efficient way to compensate for this. Technology assessment is probably the first planned and goal-oriented approach that should provide a remedy here.

Technology assessment – the traditional way to overcome the acceptance crisis

Initially, social science technology research focused on the development of an "early warning system for technology impacts." Under terms such as "technology assessment" (TA), "technology evaluation," or "technology impact evaluation," international research efforts since the late 1960s have increasingly sought to develop concepts aimed at analyzing and evaluating the conditions and potential effects of the introduction and widespread application and use of technologies as systematically as possible, with the main aim of analysis being to investigate the indirect, unintended, cumulative, and synergetic secondary and tertiary effects of the introduction and application of new technologies on the environment and society (Dierkes/Staehle 1973; Dierkes/von Thienen 1977, p. 3; Dierkes 1984, 1989a, p. 69ff.). In general, technology assessment is defined as an integrated and systematic assessment and prediction of the significant (positive and negative, direct and indirect) effects in the central areas of a society (economy, environment, institutions, general public, special groups) that occur when a technology is introduced or changed. The concept includes the requirement that the effects of technologies already in use should also be reviewed from time to time, particularly in the case of changing requirements and changes in scale. The task of a technology assessment study is therefore to use scientific analysis to identify side effects, "spill-overs," and other direct and indirect advantages and disadvantages of using a technology (Coates 1972, p. 1ff.; Dierkes/Staehle 1973, p. 5; Knezo 1972).

From the outset, TA research was conceived as a policy-related information tool that was intended to directly serve practical knowledge and action interests. Concrete proposals were developed from the research experience as to how the institutional crisis that had become apparent in the "acceptance crisis" could be overcome in the short-, medium-, and long-term. Based on the models of the "Royal Commission," the "Researchers' Parliament," and the "Science Court," differentiated variants for the reorganization of research and technology policy institutions and their effective interaction were developed (Dierkes/von Thienen 1977). This direct practical orientation necessarily led to terminological and conceptual blurring, as the definitional boundaries for studies that should be attributed to technology assessment were interpreted relatively broadly (Paschen 1986, p. 23). Furthermore, TA research was multidisciplinary from the outset, since a differentiated and systematic assessment of the possible consequences of the introduction and application of a technology would have to take into account and examine a wide variety of impact fields. This could only be achieved by integrating methods and procedures from the natural, technical, and social sciences (Dierkes 1984).

In order to counter the methodological and conceptual difficulties faced by TA research designed in this way, four approaches were adopted:

- Firstly, general flowcharts and checklists for the methodological and practical approach to studies were developed to outline the TA approach. Framework concepts of this kind, such as the flow chart drawn up by the MITRE Corporation[1] (MITRE 1973) or the Organisation for Economic Co-operation and Development's (OECD) catalog of requirements (OECD 1975), required a more precise definition in each individual case, depending on the specific research question; nevertheless, such concepts can provide helpful methodological advice for specific studies (Dierkes 1989b, p. 74).
- Secondly, TA research has pointed out that technology assessment should not simply be misunderstood as a one-off and then completed investigation process, but rather as an iterative analysis cycle in the sense of a "process-based technology assessment."
- Thirdly, concepts were developed in the direction of complementary partial analyses, in which partial studies are carried out on selected areas that are in particular need of analysis and then integrated into an overall picture (Dierkes 1981, p. 340ff.).

1 *Editors' note*: For further information, see: https://www.mitre.org/ (accessed 09.04.2025).

- Fourthly, historical analyses were to be used to reconstruct discourses on technology assessment in the past; this approach was obvious, as problems with undesirable adverse consequences of technology are as old as technology itself (van der Pot 1980). In this way, not only surprising and unexpected insights into historical processes could be brought to light, but above all research results of great topical relevance. (Dierkes 1986b, p. 145ff.; Dierkes et al. 1988).

Despite these and many other efforts, fundamental criticism of the usefulness of technology assessment has been voiced time and again. In addition to criticizing the methodological and conceptual weaknesses of TA research, the general usefulness of TA research has been questioned with reference to the impossibility of accurately forecasting the future. However, regardless of where the criticism comes from and where it is directed, it can always be countered by the fact that there is basically no choice for or against technology assessment; there is merely a field of alternative and complementary paths along which it can develop and qualify (Dierkes 1984). Particularly problematic are the usually completely inflated social expectations of TA research, with politicians in particular hoping for a quick and smooth elimination of acceptance problems. The hopelessness of this is based on the fact that TA research can provide information on new technologies and the negative and positive secondary and tertiary effects to be expected from various alternatives. However, it is not in a position to replace the debate about the opportunities and risks of technologies by providing an "objective" political decision.

In order to systematically minimize the existing differences between the knowledge needs of the public and politics on the one hand and the knowledge offered by TA research on the other, communication processes between science, the public, and politics must be developed, purposefully unfolded, and institutionally anchored. The proposals made by various organizations such as the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), the Association of German Engineers (VDI), and various social science research institutions in the first half of the 1980s were aimed in precisely this direction (Dierkes 1984).

The limits of traditional TA research

Even if the possibilities of traditional TA research have not yet been exhausted, there are also limits to this approach that leave room for alternative models. Technology control that is primarily aimed at the consequences of technology often resorts to regulations such as requirements, laws, rules, and technical standards, i.e., a form of technology regulation that can be traced back to the second half of the 19th century (Dierkes 1990b). A look at the history of technology assessment illustrates the problems with which this approach has repeatedly been confronted. Three stages of development can be identified, which can be roughly outlined as follows (Dierkes 1990a):

- The first stage: In an effort to regulate the consequences of technology, the role of the state, scientific associations, and entrepreneurs was defined very early on. The Prussian Industrial Code of 1845, for example, operationalized a large number of instructions and procedures. This type of impact regulation was characterized above all by its reactivity, i.e., techniques were first introduced and then, when unintended and undesirable side effects occurred, processes were set in motion to eliminate or at least reduce them. As a rule, these processes were partial regulations in which specific effects of a technology were subject to conditions, regulations, and occasionally also laws. However, scientific and technological progress often created new problems with the same technology, so that the process of permanent partial regulation often lagged behind and was usually only marginally effective. The shortcomings in the enforcement of many laws, which are well known today, had a particularly problematic effect, dragging the state into the ups and downs of regulating the consequences even back then.
- The second stage: A change was initiated in the second half of the last [19th] century when a more restrictive understanding of the state's role in regulating technology was developed and professional institutions were increasingly relied upon to control technology. This led to the emergence of a different state regulatory mechanism, particularly after the technical deputation for industry was established and implemented. Specific regulatory tasks began to be delegated to professional institutions, which then took on the detailed regulation in what was then known as scientific-technical collaboration, while the state essentially concentrated on defining the broad framework conditions. This regulatory mechanism is more differentiated, but remains essentially reactive: A problem arises, is recognized as requiring regulation, and is fed into the regulatory mechanism until it is eliminated. However, this strategy is still unavoidable today, because despite all efforts in the field of technology assessment, it will never be possible to fully and completely anticipate the entire spectrum of all consequences.
- The third stage: In the 1970s and 1980s, a scope for decision-making was discovered, particularly in the context of efforts to humanize work, which had not previously been perceived, at least not to this extent. The studies

of a whole series of social science institutes largely agreed that many of the consequences of technology, particularly with regard to the effects on working people and the working environment, are ultimately rooted in the specific organizational framework created for the use of technology. The most popular example is probably the well-known studies on the use of CNC machines. In many cases, technology impact problems that arise in practice are solved using corporatist negotiation models.

Even if this sketch is only very rough, it still points to the question of whether the traditional mechanism of technology control does not have weaknesses that can be, if not remedied, then perhaps reduced by complementary approaches to technology control.

3. Technology genesis as an opportunity to supplement traditional TA research

One approach that has been aiming to expand traditional control mechanisms for some years now, and which is also mentioned in a memorandum on social science technology research in the Federal Republic of Germany published in 1984 (Dierkes et al. 1984, p. 10), is technology genesis research. The phase of technological genesis, i.e., the stage of technical development that extends from the definition of the problem to the first usable industrial product, and in which the pathways are defined that act as a kind of "invisible selection filter" for further developments, is to be identified, described, and comparatively researched. In particular, the interactions between technical and social change should be given greater consideration in social science technology research (Dierkes 1988, p. 50, 1989a, p. 3ff.; Knie 1989b, p. 378).

The genesis of technology: research beyond social and technological determinism

When approaching the field of technology genesis, i.e., the area in which decisions are made about R&D, in which technical lines of development are promoted, stopped, redirected, or abandoned, according to criteria that are intrinsic to the respective institution that makes the decisions, then one is almost inevitably confronted with a classic alternative question: Is there a technological determinism or a social determinism? Or, to put it less sharply: Which of these two determinisms prevails? Two quotes illustrate the rather contradictory positions taken on this topic. At a colloquium in Berlin, Professor Spur expressed the following view:

> It should not be overlooked that technology is an economic and political factor with its own laws, which has considerable social significance, but which, on the other hand, has its own dynamics that can hardly be controlled on a global scale (Spur 1989, p. 5).

This is in extreme contrast to the view expressed by Habermas in 1963: "Judged by their structure, we see no functionally equivalent alternative anywhere for the non-institutionalized progress of science and technology. The innocence of technology, which we must defend against its suspicious despisers, consists quite simply in the fact that the reproduction of the human species is bound to the conditions of instrumental, even purposive-rational action, and that therefore not the structure, but only the scope of the technical power of disposal can change historically." (Habermas 1986, p. 348)

There is a great danger of getting lost in this maze of alternative questions and being trapped in practical terms. If, for example, technological determinism were actually at work, especially in such a way that scientific and technological progress is driven forward by an almost uncontrollable momentum of its own, then all efforts to influence it would a priori be pointless and without consequences. There would only be a choice between technological fatalism and abandoning technology. On the other hand, technology-deterministic tendencies can hardly be dismissed as purely intellectual constructs. It is obvious that what is available in terms of technical knowledge very much determines what is considered feasible and sensible in the future. And major infrastructural investments, for example, very effectively define technical development paths. If a society has invested so much in its highway and road network, then technical progress in the field of transportation will be pushed in the direction of developing modifications and improvements to the automobile or similar vehicles for a very long time. As a rule, technical alternatives that require a completely different infrastructure will inevitably find it extremely difficult to establish themselves. A model of the technological-genetic field should therefore be located beyond the extremes of pure technological or social determinism, as this is the only way to avoid the danger of one-dimensional and one-sided explanations of technological progress.

Outline and structure of the techno-genetic research approach

In summary, technology genetics research is based on the assumption that the selection and elimination decisions in the process of developing technology are shaped by the organization-specific interpretation of general technical models. The implementation of these guiding principles in organizationally characteristic research strategies takes place using organization-specific construction styles and is based on the selection and application of existing scientific and technical knowledge determined by construction and research traditions. There are therefore four main factors that influence decisions in the field of technology genesis, namely construction and research traditions, construction and research styles, organizational and corporate cultures, and guiding principles.

- *Traditions of construction and research*: These function as a kind of historically-oriented perception filter to which all existing knowledge that is somehow relevant for a new development is subject. Not all existing knowledge is equally present in R&D decision-making processes at all times. Shaped by the filter of their respective R&D traditions, certain groups of engineers or certain teams of scientists see the various segments of existing knowledge as having different relevance in relation to the innovations they are striving for. These traditions serve them – consciously or unconsciously – as selection criteria for determining which knowledge segments of the entire knowledge pool are relevant and which are not (Dierkes 1988, p. 55; Knie 1989a, p. 45ff.). At the time when Rudolf Diesel developed his engine, for example, many engineers were actually striving to develop decentralized power generation systems because the previously dominant paradigm of centralized power generation – i.e., the large steam engine with the corresponding peripherals – was increasingly reaching its efficiency limits. And all of those working on this problem drew on existing knowledge – only they did so in different ways. Diesel saw the problem through a different lens than the traditional engine builders because he came from the refrigeration industry, where he was used to working with materials that could withstand high pressures. The traditional steam engine engineers, on the other hand, started from the experience that there was a certain limit to the level of pressure that could not, in principle, be exceeded for material reasons. Diesel basically did nothing other than perceive the existing knowledge differently, select it, and then recombine it. He illuminated it with a different spotlight, so to speak, and thus developed a new engine concept. Bound up in the design tradition of the steam engine, engineers at the time were unable to make use of this concept because their specific patterns of perception of the aspects of existing knowledge to be regarded as relevant systematically excluded precisely those elements from their search grid that Diesel considered relevant based on his completely different experiences.
- *Construction and research styles*: Construction and research traditions do not determine the patterns of thought, behavior, and decision-making in the development process in a straightforward manner. Whether and to what

extent these traditions are stabilized, reinforced, broken, or recombined in the organizational contexts of companies and research institutions depends on which generalized ideas about appropriate problem-solving procedures and which concrete type of approach to R&D tasks – from the selection of the instruments used to the measurement procedures to the evaluation criteria – dominate in these organizational contexts. The term "research and construction style" aims to capture the cognitive, methodological, and material form of technical problem-solving specified in the organizations (Dierkes 1988, p. 55; Knie 1989a, p. 47ff.). The importance of such styles is particularly evident in the open decision-making situations characterized by great uncertainty that are typical of R&D processes. When, in the last third of the 19th century, the demand for decentralized energy in many areas of the economy increased by leaps and bounds, but steam engine technology came under increasing criticism due to its high acquisition costs, costly maintenance, the nuisance caused by smoke emissions, and the constant danger of boiler explosions, companies in the German engine manufacturing industry stuck to the established energy technology development line. Although hot-air and gas engines were already being developed as alternatives, the prevailing design and research style in the companies concentrated on adapting this established line to the changed requirement profiles within the framework of the limited technical possibilities.

- *Corporate and organizational culture*: At the latest since the shift in R&D processes from the individual level of the more or less isolated single inventor to R&D teams in organizations, the weight of organization-specific factors has increased considerably (Dierkes 1988, 1989b, 1990c; Dierkes/Berthoin-Antal 1985; Dierkes/Knie 1989). Technology genesis decisions are usually those that are made under great uncertainty of outcome. However, the greater this uncertainty is – whether due to the long-term nature of the input-output relationships or to their non-linearity – the more they are determined by the fundamental perceptions, values, basic assumptions about strategies, and behavioral concepts that dominate in the organization in which these decisions are made. The aim of the organizational culture approach is to capture the ensemble of coupling factors between the external and internal worlds of organizations (Dierkes 1987, p. 163f.). This approach thus focuses on two analytical perspectives. On the one hand, the aim is to capture the totality of these factors and their interplay, their synthesis; on the other hand, the organizational culture approach aims to do this not in an abstract system-theoretical way, but in an object-specific way, by trying to capture the

particularity and uniqueness of this ensemble and not to abstract it away.
Organizational culture can be briefly defined as "collective programming of the mind" (Hofstede 1980, p. 30). It is a pattern of basic assumptions developed by a particular group of people who have worked together long enough to have shared significant experiences in their efforts to solve the problems of adaptation to their external environment and internal integration. Such basic assumptions are internalized by the members of the organization through their everyday cooperative relationships and often act as tacitly assumed background knowledge on organizational decision-making behavior. Anyone who has changed institutions in their professional life or who has worked in different institutions at the same time has certainly experienced that there are often subtle but nonetheless effective differences. It is equally obvious that companies perceive the same environment in different ways depending on the organization. The automotive market of the future, for example, will look different from the perspective of different manufacturers, even if they use the same or similar data as a basis.

- *Guiding principles*: Wherever people discuss, argue, and decide with each other about scientific and technological progress, its direction, and its content, certain technical guiding principles are encountered. These guiding principles bundle the intuition and knowledge of individuals as well as the collective consciousness of the institution about what is feasible on the one hand and desirable on the other (Dierkes 1988, p. 54, 1990b). Thus, technical models are clearly different from science fiction – although they may have some relation to it – because they are defined by two boundaries. On the one hand, they operate at the limit of what is still technically conceivable, possible, and, above all, feasible, and on the other, at the limit of where people have or could develop a need or desire for it, i.e., where potential markets, needs, or users exist for a technology that is regarded as conceivable and feasible. Such technical concepts are well known. The "paperless office," the "unmanned factory," and "artificial intelligence" are just a few examples. An image that is no longer fondly remembered, namely that of the "car-friendly city," shows the material power that such technical models can assume. Entire generations of architects and urban planners were trained under this model, and thought and acted according to its calculations.
In discussions about the specific direction in which certain technologies should develop, technical models act as fixed points and points of reference. Of course, guiding principles are also inevitably subject to changes and cycles. There are international fashions under which guiding principles change,

> and there are obviously countries that are more influential than others in international competition. If certain countries are fixated on certain technical models in certain fields of technology, this often has a kind of suggestive pull effect. Technical models are often also supported and disseminated by professional associations in individual fields of technology or sectors of industry, but also by subgroups of these.

With this brief outline of the technology genesis approach, which is based on the four central concepts, a general hypothesis framework has been developed that needs to be tested, modified, and, if necessary, falsified in specific empirical studies. Despite all the skepticism that has been expressed toward this approach, which is based on the rather "soft" factors of technology development, it seems to be worth examining whether it has the potential to complement TA research as a traditional form of technology management. One focus for the future should be on empirical studies on the genesis of technology in particular, as only being measured against reality can provide information on the ability of technology genesis research to assist in society-oriented technology management.

4. Next steps in technology control: Regulating consequences and controlling causes

Experience to date has shown that the concept of technology assessment, particularly with its focus on a broader set of objectives than previous cost-benefit studies, including side effects of a more distant nature, can make a significant contribution to improving the decision-making basis for the application of new technologies. This is likely to be a first important step toward steering technical progress not solely on the basis of private-sector criteria, but with a stronger focus on society. Despite the success of traditional TA research, it seems at least worthwhile to also pay attention to technology genesis research and its potential for efficient technology management. However, we must urgently warn against seeing a new doctrine of salvation in the genesis of technology, as we can expect nothing more than a complementary model to the forms of control practiced to date. A look at their respective core orientations shows how fruitfully these two approaches can complement each other. While the TA approach as a "hard" form of control focuses on the paths of technical progress and their direction in order to prevent technical development and its secondary and tertiary effects from escalating and becoming unbalanced, the technology genesis approach with its "soft" technology control aims to put different development paths up for discussion and thus also for negotiation. TA research and the technology genesis approach can – provided that these two approaches interact harmoniously – be taken as an example of the interaction between different models for technology management, which also leave room for other ideas and concepts for technology management. Traditional TA research would then form the common starting point for different strands of research, which could perhaps one day be united as the building blocks of a social science theory of technology development to form a coherent theoretical structure. Efforts in this area could be particularly worthwhile at present, as the field of technology seems to have become quieter in the social sciences in the 1990s. This is a good opportunity to take time out from the hectic day-to-day business to consider the question of how technology can be shaped and the consolidation of different research approaches.

However, it should be emphasized once again that it will never be possible to fully anticipate new knowledge or completely predict all possible effects of new lines of technical development. No approach to technology control and no closed theory will ever be able to do this. TA research can provide information on the possible and probable effects of new technologies; it can provide decision support in order to select the alternative with the least negative or highest positive secondary or tertiary effects from several available alternatives. It can also suggest measures to reduce, correct, or compensate for unintended negative consequences of the use of new technologies (Dierkes 1989b, p. 76). In short, it can create a basis for the normative evaluation of technology in terms of acceptability and provide basic knowledge for a public discourse centered on this, thereby substantiating and qualifying this discourse, but it cannot replace this discourse.

It is therefore important for the use of TA information in politics, science, industry, associations, and organizations as well as the general public that institutional arrangements are also created to bundle the scattered knowledge from different technology assessment processes in such a way that it is available quickly and in a targeted manner when required. This process has three main objectives:

- Integration of the individual results obtained into generalized bodies of knowledge about the relationships between technical development and social, ecological, and political systems;
- Communicating this condensed TA knowledge, which is integrated into overarching contexts, to decision-makers in politics, business, associations, and the general public interested in these issues, and
- Collection and bundling of methodological and organizational experience in the implementation of TA processes.

The importance of this task, which should not be underestimated, is related to the fact that only the integration of as much of the available knowledge as possible can ensure that political decision-makers are provided with well-founded and substantial findings on new technologies that enable a qualified discursive debate and thus a responsible decision about new techniques in the first place (Ullrich 1997, p. 105).

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Carl Friedrich Gethmann

Rational technology assessment[1]

The development of modern science and technology since the 16th century has by no means always been received with unreflected euphoria and without critical commentary. Apart from rather selective antipathies toward individual technical innovations, e.g., the introduction of the railroad, entire epochs such as Romanticism were fundamentally skeptical about the assumption of progress with regard to modern science and technology. In the 19th century, the social consequences of the technical process, for example for the health and welfare of workers, and the underlying questions of distributive justice within society, were the main focus of the debate on technology and science. However, these experiences and reflections did not lead to a *fundamental* problematization of science and technology. Rather, it was about the question of ownership of these "means of production" and their social embedding. Between the major political-social antagonistic system concepts of the 19th and 20th centuries, the role of science and technology in guaranteeing progress was therefore not fundamentally controversial. Rather, fundamental criticism of science and skepticism of technology were regarded as characteristics of pre-modern attitudes to life and reactionary political concepts. The solution to the consequential problems of scientific and technological developments was seen on the one hand in political or economic control measures, such as the establishment of the welfare state, and on the other hand in revolutionary ideas about fundamental social upheavals. A social discussion about the fundamental justification conditions for scientific and technological action has therefore only been possible since the grand concepts of socialism and capitalism began to lose their power to provide orientation, for various reasons.

The desideratum of a critical reflection on the development of science and technology in recent decades is closely linked to events that have rendered the basic optimistic attitude toward progress and new scientific and technological developments implausible. Disgust at the military implementation of scientific

1 *Editors' note*: This article is the introductory chapter to "Rationale Technikfolgenbeurteilung" (Grunwald 1999). As it contains references to other chapters included in the present book, the article has been adapted and shortened accordingly for our purposes.

discoveries (e.g., as part of the Manhattan Project[2]), unease about the increasing speed of mechanization, fears about the limits of growth, and growing sensitivity to technology-related risks to the environment and society have led to an increasing "demystification of technological progress" since the 1950s. Since then, the justification of science and technology has been called into question by considerable groups in the public debate. In this debate, the sciences play a complex and ambiguous role both as problem-*causing* (e.g., as producers of chlorofluorocarbons; CFCs) and problem-*discovering* (e.g., as empirically determining the depletion of the ozone layer) and problem-*solving* bodies (e.g., in the provision of substitutes). Since the 1970s, this ambiguity has given rise to an increasing need for critical reflection to advise politicians and society on controversial issues relating to the development of science and technology, to shape science and technology policy, and to avoid negative consequences for society and the natural environment. This advice, for its part, should meet the standards of scientific rationality.

1. Technology assessment and ethics of technical action

The scientific approach to the consequential problems of scientific and technological developments can be traced in two main lines of discussion: Technology assessment (a), which is more influenced by the social sciences, and the ethics of technical action (b), which is anchored primarily in professional philosophy.

(a) Initiated by the American discussion on "technology assessment" (TA), a large number of advisory institutions have been founded in the last 25 years, through which science and technology policy decisions are to be placed on as broad a basis as possible in order to be able to take account of the aforementioned objectives in the complexity of these decisions (Westphalen 1997). Scientific advisory capacities in science and technology issues are essentially designed as internal administrative bodies to advise the executive, as parliamentary institutions, independent scientific institutes, or according to a network model of these institutionalizations. These are often relatively small institutions that primarily provide methodological expertise and work together with research institutions and experts from the relevant specialist areas on specific topics. In this way, TA

2 *Editors' note*: The Manhattan Project was a U.S. research and development program during World War II to produce the first nuclear weapons. It was carried out in collaboration with the United Kingdom and Canada (see also Bechmann & Frederichs in this book).

has become an institutionalized and interdisciplinary cross-sectional task of the science system, which in many cases, however, is integrated into the political institutional structure and whose "scientific nature" has therefore been repeatedly problematized.

Examples include the following institutions:

- Parliamentary TA institutions: Office of Technology Assessment (OTA) at the U.S. Congress (founded in 1972, dissolved in 1995), Danish Board of Technology, Netherlands Organization for Technology Assessment (NOTA, Rathenau Institute), and the Office of Technology Assessment at the German Bundestag (TAB);
- TA networks: European Technology Assessment Network (ETAN), European Parliamentary Technology Assessment (EPTA), and International Association for Technology Assessment and Forecasting Institutions (IATAFI) as examples of loose associations of individuals or institutions.

Such institutions attempt to implement various methodological and strategic concepts (Gethmann/Grunwald 1996). What they have in common is an approach that is more in line with the original concept of the OTA, which can be described with a certain degree of coarseness as "descriptive". The focus is on reports prepared for the purposes of decision-makers on the state of knowledge and skills with regard to the probable consequences. The most important task, in addition to identifying options for action, is to assess the existing use of technology, its consequences, and possible socio-political repercussions. Normative judgments about the scientific and technological options are either excluded or at least undesirable by the commissioning of the research, and are at any rate not part of the institutions' self-image. The distinction between technology impact research and technology assessment (cf. Ropohl 1996; VDI 1991) reflects this descriptivist self-determination. Behind this is the view (supported in the philosophy of science, particularly by Max Weber and critical rationalism) that normative statements cannot be justified in a generally binding manner and are therefore a fortiori not scientifically valid. Instead, "evaluations" are relegated to a sphere that is often described in an unclear sense with the word "politics". This reticence toward "evaluations" documents the "positivist hesitancy" of TA (Petermann 1991, p. 285) as the result of a decisionist division of labor: According to this, science provides ("value-neutral"!) facts, and politics then makes the value-laden decisions (cf. on this criticism also Nida-Rümelin 1996a, p. 808f.).

(b) Philosophical ethics has a long tradition of dealing with questions of science and technology (Mittelstraß 1992; Gethmann 1996a/b; Nida-Rümelin

1996b). This is probably one of the reasons why the representatives of philosophical ethics who deal with applied questions of science and technology have only recently addressed TA in the sense of (a) (Mittelstraß; Gethmann). Discussions about a professional ethos for engineers and about the responsibility of scientists in the wake of the atomic bombing of Hiroshima and Nagasaki are examples of philosophical reflection in the sense of this ethics of science and technology. The "rehabilitation of practical philosophy" (Riedel 1972) increased the openness of professional philosophy to the moral issues of technological progress. However, it was not until the "principle of responsibility" (Jonas 1979) that a broader public began to take notice of the specialist philosophical debate. Since around the mid-1980s, a boom in the ethics of science and technology can be seen in a large number of publications, conferences, and case studies, the founding of new institutions (Bender/Hartenberger 1997), the establishment of ethics commissions on various topics, and, last but not least, in a differentiation of technology ethics according to subject areas and concepts (Grunwald 1996c, 1998d).

The aforementioned reticence of (social science-oriented) TA toward prescriptive statements is historically due to an ideal of value freedom in the sciences that goes back to Max Weber and was further supported and disseminated by K. R. Popper (Gethmann 1998). As a result, the TA discussion strand remained almost unconnected to the parallel discussion in philosophical ethics on questions of scientific and technological progress, because philosophical ethics sees itself as a normative undertaking. If, on the one hand, there are primarily normative deficits, approaches in philosophical ethics often have operationalization deficits on the other. Instead of a fruitful discussion about the mutual deficits, however, for a long time only an exchange of positions took place (for example, in Grunwald/Sax 1994).

2. Technology assessment as a rational enterprise

The concept of *rational science and technology assessment* can be understood as a critical reflex to the omissions and unreflected assumptions described above, in that it claims to address not only the epistemological questions of the consequences of science and technology, but also and especially their ethical aspects under the claim of scientific rationality. This should not be understood as an attempt to transfer the complex of topics from one subject area (e.g., sociology) to another (philosophy). Rational science and technology assessment is first and foremost an *interdisciplinary* undertaking between the relevant scientific disciplines, and furthermore a *transdisciplinary* interaction between the scientific system in general and the social environment which it presupposes as its basis of life and which it influences (Mittelstraß 1992, p. 120ff.). Rational science and technology assessment is intended to offer operationalization proposals for transdisciplinary problem solutions by methodically reconstructing core concepts of the technology impact debate and thus making them accessible for interdisciplinary work. By explicitly including reflection on scientific languages as the condition for the possibility of interdisciplinary understanding in the program, transdisciplinarity is not primarily understood here as a social event, but as a cognitive achievement and effort that requires reflection on the theory of science. In this sense, transdisciplinarity represents a condition for the possibility of complex problem-solving (Mittelstraß 1989). The fact that science is understood as a problem-solving enterprise means that it makes no sense from the outset to draw a line between cognitive and social endeavors. Epistemology and ethics are two complementary parts of *one* philosophy of science program.

The attribute "*rational*" refers to the need to justify statements and the need to justify actions: Actions should be described as rational precisely when they occur based on action orientations that can be shown to be reasonable or justifiable for everyone (Gethmann 1995). This is based on the conviction that, firstly, normative conflicts are also accessible to rational assessment (cf. Habermas 1973; Gethmann 1982, 1998), and secondly, that the statements of the sciences themselves are not due to the constitution of their subject areas, but to the *processes* of their production. Reflection on the consequences of science and technology therefore also includes – and this also distinguishes rational technology assessment from TA – the reconstruction and critique of the conditions of validity of their results in terms of scientific theory. In the science or technology policy decision-making process, the focus on rationality is reflected in the emphasis on decision-making and planning rationality – this too has hardly been taken into account in the conceptions of TA.

The *concept of technique* underlying here is primarily procedural. The term "technique" refers to both the mastery of action schemata such as, e.g., the technique of playing the violin, or surgical techniques, as well as the relic-like results of poietic actions, i.e., the *artifacts*. "*Technology*" represents the (scientifically disciplined) discourse on techniques, in particular on the ensemble of rules characteristic of a technique. Artifacts are referred to as "devices" insofar as they are used as instruments in other technical practices. The concept of technology thus refers both to "hardware" and to regulated processes. For the reconstruction of technical processes, it should be noted that the methodological primacy always applies to poietic actions over artifacts. In contrast, an "ontology" of technical objects is methodologically secondary.

According to these semantic definitions, bred animals and designed gardens, for example, are also technical artifacts. In terms of the philosophy of technology, there is no obvious difference at this level between a mechanical engineer and a dog breeder: Both produce artifacts for a specific purpose with regard to the anticipated context of use. Of course, this view of the philosophy of technology does not imply any ethical prejudices, such as that a dog should be treated in the same way as a machine. The procedural concept of technology makes it clear that the discussion on the consequences of technology must not only focus on the artifacts as the end products of a research and development process that extends over years or even decades, but that the underlying poietic and scientific processes in particular require reflection. Technology assessment is therefore always also an assessment of the consequences of science and vice versa. This means that, strictly speaking, a distinction between scientific ethics and technology assessment cannot be maintained.

The concept of the *consequences* of technology requires an explanation. First of all, we must remember the distinction between the *result* of an action and the *consequence* of an action (von Wright 1971; Hartmann 1996): The result of the action is the state of affairs that arises after the action has been carried out (after the construction of a production plant, there is a production plant at the location in question). The concept of consequences, on the other hand, refers to other related poietic and practical circumstances (production takes place in the production plant). This concept of consequences is initially neutral with regard to the evaluation of these consequences: Even desired consequences of technology – and this also includes the often neglected *purposes* of technology development – are consequences of technical action in terms of action theory. Purposes are intended consequences, side effects are unintended consequences (this distinction is obviously to be read pragmatically and not ontologically, i.e., it does not presuppose the assumption of a "mental" sphere in which the intentions reside). Opportunities and risks can be subsumed under the concept of consequences. Rational technology assessment is not only concerned with those aspects that are often apostrophized as "side effects", but explicitly also and especially with the justifiability of *purposes* for science and technology.

"*Assessment*" is understood as a rational clarification process that proceeds according to rules to be justified and in this way legitimizes the results of the process.[3] In contrast to the colloquial meaning of “evaluation,” emphasis is therefore placed on comprehensibility and trans-subjectivity; at the same time, this implies that assessment procedures can cover both descriptive and prescriptive aspects. In contrast to the concept of technology *evaluation*, assessment focuses on the procedural element and not on the orientation toward material values, however formulated and justified. Rationality assessments are not based on factual acceptance, but on the normative *acceptability* of decisions, which itself can only be determined procedurally. Of social interest is precisely the question of the extent to which it is justifiable *to expect* certain individuals and groups to accept a technical development in the interests of the general public. Distributive justice in relation to opportunities and risks plays a special role here.

The *pragmatic starting point* for all normative considerations are potential and, above all, virulent *conflicts* about how society should deal with the consequences of scientific and technological developments. In conflicts about science or technology and their consequences, the essential future models of society compete; the questions raised are therefore highly relevant in ethical and political terms. Technology conflicts must be distinguished from disagreements regarding the validity of factual assertions and the factual validity of moral judgments (cf., e.g., Renn/Webler 1996, p. 356). Depending on the type of conflict, other forms of discourse must be used to resolve the conflict (rationale or justification discourses). Technology conflicts and related decision-making uncertainties are essentially generated by the different moral concepts of those affected. In rational technology assessment, different morals should be worked through with the available means of practical rationality in order to judge the desirability or acceptability of the consequences of science and technology.

Rational management of conflicts surrounding science and technology is an essential prerequisite for long-term reliable science and technology policy. Rational technology assessment therefore aims to provide the means to offer *advice* within the framework of the possibilities for preparing decisions and reflecting on technology and science. The addressees of this advice are:

- Political bodies and institutions that either regulate the framework conditions, guide the progress of scientific and technological development through funding measures, or directly intervene through state technology decisions;

3 *Editors' note*: This understanding of ethics has recently been unfolded as a foundational philosophical monograph (Gethmann 2023).

- Professional groups and individuals who are involved in shaping scientific and technological developments in the course of their work. This applies in particular to the self-regulation of the scientific system;
- The general public, communicated via multipliers and the media.

This advice also relates to the problem of how a long-term, reliable technology and research policy can be designed and implemented. The prudent use of society's scarce financial and human resources requires a forward-looking, long-term, and sensible approach to scientific and technological development. Serious course corrections at an advanced stage of major scientific and technological projects, on the other hand, often require considerable economic resources; breaking-off lines of development leaves behind investment ruins and can result in considerable legitimacy problems. Rational technology assessment therefore ideally refers to the research and assessment of the consequences of science and technology at the *earliest* possible *stages* of their development, in which social control measures are still effective without serious economic consequences, and acts as a reflection to accompany science and technology.

The focus on long-term orientations in the shaping of scientific and technological progress means that rational technology assessment – unlike the advisory services of parliamentary TA institutions, for example – is less geared toward *direct* implementation in concrete decisions. Instead, it is intended to allow perspective assessments of the realms of possibility in which scientific and technological developments occur. It is therefore *practice-oriented*, but not directly *implementation-oriented*.

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Armin Grunwald

Technology assessment – between sociological systems theory and philosophical ethics

1. Technology management, technology assessment, and technology ethics

The development of technology was rarely if ever perceived as a social problem as long as new technology seemed to show mainly economic or practical advantages in a progress-optimistic attitude. Although undesirable consequences were sometimes obvious, e.g., in the working world of the 19th century, they did not lead to a broad social or scientific discussion about the justification conditions for technical action. It was only when the identification of the new with the good (or at least the better) was widely denounced in the wake of the awareness of the "limits to growth"[1] and ecological dangers, including apocalyptic scenarios, i.e., with the end of optimism about progress, that questions about the design of technical change became the focus of public, and later also scientific, discussions. The concept of "technology control," the attempt to steer technical developments in the direction of what society wanted ("control optimism"), emerged. However, initially optimistic expectations, for example, in the "finalization debate" in the 1970s, that undesirable developments and technological consequences could be completely or at least partially avoided through state control, informed and advised by technology assessment (TA), turned out to be irredeemable. Thus, the history of TA itself can be interpreted as a tentative experimentation and constant learning process, in which each new approach claims to avoid certain shortcomings of the previous approaches, but in doing so raises new questions and produces other shortcomings (for an overview, see Gethmann/Grunwald 1996).

In terms of technology design, control optimism represents a late form of the general planning euphoria that characterized the 1960s and 1970s (Grunwald 2000). In satirical exaggeration: "as a universal remedy [...] for mastering the future, [...] for the formation of a (planned) new human being in a planned

1 *Editors' note*: "Limits to growth" here refers to the well-known publication by Meadows, D. et al. (1972): *The Limits to Growth; A Report for the Club of Rome's Project on the Predicament of Mankind*. In the decades that followed, the issues raised in the report and its findings attracted considerable public interest regarding global environmental issues.

planning paradise" (Schelsky 1966, p. 160ff.). Behind the planning euphoria is the image of a central planning and planning-executing authority within society, embodied by the state. An important tool for this society-wide control is empirical social science research, which should provide the necessary knowledge in the form of impact research, technology impact research or technology genesis research in order to be able to control in a targeted manner. When TA is assigned the task of "systematically recording and evaluating the overall context of technological and social change as a complex system of mutually dependent causes and effects" (Deutscher Bundestag 1987), this is essentially based on trust in empirical social sciences, which, following the example of the natural sciences, promised to provide complete legal knowledge about society (criticism of this can be found, for example, in Grunwald/Lingner 1999).

Sociological systems theory (Luhmann 1984, 1990a, 1997), on the other hand, has rejected planning optimism for reasons of principle. The functional differentiation of society into autopoietic subsystems (science, economy, law, etc.), each of which operates *autonomously* on the basis of its own guiding distinction (true/false, pay/not pay, right/wrong, etc.), leaves no room for a central social authority. In particular, the state cannot assume this role because the political system is also only a social subsystem that processes its own key distinction and cannot dominate the other systems. This system-theoretical diagnosis of modernity has massive consequences for the relationship between ethics and the practice of technology design, at least from the point of view of its advocates (Luhmann 1990b; Bechmann 1993).

Philosophical ethics reacted relatively late to the challenges of modern technology with its own initiatives and concepts. It took the "principle of responsibility" (Jonas 1979) as an initial spark to trigger a broad ethical discussion of technology. Since around the beginning of the 1980s, there has been a veritable boom, which is reflected in a large number of publications, conferences and case studies, the founding of new institutions, the establishment of ethics commissions on a wide range of topics and, last but not least, a differentiation of technology ethics according to technology areas and concepts (Grunwald 1998). The frequently used addition "*new* ethics" marks the pressure of expectation on technology ethics in a particularly accentuated way.

Interestingly, the two reflective strands of discussion surrounding the problem areas of technology development, technology design and technology consequences – technology ethics and TA – have remained largely separate, seemingly even in partial ignorance of each other.[2] While the social science view of TA has found its place primarily in TA institutions in the intermediate area between science and politics, the area of the ethics of technology has tended to remain the more remote area of university discourse. In addition to its – quite understandable – rejection of planning optimism, systems theory has now declared ethics to be largely obsolete for technology issues (Luhmann 1990b; Bechmann 1993; cf. Stegmaier 1998). In turn, philosophical ethics has accused systems theory of failing in normative questions (DLR 1993; Gethmann 1994). This article is dedicated to explicating this dispute, the reasons for the conceptual tension between systems theory and ethics, and its significance for an assessment of the possibilities and limits of TA.

In the following, this will be done on the basis of various key questions related to the control problem. It is assumed as undisputed that there are problems with undesirable and unintended consequences of technology and technologization, that at least in some areas there is a lack of orientation or even helplessness in society about how to proceed, and that there is a need for concepts to deal with this situation. Furthermore, it is assumed that the current technology policy practice is in fact constantly being steered, e.g., through research funding, by promoting technology transfer or through regulations (think of the steering mechanisms that led to the widespread introduction of first lead-free gasoline and then the regulated catalytic converter). However, if steering is actually taking place, then it is undoubtedly a legitimate task to develop and test theoretical concepts for improving and safeguarding this actual steering practice, *without* having to succumb to any kind of steering optimism.

In principle, however, what Luhmann said about ethics also applies to other TA concepts in this area: "In any case, political need alone is not enough, nor is the good will of those who strive for it" (Luhmann 1990, p. 42). Instead, in a selection situation – and the competition between different scientific concepts for dealing with a problem also represents a selection situation – an appropriate

2 An example from the field of medical technology: A monitoring report by the Office of Technology Assessment of the German Bundestag (Petermann/Sauter 1996) complains that TA studies in this area are economistic and technicistic and neglect legal and ethical concerns. In addition to the "actual" TA on these issues – to which the accusation may apply – there is, however, an extensive international discussion on medical ethics, which seems to be completely ignored in the TA context. A sectoralization of the discussion can be observed here, which runs counter to the purposes of *comprehensive* assessment necessities of modern technology and urgently needs to be overcome.

or optimal concept must be selected rationally from a means-ends perspective. Successful management in this sense requires:

- *Diagnostic* knowledge about the situation in which steering measures are to be implemented in order to achieve something (situational knowledge) and the subject area of steering (the "what" of steering),
- *Instrumental* knowledge of means-ends relationships, regularities, processes, laws: the "how" of controlling (means-ends knowledge),
- *Orienting* knowledge about the purposes of steering, metaphorically speaking, about the direction in which steering is to take place: the "where" of steering (orientation knowledge).

Even this small, differentiating consideration makes it clear that neither normative considerations alone can be used in technology design – they would lead to a "normativist" fallacy by dispensing with an empirical basis – nor that instrumental and diagnostic knowledge alone can be sufficient – this would entail a descriptivist fallacy and a lack of direction in steering. The obvious thesis is therefore that we should not speak of a relationship of confrontation between normative ethics and descriptive systems theory, but rather, at least in certain respects, of a *relationship of complementarity*.

In order to develop this thesis, the mutually raised and sometimes serious objections must first be questioned with regard to their tenability and presuppositions (Part 2), so as not to produce superficial gestures of reconciliation prematurely. The result is that the suspicion of the irrelevance of systems theory to ethics can be constructively rejected by demonstrating its practical relevance; however, the systems-theoretical diagnosis of modernity has consequences for the practical relevance of technology ethics (Part 3). It can be seen that in modernity, not only the *setting* of limits to technological development is placed at the disposal of society; society must not only decide *which* limits it wants to set, but *whether* it wants to do so at all. In this way, the discussion between ethics and systems theory leads to the constitutive features of modern society's self-description and self-understanding.

2. Systems theory or ethics for technology design?

In the following, the main arguments of systems theory and ethics against the other side are listed and briefly assessed or rejected in their relevant aspects (cf. Grunwald 1999).

2.1 The suspicion of irrelevance in systems theory vis-à-vis ethics

Sociological systems theory has raised a number of objections to ethics, which lead to the conclusion that in the modern age ethics can only be applied to direct face-to-face communication, but not to socially relevant control problems (see Luhmann 1990b; Bechmann 1993). In the following, the essential aspects for the context of technology control are highlighted: (1) ethics, unlike morality in traditional societies, can no longer have a socially integrating effect in modernity, (2) ethics is in need of justification due to social plurality, (3) ethics suffers from the loss of its object because the consequences of technology are unpredictable, and (4) ethics has lost its addressee due to functional differentiation.

(1) Ethics and the integration of society

Traditional societies are essentially held together by moral concepts that are binding for everyone. This mechanism of social integration is no longer available in a functionally differentiated and pluralistic society. Luhmann now accuses ethics of being unable to fulfill its supposed claim of being able to integrate society by establishing universally valid norms. Max Weber already warned against making ultimate principles binding for everyone; it is precisely these that should remain controversial. Luhmann's concern is that moral communication, by correlating with the self-esteem of those involved, is always close to conflict and violence: The moralization of conflicts does not promote understanding, but rather hardening fundamentalization.[3]

An answer presupposes the explication of the underlying understanding of ethics. Ethics is understood as the theory of reflection on the "right" morality (cf., e.g., Luhmann 1990b; Gethmann 1994): Morals are factually action-guiding maxims and rules of an individual, a group or society. Ethics, on the other hand, is concerned with the justification of rules of action that can claim validity beyond the scope of merely particular morals. In particular, ethics serves the understanding-oriented management of conflicts arising from the actions of actors on the basis of different moral concepts. If moral concepts are direct guidelines

3 Some current technological conflicts (Castor transports, genetic engineering) quickly show that this thesis is anything but implausible.
Editors' note: The transport of Castor containers was politically controversial in Germany in the 1980s and 1990s and became a symbol of social conflict in the field of nuclear energy. The Castor containers were transported on special wagons for nuclear freight from the Grafenrheinfeld nuclear power plant to the La Hague reprocessing plant in France. These transports were regularly accompanied by massive protests.

for action and decision-making, ethics should provide additional guidance *in the event of conflict*. Morals have *factual validity*, but only ethical reflection can generate *legitimacy* in the sense of *normative validity.*

In the sense of this description, it is not clear that ethics should be burdened with the integration of society. Conflict resolution in individual cases may contribute to the integration of society. However, to derive from this the demand that ethics should assume the former function of binding morals in order to then argue that this demand cannot be met is not tenable. It is clear that Luhmann says ethics, but ultimately only means a special variant, namely the Habermasian or Apelian variant of discourse ethics with its intentions of ultimate justification and strong claims to universalization. Ethics understood pragmatically in the above sense is therefore not subject to the above accusation (Stegmaier 1998).

(2) Ethics, technological conflicts, and pluralism

The above-mentioned definition of ethics as a discipline of reflection on factual morals is only meaningful in matters of technologization if decisions in technology discussions are *subject to moral conflicts*. Insofar as technical design processes are carried out exclusively from a cost-benefit perspective and these criteria are accepted by those involved, technology design is carried out under purely economic, business or macroeconomic aspects. Without conflicts over moral issues, there is no need for ethics: Technology conflicts with their moral implications form the thematic center of ethics in technology design. They are not only conflicts about technical means, but also or even primarily conflicts about ideas of the future, about images of man and concepts of society. Discussions and controversies about new technology quickly become surrounded by the questions of what kind of society we *want to* live in, what images of humanity we assume and whether or under what conditions this in turn is desirable. Conflicts over technology are therefore always also ethically relevant political conflicts (Grunwald 1999).[4]

This emphasis on the existence of conflicts for the practical relevance of ethics makes it clear that moral pluralism does not speak *against* the possibility of ethics, as claimed by systems theory (Beck 1986; Luhmann 1990b; Bechmann 1993), but is in fact its precondition: If morality were binding, there would be

4 One thinks here of "data protection" or "safeguarding intellectual property" in the information society, of "residual risk" and "worst-case scenario" in the nuclear energy debate or of new biological or medical techniques in reproductive medicine, human genetics or the neurosciences (right up to the current debate on human cloning).

no need for a discipline of reflection on conflicting morals. The task of ethics is therefore a *constructive* one: Namely, to develop and offer possible solutions to technological conflicts beyond the actual fronts of discussion. This does not imply that ethical reflection *can* provide answers to all relevant questions or resolve all moral conflicts, nor that the results of ethical reflection are actually implemented in the design of technology. As soon as participants in technology design engage in ethical reflection by searching for possible solutions to moral conflicts in an argumentative and consensus-oriented manner, they ensure the practical relevance of ethics (Grunwald 1999).

(3) Ethics and the uncertainty of predicting the consequences of technology

It is well known that the consequences of technology, both as systemic cumulative effects of many individual actions and as the occurrence of incidents, are often unpredictable or can only be estimated with a certain degree of probability. Systems theory emphasizes this unpredictability of consequences and side effects of technical action. Functional differentiation means that the consequences of technology must be tracked across several subsystem boundaries; however, due to the autonomy of the subsystems, their reactions cannot be predicted. As a result, the *object* of technology ethics is in danger of disappearing (Bechmann 1993). However, only known, or at least reliably assessable, consequences of action can be reflected upon ethically. The fact that many actual technological consequences were not known to their originators (this applies, for example, to the consequences of the use of chlorofluorocarbons for the ozone layer until the 1980s), and that this certainly also applies to current actions in many areas, is used as an argument against the possibility and relevance of technology ethics (Bechmann 1993).

However, without wishing to trivialize forecasting problems, this is only a sham argument. Many aspects of technological development can certainly be predicted or rationally anticipated. This applies in particular to the *purposes* of technological development. Insofar as these are controversial (e.g., in questions of manned space flight, cf. DLR 1993), an ethical discussion is in any case possible without forecasting problems of the kind mentioned. Above all, however, technology policy action is then always *action under risk* and as such is *by definition* of explicit ethical relevance, because dealing with the reasonableness of risks will probably always lead to moral conflicts. Talk of the unpredictability of the consequences of technology rightly draws attention to the cognitive problems of TA. However, it cannot be used as an argument against the possibility of technology ethics; *on the contrary*, it can be used *as an argument for its necessity*, since dealing with ignorance or uncertain knowledge always raises the question of the ethical justification of actions in a special way (Gethmann 1994).

Conversely, however, competing conceptions of technology design must also face the question of how they deal with the lack of predictability of the consequences of technology. In the case that systems theory usually raises in its objections to ethics, namely that the consequences of technology are completely unpredictable, other conceptions do not help either. Without empirical or analytical knowledge – which may well be knowledge about probabilities – it is not possible to reflect on the design of technology.

(4) The lack of addressees of ethics

According to the systems theory diagnosis, technology development in the modern age is decentralized and based on a division of labor. The subsystems of society involved (above all science, business, law and politics) operate autonomously and only register the achievements of the other subsystems as "irritations," which they process according to their own mechanisms. Accordingly, there is no central social authority that has an overview of technological development and can control it from this perspective. According to the central and most serious criticism of systems theory, this "subjectlessness" leads to ethics losing its addressee. However, ethics without an addressee can only consist of empty appeals and can no longer claim any practical relevance, because moral communication finds no connection in the structure of functionally differentiated social subsystems, but only leads to a noise without an echo: "One calls loudly for a new ethics – and there is not even an echo, but only communicative noise in society" (Bechmann 1993, p. 215). In view of the reality of technological development, ethics is in danger of turning into mere appealing *rhetoric* of responsibility and diffusively disappearing.

With regard to this objection of systems theory, it must be said that systems theory rightly points out practical relevance problems of ethics and makes partly accurate diagnoses of modernity. Ethics must deal with the tenable parts of these arguments (cf. Hastedt 1991; Grunwald 1999). For example, the relativization of the significance of individual actions in the development of technology massively affects the ethics of responsibility as a special ethical approach to technology, and here in particular engineering ethics (Grunwald 1999). For other approaches, the "loss of the subject of responsibility" is a fact that is associated with structural changes in the social construction of technology. However, this fact does not provide an argument against the possibility and relevance of an ethics of technology that does not concentrate on the responsibility of individuals and its distribution, but on the procedural facilitation of rational decision-making processes in technology controversies.

The argument of the loss of addressees assumes as a *necessary condition* for the practical relevance of ethics the existence of central controlling actors who are responsible for technology development and could therefore be addressees of ethics. Their loss of significance in modern technological development is then stated in favor of a shift to anonymous "systemic processes," from which the conclusion is then drawn that ethics is obsolete for the control of technology. However, this line of argument already fails because the premise cannot be justified. Why should ethical reflection require a central addressee? This speaks to an understanding of ethics that is oriented toward the moral instances of pre-modern societies. Ethics in the sense defined above – actually very close to Luhmann's view of ethics – as a discursive management of moral conflicts can also develop its reflexive potential *in a decentralized* manner, namely at the various levels of technology design and in the functionally differentiated subsystems. Functional differentiation may well mean that no single center of society can assume the steering function in one place; for ethics, however, this only means that it should also differentiate itself functionally in order to be able to offer ethical reflection within the social subsystems. This is precisely the process that characterizes the movement toward "domain ethics" (Nida-Rümelin 1996): Ethical reflection follows functional differentiation, but does not become obsolete as a result.

2.2 The accusation of normative deficits in systems theory

The main criticism in the opposite direction (see DLR 1993; Gethmann 1994) can be summarized in general terms as follows: (especially system-theoretical, but also other) sociological approaches can provide relevant knowledge about the "what" and the "how" of technology control, but not about the "where." The first two aspects mentioned are necessary but not sufficient conditions for rational technology management. There are two ways of dealing with the "where": Either reference is made to factual acceptance, after which the direction of control is obtained from currently accepted attitudes of the population, or the question of "where" is not asked at all because it is of no interest from an "evolutionary" system perspective.

To the extent that systems theory only includes empirically ascertainable, i.e., factual, recognition relationships in its analyses, it only ever leads to naturalistic false conclusions from factual being to ought, according to the accusation of ethics. It is undisputed that political decision-makers need to know which value preferences actually exist in order to implement technology policy programs. However, the factual acceptance of values says nothing about their moral *legitimacy*, which can only be decided by means of an ethical examination. Here, factual acceptance is confused with normative acceptability.

The second – and for systems theory probably more characteristic – approach is to refer to the evolutionary development (self-organization) of society in contrast to its ability to be planned. Here, ethics poses the critical question of what use an evolutionary "system rationality" (Luhmann 1990a, 1997) is to those who are faced with a (e.g., technology policy) decision. According to the criticism, the evolutionary perspective is of no use to the decision-maker because it does not allow any statement to be made about the direction of control. For example, from the perspective of a technical planner, Luhmann's definition of planning as influencing future decisions (Luhmann 1971), which only makes sense from the observer's perspective, is at best cynical and at worst irrelevant to him. A planner of technical systems, for example, who is trying to find some kind of "optimal" solution in a specific situation and has to solve selection problems and make decisions, for example, is obviously not helped if he is told that his planning will change the basis for future decisions, because – and this is crucial – this would be the case *regardless of* how he interprets his planning. Precisely the most important element of decision-making for the planner, the "best choice," is eliminated by system theory: According to this, it is simply completely irrelevant "where" technical development evolves – the main thing is that social evolution continues. The normative element – the root of which will be pursued further – of controlling technological development, namely the generation of orientation knowledge, is not taken into account by systems theory. Therefore, according to the criticism, systems theory can hardly offer any assistance to decision-makers in technology design.

As a result, it should be noted that systems theory cannot provide certain forms of knowledge required for technology management, namely orientation knowledge. It lacks a connection to decision-making situations – the normative deficits are also the result of its great distance from the practice of planning and decision-making, caused by the "evolutionary" perspective. Thus, the apparent paradox arises that systems theory, which accuses ethics of lacking practical relevance, cannot itself take sufficient account of the requirements of practice. This paradox deserves closer examination.

3. Ethics and the control of technology development

In the following, the above-mentioned disagreements between systems theory and ethics will be expanded to include a reflection on the foundations of both with regard to the necessary conditions for their practical relevance.

3.1 Practical relevance of ethics in technology design

The best way to refute a suspicion of irrelevance is to prove relevance. This is briefly outlined below, whereby the *conditions* of this relevance must also be examined. The demand for the practical relevance of technology ethics – without which it would obviously be meaningless – must be specified to the effect that ethics should have *potential* consequences for the practice of technology design, a "chance of implementation," so to speak (Grunwald 1999). Its duty is to ensure that its results *can* be reflected in the relevant decisions and actions in practice. Practical relevance thus does not mean *factual*, but *potential* effectiveness. It is a *necessary*, but not the sole condition for the factual effectiveness of ethics. To conclude that ethics is meaningless (Beck, Luhmann) from its supposed factual ineffectiveness is a false conclusion.

The practical relevance is justified by specifying the *pragmatic places* where ethical reflection can be incorporated into decision-making processes. Ethics must be integrated into existing or newly established "practices" of technology design in society. This can be done, for example, by implementing ethical reflection in means-ends contexts, decision-making complexes, political regulations, planning procedures and other procedures of technology design. Ethics is always relevant in practice when *participants* in technology design engage in ethical reflection in such conflict situations.[5] The accusation of a lack of practical relevance is obsolete here: Ethical reflection, if it is undertaken, is always *potentially* effective because otherwise it would not be undertaken by the participants at all. As soon as participants in technology design engage in ethical reflection, they enable potential effectiveness and ensure practical relevance.

However, the question of practical relevance arises in an intensified form – and systems theory rightly points this out – when it comes to ethics brought to technology design from outside, for example, from the "academic ivory tower." The ethical standards provided there are no longer relevant to practice *per se*

5 Participants in shaping technology are not limited to politicians, managers, and engineers. There is also room for the participation of those affected (Renn 1998).

because they were not developed from the perspective of the participants. What is needed is a transfer into practice and an effort to *appropriate* them by the practice in question. It follows from these considerations that practice-relevant ethics must enter into the concrete contexts of technology design. Its competence would then consist in providing methodological advice to the participants in technology design, but not in establishing general propositions and calling for their observance. Ethics in this sense would not be *merely appellative* (as Bechmann 1993 accuses), but literally *advisory*.

Apart from the role of the citizen as technology consumer, pragmatic places of ethics in technology design can be represented in the tension between, on the one hand, ethical advice on regulatory issues in direct proximity to political ethics and, on the other hand, ethical reflection on the morals of the professions involved in technology design, companies and engineers. Traditionally, in the ethical reflection of technology design, significant importance is attached to the actions of engineers (e.g., Lenk/Ropohl 1993; Ropohl 1996). Although this is trivial to a certain extent, because without engineers technology would not come into being at all, the conclusion that engineers are therefore the primary addressees of ethics in technology design is nevertheless a false conclusion. The ethical relevance of engineers' actions for technology design must already be relativized in relation to corporate actions. It is not the technical "pizzazz" of an *invention*, but the economic success of an *innovation* that determines the actual course of technology development, although in many cases the invention is a necessary precondition for an innovation. If the "traditional" position of technology ethics tends to place excessive expectations on engineers, it is equally unjustified, on the other hand, to completely absolve engineers of moral responsibility for technology development, e.g., because they are merely a largely uninfluential "cog in the machine." Technology design is a complex process in which engineering action is only one type of action among many others and which, even if it may be methodologically primary, is often not, or not solely, decisive for the actual course of technology development. It is precisely in view of this complexity that the question arises of an *appropriate* attribution of responsibility to engineers relative to the responsibility of other groups of participants in technology design (Grunwald 1999). If, from a systems theory perspective, technology design is the result of the unpredictable interaction of different functional systems (political system, legal system, economic system, scientific system), it follows from this understanding that ethical reflection itself must be decentralized: It takes place as a reflection effort *within* the respective systems. The practical relevance of ethics and the functional differentiation of society are by no means mutually exclusive.

A further question would be the conditions for the practical relevance of ethics, in particular the mechanism that can prevent normativist false conclusions with mere appellative content. This question leads into the area between prescription and description: What must be *factually* recognized in order *for counterfactual* ethical prescriptions to be legitimized? There must be a connection between the intended and the factual, because otherwise the intended would have no prescriptive legitimacy; on the other hand, however, this connection must not lead to a naturalistic fallacy (which should actually be called descriptivist), which would also have no legitimacy. Ethics is possible and relevant to practice, according to the thesis only briefly hinted at here, if this is *intended*, i.e., if the counterfactual assumptions of ethics are not merely the imagination of philosophers, but are rooted in practice itself and are *factually effective* there. If participants in technology design do not want to engage in ethical reflection, but prefer to let the practical constraints take their course and disregard the moral respect of persons, the active purpose of shaping the future, and much more, then this can no longer be countered discursively. However, the prediscursive agreement of ethics is permeated by such counterfactual assumptions and cannot simply be revoked because it extends into society's self-image. The conditions of the practical relevance of ethics are part of the presuppositions of our lifeworld and social practices and actions; they are, as it were, inscribed in it.

Requirements and expectations of ethics in technology design must be justified against the background of what is desired with regard to normative conflict resolution or what is assumed to be desired in practice. In this way, expectations of ethics are linked back to the willingness to give ethical reflection practical relevance: A kind of self-consistency obligation. It is not enough to call for ethical orientation – this call is cheap insofar as the caller is not prepared, as a participant in the design of technology, to contribute constructively to the practical relevance of ethical reflection in accordance with the role he has assumed there.

3.2 Observer or participant perspective?

Systems theory is a theory of observations; it understands science *a fortiori* as the feedback system of observations of observers, i.e., a second-order cybernetics (Luhmann 1990a). Systems theory is always practiced *from* an *observer's perspective*: The theorist observes social processes and interprets them against the background of a theoretical foil, in this case the system concept. In relation to contexts of action, this results in a preference for *evolutionism* over the planning or decision-making perspective: Evolution can only be observed, but not planned.

Talking about evolution only makes sense relative to an observer's point of view.[6] The suspicion of irrelevance of systems theory vis-à-vis ethics is to be understood relative to this choice of observer perspective; the observer perspective is part of the chain of reasoning that led to this suspicion. Since the observer perspective always talks about *factual relationships of recognition* – this is accepted, that is not, a change in values has occurred here, etc. –, it is not surprising, but a direct consequence of this approach, if there is no room for ethical reflection, which could question the factual relationships of recognition.

The point, however, and this is probably the center of the field of tension between systems theory and ethics, is that the restriction of social reality to that which one believes to observe in an evolutionist or causalist way represents a *reductionism*. Systems theory and ethics differ in their description of society: Description from the perspective of the participant or the observer? According to this analysis, the system-theoretical conclusion on the irrelevance of ethics is not based on empirical results, but is the result of a basic decision that is necessarily linked to the choice of observer perspective, namely the *restriction to the observation of factual recognition relationships*. This conclusion therefore says nothing about desirable or rejectable directions of technology control, but rather about the methodological frame of reference of systems theory and thus forms *a self-constructed result*.

The arena model, which is widely used in TA (although not purely system-theoretical), can be used to illustrate this because it models the difference between the observer and participant perspectives very well (see Renn 1998, p. 20ff. and the literature cited there). The arena model is based on the *observer perspective* and is created by observing the factual behavior of conflict interaction from the outside under the premise of interpreting the action from a *purely strategic* perspective. This occurs, for example, when behavior is interpreted behavioristically as the use of resources to assert one's own position. The counterfactual element of ethics, that a moral obligation exists for reasons of mutual recognition, appears naïve at best from this perspective and is probably completely incomprehensible in theory. From an ethical perspective, however, the obligation to justify does not only exist for situations that have not already been decided ("social-Darwinistically") in terms of power politics or the factual distribution of resources. The metaphor of the tournament chosen by Renn characterizes this divide: Here, it

6 When Luhmann assumes that "there really are systems" (1984, p. 30), he represents an epistemologically highly vulnerable realism that completely ignores the "constructivist" parts of his own position.

is precisely *not* an intention of consensus or understanding that is decisive, but rather thinking in terms of winner-loser categories. This is a strategic, not an ethical perspective.

Modeling social processes from the perspective of external observers is useful and indispensable for many purposes. However, reducing it to this point and ignoring the participant perspective is inadmissible. "What may appear to be a subsystem from the observer's perspective remains an action-like execution of practice from the participant's perspective" (Ott 1997, p. 99). In fact, actions, decisions, plans and considerations are constantly being made – regardless of whether an outside observer interprets this from an evolutionary perspective. The improvement of practice through ethical reflection can therefore, for analytical reasons so to speak, only take place from the participant's perspective: "The relationship between practice and ethics is not an external relationship; rather, normative *questions* are inherent to practice" (Ott 1997, p. 124f.). The *planning and decision-making perspective* consists precisely in asking in concrete situations whether certain ends are achievable and justifiable and what the optimal use of means is. The fact that this can be described as an evolutionary process from the observer's perspective does not contradict this in any way – but this description does not replace the rationality of planning and decision-making.

Of course, planning as *flexible* planning must always remain provisional in its normative premises, the knowledge used and the purposes pursued (Grunwald 2000). Social technology design under the aspect of planning rationality cannot be an algorithmic production of fixed development strands or final states, but can only represent future-shaping action under a permanent obligation to reflect. Of course, only individual "projects" can ever be planned. The question of whether the entire history can be planned, on the other hand, is pragmatically pointless. It would presuppose the existence of an observer and planner who has an overview of the whole. However, and here we must follow systems theory, this is not available. Talk of planning and decision-making rationality in no way presupposes the existence of a central planning or controlling authority. Like ethics, planning also has a pragmatic place as a decentralized effort in the functionally differentiated practices of society.

4. Ethical limits of technology?

As a normative endeavor, ethics also has an acceptance component that protects it from normativist fallacies. Certain counterfactual assumptions must be factually accepted in society; this is the tightrope walk between a mere acceptance orientation with the consequence of a naturalistic fallacy and an ivory tower ethics without anchoring in social practice; the tightrope walk between the Scylla of the descriptivist fallacy (reference only to the factual) and the Charybdis of the normativist fallacy (no reference to the factual) (Grunwald 1999). If everyone agrees to be treated exclusively from the observer's perspective, e.g., as cybernetic machines, and to renounce their recognition as moral persons, then the counterfactual ceases to exist, leaving only the description of the factual and its relations of recognition. This would lead to a society that is very far removed from ours, perhaps to a society in which the self-description as autopoietic would not be a reduction, but the full reality. This thought experiment makes it clear that the practical relevance of ethics can vary culturally. Ethics as a discipline of reflection is therefore only ever an *offer* to realize practical rationality. The practical relevance of these ethical boundaries for technology depends on whether they are intended. Ethical limits to technology are possible if they are wanted. Whether or not this is the case is not culturally invariant.

Systems theory points to important structural changes in society. Some of its diagnoses in this regard can be shared, even if not all of the theory's components are adopted. The functional differentiation of society as such a diagnosis does not make ethics in technology design impossible, but only the possibility of central addressees for technology control. Systems theory and ethics are complementary to each other in terms of their contributions to rational technology control: If systems theory is descriptive and explanatory from the observer's perspective, ethics is normative. Technology management requires factual knowledge about technology and society as well as reflexive orientation knowledge. This emerging "division of labor" between the social sciences and ethics is, incidentally, laid out by Luhmann himself (Luhmann 1990b, p. 17; cf. also Stegmaier 1998).

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Armin Grunwald

The epistemological status and cognitive limits of technology assessment

1. Relevance of cognitive problems in TA

In the literature on TA, there has been a tendency in recent years for the relevance of cognitive problems to be increasingly devalued in favor of discussion of communication problems in the TA process or implementation problems (cf. some of the articles in Petermann 1991). Of the possible explanations, the following (with the exception of the first point) should all apply to some extent:

(a) Success: The cognitive problems are largely solved. It would then be logical to address the other (non-cognitive) problems in order to optimize TA.
(b) Resignation: The cognitive problems are recognized as unsolvable. The only hope that remains is to compensate by making special efforts in other areas.
(c) Insensitivity: The realization that the success-determining aspects of TA do not lie in the area of cognitive problems, but in communication.
(d) Systems theory: If the relevance of problems is only seen at the level of second-order observation (Luhmann 1984, 1990), then talking about cognitive problems seems almost old European.

The fact that communication is of fundamental importance in technology development is as true as it is trivial: no matter how good the TA results are, they will remain ineffective if they are not communicated in a suitable forum. However, the counter-question must also be allowed as to whether all TA results that are communicated in a suitable forum have a fruitful effect there, regardless of the cognitive quality of what is communicated.

The thesis that dealing with the cognitive problems of TA is not only not anachronistic, but even urgently required, is supported by an argument that cannot be ignored for reasons of action theory. The methodological primacy of the cognitive side follows from the fact that reliable TA results must first be available before any thought can be given to communicating and implementing these results. No matter how good the policy of implementing TA results is, sooner or later it will disavow itself if the implemented results prove to be nonsensical, inappropriate or otherwise counterproductive in relation to the expectations of TA.

Furthermore, the role responsibility of TA requires that it fulfills its task of informing the decision-maker about the risk remaining in its own statements, namely about the reliability of its statements. This task alone requires a cognitive and scientific-theoretical effort, namely a reflexive focus on the validity of the results produced.

If one also considers that the critical function of TA vis-à-vis particular interests can only be maintained through scientific-theoretical efforts, this is a further argument for reflecting on the validity problems of TA statements. Disregarding the cognitive side of TA would therefore not be conducive to its own business in several respects. The dependence of TA on the cognitive quality of its results should thus be sufficiently proven.

2. Fields of investigation and methodological approach

Dealing with cognitive statements of TA implies a renunciation of the assessment of evaluative statements: It is only about the cognitive function of TA. Methodologically, cognition precedes evaluation: Before a fact can be assessed under previously justified criteria, it must be recognized, i.e., a descriptive sentence containing this fact must be available.

In the analysis, TA statements are differentiated according to their decision- and action-theoretical status:

- Statements about means-ends relationships, degrees or possibilities of achieving the purposes through new technology (problem-induced TA).
- Statements about all classes of consequences of the introduction (or the decision to introduce) (production, use, disposal) of a technology (technology-induced TA).
- Statements about current or future contexts of technology implementation and use: Need for use or problem-solving, future actual use, acceptance, etc. (any TA).

Particular problems of knowledge arise, for example, in the areas of:

- quantified knowledge,
- assessment of risks,
- determination of causal relationships and chains,
- long chains of effects.

The omnipresent problem of forecasting TA statements is different in each of these areas. I will deal with some basic problems, such as the ex ante assessment of their reliability, in Sec. 3 and 4.

3. Epistemological status of TA

Central concepts of epistemology are truth, falsifiability and justification. The epistemological status of TA is discussed below along these concepts.

The concept of truth in constructive philosophy of science (Lorenzen 1987; Hartmann 1990; Grunwald 1989) as a situation-invariant justification of a statement places the verifiability of the results of actions at the beginning of justification chains. It may come as a surprise that this concept of truth is mentioned in connection with TA, since TA statements are always statements about future circumstances that cannot be conclusively assessed for truth and are therefore justifiable but not capable of truth. Insofar as we are dealing with predictions of action contexts, this objection can be accepted immediately. When predicting the consequences of actions (including the consequences of technology), however, a differentiation is appropriate.

A distinction should be made between the situation-invariant (and thus necessarily) occurring and the situation-dependent (contingent) consequences of an action. Necessary are, for example, secondary consequences of technical action that can be deduced from the design plan of a machine, since the use of the corresponding machine necessarily leads to these secondary consequences. They are inherent to the technology and can therefore be derived analytically from the design principles of the technology in question. The occurrence of contingent secondary consequences, on the other hand, depends on the circumstances at the time the corresponding actions are carried out. The distinction between "situation-variant or situation-invariant" reconstructs the common ontological distinctions between direct and indirect consequences or consequences and effects from the perspective of action theory.

Since statements about contingent secondary consequences always depend on prognostic and therefore non-truthful statements about future situations, statements of this kind are not truthful. In contrast, analytical knowledge of consequences is certainly capable of truth (Janich 1994). This is because if this knowledge can be derived from the design plan of a technology, it can be conclusively tested for truth by making a decision about it in the laboratory.

Since the contingent consequences or secondary consequences are usually of decisive importance in TA practice, the question arises as to the relevance of the concept of truth in an epistemological assessment of TA. Trivially, the reliable determination of analytical side-effects is the methodological and logical prerequisite for the discussion of contingent side-effects. The importance of analytical consequence statements is therefore evident.

On the other hand, the question of the advantage of truth-predicated statements leads to the concept of reliability. In constructive philosophy of science, labeling a statement as true allows it to be judged as reliable relative to a prediscursive agreement (Grunwald 1989). However, if the (usually more relevant) contingent TA statements are not capable of being true, their reliability cannot be guaranteed. Worse still, it is not even possible to reliably determine the degree of reliability of statements and thus the risk involved in decisions based on them. This is because such a determination would itself be a forecast that would have to face the question of reliability. This consideration obviously leads to an infinite regress.

Now, in the tradition of critical rationalism, one could use the criterion of falsifiability and attempt to operationalize the reliability of TA statements by means of the concept of the degree of reliability, based on the classification of TA statements proposed in Sec. 2.

Statements about means-ends relations, degrees or possibilities of achieving the purposes through new technology are falsifiable: It may turn out empirically that a technology in which great hopes were placed does not lead to the planned purpose realization after all, or not to the full extent. Reflecting on such failures is the engine of learning through the improvement of means-ends relations and their application conditions.

Statements about current or future contexts of technology implementation, such as the need for use or problem-solving, acceptance, etc., on the other hand, can only be falsified if self-influencing forecasts can be ruled out. If actions are carried out on the basis of predictions in such a way that the prediction actually occurs or does not occur, empirical and methodologically independent falsification would not be possible.

Finally, situation-variant statements about all classes of consequences of the introduction of a technology are, since they depend on context predictions, even more subject to falsification. In part, they are purely hypothetical in nature: Whenever it is a matter of weighing up alternatives, which is only possible on the basis of predicted degrees of purpose achievement, secondary consequences, etc., the statements about alternatives that are not chosen can never be verified (cf. Weyer 1994).

Even if some of the TA statements are falsifiable, there is a pragmatic reason why this criterion cannot be used in TA. This is because the problem situation in TA is completely different from that in the natural sciences, from which the principle of falsifiability is adopted. TA is not concerned with the repeatability of experiments under variable parameter conditions to test the validity of hypotheses, but with generally singular cases of the realization of technologies. There is no interest here in falsifying hypotheses, nor are time or resources usually made available for this. Rather, the aim of TA is to contribute in a comprehensive sense to the success of technical development and the achievement of its purposes in each individual case.

If truth and degree of reliability are largely omitted as categories in the operational assessment of the reliability of TA statements, the question arises as to how TA can constructively deal with the dilemma that prognostic statements should be decision-oriented about technology whose reliability can neither be reliably assessed ex ante nor even guaranteed.

According to the thesis, the concept of justification functions as a pragmatic substitute for the guarantee of reliability in complex decision-making situations in pluralistic societies. It is the justification of TA statements that is decision-oriented, not the reliability of the statement. If reliability were the decisive attribute of prognostic TA statements, the only remaining option would be to wait for them to materialize or not. The fact that the reliability of forecasts cannot be guaranteed is compensated for discursively and pragmatically by justifications: The quality of a justification determines the degree to which a future-oriented argumentation can be accepted in technology discourses.

The justification of a TA statement turns out to be a decisive epistemological touchstone of TA because it determines the claim to validity in technology discourses. Non-violent conflict resolution in modern plurality requires as a formal criterion the critical comparison of the scope of the validity claim of competing justifications. At this point, we are thus referred to trans-subjective justification as the epistemological core of the TA problem (on procedural justification and justification procedures, cf. Gethmann 1979, 1982).

If we continue to ask, with a reconstructive intention, about the purposes of substantiating predictions, it is clear that neither a guarantee nor an increase in accuracy can be decisive arguments (although an empirical study would presumably show that substantiated predictions are in most cases more accurate than unsubstantiated ones). Because fortune-tellers can make astonishingly good predictions in individual cases, a substantiated prediction is by no means more accurate per se than an unsubstantiated one.

The significance of the justification lies rather in the fact that it lends trans-subjectivity to the prediction. A fortune teller's prediction can only be believed or rejected: It cannot be understood trans-subjectively with reasons and is not capable of discourse. Only scientific justifications of TA predictions make it possible to make rational decisions in modern pluralistic societies by justifying the decision-oriented predictions and thus making them comprehensible to everyone. In this way, they are able to compensate for the impossibility of guaranteeing reliability by fulfilling the universal claim to validity that must be directed at decision-oriented TA statements. The justifications in TA must therefore also be taken into account from this perspective.

The epistemological status of TA could thus be classified according to different types of justification from a pragmatic perspective. These could include, for example:

- true sentences as situation-invariant justified sentences (analytical sequences),
- deductive-nomological predictions based on knowledge of the law,
- other forms of TA statements (Delphi forecasts, etc.).

However, no further details can be provided in this article.

4. Cognitive limits of TA

Cognitive limits of TA as limits to its justifiability will be explained below using quantitative results and deductive-nomological prognoses (for more details see Grunwald 1994a, 1994b).

Quantification is a way of acting that assigns numerical values to certain quantities of a subject area – without the access of quantifying action, everything is initially qualitative. Its purpose is to establish intersubjectively comprehensible and reproducible comparability. A necessary prerequisite for quantification in TA would therefore be that procedures and quantification rules can be defined that guarantee the intersubjective and situation-invariant reproducibility of the assignment of numerical values.

Such a prescriptive theory of measurement exists for the quantitative natural sciences (Lorenzen 1987 and the literature cited there). The success of quantitative methods in the natural sciences is based on the fact that they can actually be applied in a “value-neutral” way. In the social and cultural sciences, on the other hand, no such strict decoupling of ethics and politics is possible (Janich 1979). For example, the assignment of a monetary measure to a commodity is not independent of political and ethical questions, as no universal procedure for determining this value can be specified. Rather, the significance of quantitative measures for culturally determined values lies precisely in their dependence on situations, actions and decisions.

If it is only about the descriptive recording of variables and not about forecasts, this restriction is not yet a cognitive limit. The absence of situation-invariant quantification norms then merely relativizes the statements with regard to situation variance. Situation-invariant statements – and this applies to all cultural studies – are, however, only insufficiently suitable for justifying forecasts, because the future situations for which forecasts are made can be different and, as a rule, are also different due to the unpredictability of human actions.

Renouncing quantification does not mean renouncing objectivity, as is often claimed (Shrader-Frechette 1982). The distinctions subjective/objective and qualitative/quantitative are linguistically pragmatically independent of each other. Objectivity is constituted as the result of reasoning discourses. This can be achieved for both quantitative and qualitative statements.

The question of the conditions for the possibility of proving laws of progression as a prerequisite for deductive-nomological predictions leads to the following: For a law of progression to be recognized as proven, the corresponding progression must be reproducible. However, reproducibility can only be verified if it is possible to reproduce the initial situation, i.e., a finite system of rules must be specified, the observance of which results in the production of the initial situation. If the same effect occurs again and again in the produced initial situation, the law of progression is considered to be true. The following therefore applies: The validity of progression laws requires the reproducibility of the initial situation as a necessary condition and the reproducibility of the same effect as a sufficient condition.

Due to people’s ability to learn, the necessary condition for the proof of laws of progression is not fulfilled in the case of social technological consequences. Therefore, one should not speak of laws of progression in connection with social developments and should not make any corresponding forecasts. As with questions of quantifiability, the situation-independence that would be necessary to establish laws of progression is not given here either. The cognitive limit is that predictions in the social sphere are inevitably situation-dependent, namely in relation to the concrete and changing meaning and knowledge of people.

5. The theory-practice dilemma of TA and its resolution

The cognitive limits of TA as the limits of the justifiability of its results are simultaneously the limits of its rationality. Because they are uncomfortable, such problematizations of scientific theory often remain without consequences – in TA no differently than in the specialist sciences. Johannes Weyer (1994) constructs a theory-practice dilemma at this point: However, "expert opinions are delivered to the various clients that do what is described as impossible in theoretical reflections, namely: anticipating the future and participating in its planned design" (Weyer 1994, p. 7).

In fact, the theory says that the anticipation of the future cannot succeed, i.e., that no matter how good the justification, it must not be confused with a guarantee of reliability. However, according to G.W.F. Hegel, one cannot rationally demand what cannot succeed. It is therefore one of the aims of this article to support the gradual reorientation of TA away from a focus on anticipation and toward a focus on justification and planning. TA cannot be about making "correct forecasts," as this term cannot be operationalized: There is no other way to determine whether a forecast is correct than to wait and see. However, this is generally pointless because the technology-related decision has to be made ex ante.

Furthermore, the widespread misunderstanding that the task of TA is to forecast the development of technology must be dispelled. Weyer (1994, p. 11), for example, asks "what TA can be useful for if not for the reasonably reliable prediction of future developments in technology." However, this would be both an excessive demand and a failure of purpose. TA as decision advice is not intended to anticipate the future, but rather to substantiate the hypothetical consequences of individual decisions. TA is never generally about the development of "the" technology.

As discussed, taking the impossibility of anticipating the future seriously requires a shift from the question of reliability to the question of justification. Justifications enable the trans-subjective recognition of TA statements as a common basis for decision-making, action and planning. In this way, one of the main functions of TA comes into view, namely to exercise a conflict-regulating function in technology discourses. As a discourse moderator, TA is dependent on critically examining the validity of the arguments put forward and thus the justifications. It must therefore be all the more careful to attach particular weight to the justifications for its own statements. In this way, TA is placed at the center of a social technology control and risk minimization strategy in questions of technology.

In this way, the theory-practice dilemma proves to be an apparent dilemma: It is resolved in pragmatic reflection by the fact that the planned shaping of the future is by no means dependent on its anticipation, as the above quote from Weyer suggests. Rather, planned shaping of the future is possible through collective reference to trans-subjectively set purposes and the respective available trans-subjective knowledge of action and prognosis. However, trans-subjectivity can only be produced discursively in justifications.

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Gotthard Bechmann, Günter Frederichs

Problem-oriented research: Between politics and science

1. Technology assessment as "problem-oriented research"

The classic idea that technology assessment (TA) is scientific policy advice in an instrumental sense (Pinkau 1991) has lost its plausibility, at least as far as it contains the image of giving and taking scientific information. Alvin Weinberg (1972) already pointed out that science cannot provide answers to many questions. In the meantime, descriptions of a "politicization of science" and a "scientification of politics" have also become popular, and there is ample opportunity to observe corresponding mixtures of science and politics in which an advisory influence of one side upon the other is hardly discernible. Only rarely is it possible to identify the respective scientific "message" and its political implementation, when it is being "talked to death" in expert disputes and there are no clearly attributable political actions.

Has technology assessment thus lost its guiding principle? Or even the addressee? The never-ending discussion of new TA concepts could be taken as an indication that people are still, or repeatedly, searching for the "actual" idea of TA. For example, in the Netherlands ("constructive TA") or in Denmark ("proactive TA"), new TA concepts are being propagated (Hack 1995), and traditional TA research is ironized as "reactive reporting TA," which starts too late in the development process of a technology and has overly high expectations with regard to its political impact. The "control dilemma of technology development" by Collingridge (1980) is used to locate traditional TA: Between the forecasting problem in the early stages of a technology, when it is a question of early recognition of consequences, and the power problem, when it is more a question of recognizing them at a later stage, traditional TA has located itself close to the power problem (Gloede 1994). It relies on the strength of the argument. "Constructive TA" and "proactive TA," however, would like to intervene in the social process of technology development at the earliest possible stage, and both see the possibility of exerting influence in the form of direct participation in the "seamless web" of technology (Bijker et al. 1987).

Nevertheless, in these as in most other cases of the TA discussion, the old impetus remains: One wants to achieve "better" policy using the means of science. The influence of constructive TA on the "seamless fabric" of social interactions is also politics in the name of science. Although the old formula of scientific policy advice can no longer be used as naively as it perhaps once was, the underlying conception of the problem (the insufficiently informed nature of political decisions) and the solution approach (utilization of science) still seem to be a driving force in the TA movement. The above-mentioned discussions in the Netherlands and Denmark as well as activities at European Union level (Rader et al. 1996) show that these motives have evidently not yet disappeared, despite the equally unflagging resistance and destruction (e.g., in the OTA case). In view of the urgency of old (e.g., environmental problems, North-South conflict) and new problems (e.g., climate change), it would be surprising if politicians did not make use of one of the most important, or at least most expensive, social resources.

However, if it has become evident today that TA cannot be reduced to a purely instrumental relationship to politics, then one would naturally like to know whether, in the light of over twenty years of TA experience, there are not equally evident indications of a different meaning. This essay places this question in the broader framework of the relationship between science and politics. For the practice of technology assessment shows what the theoretical discourse must first laboriously come to an agreement on: The thematic link to technologies is repeatedly abandoned, the projects often go beyond purely technology-related issues, and the approaches and problems often overlap with those of other research areas, such as risk research and environmental research.

This reveals the context of a development that has increasingly taken shape since the Second World War (1939–1945) and is now emerging as a new type of scientific research. As will be shown below, it can be distinguished from basic research and applied research as "problem-oriented research." There is talk of a change in the function of science since 1945, which is only taking full effect today.

2. The changing relationship between science and society

Beginning with the "Manhattan Project"[1] and the construction of the atomic bomb, the increasing integration of science into the field of politics had begun. A

1 *Editors' note*: The Manhattan Project was a U.S. research and development program during World War II to produce the first nuclear weapons. It was carried out in collaboration with the United Kingdom and Canada.

scientific establishment was formed (Price 1965), which over the years played an important role in the process of policy formulation. Scientists no longer limited themselves to the communication of hard "facts," or to a certain extent to the analysis of clearly comprehensible empirical facts, but also participated in the definition, analysis, and solution of so-called "big problems," as Weinberg once called them.

"Big problems" are, for example, questions of national security, the expansion of the welfare state, and the development of technology programs (Weinberg 1972). Science thus takes on the task of providing an answer to political goals and social needs. Scientific representation of practical contexts, including prognostic services, is increasingly needed for political and social innovations, now that the secondary consequences syndrome (unintended consequences) has grown to an incalculable size. Finally, scientists have also assumed an important interpretative function where, according to current standards of scientific knowledge, only unverifiable knowledge can be obtained, be it in relation to the development conditions of society or in the analysis of possible crises or upheavals in the social process. These more or less plausible interpretations are incorporated into the background knowledge of political decision-makers and form an orientation framework for alternative political strategies. In other words, science leaves its laboratories and intervenes in the public debate.

> Effective policy making required fast what scientists believed they had to offer: objective shifting of the facts, balanced visions, thoughtful reflection and the mobilization of the best wisdom and highest competence (Wood 1964, p. 64).

The political decision-making process now presents itself as an interplay between scientists, professional interest groups, administrative experts, and politicians, whereby the final decision-making power is reserved for the politician, but the scientist increasingly has the power to define and find solutions. However, scientists not only play an influential role in the political process but also in the public sphere. In the major controversies surrounding new technologies (nuclear power, genetic engineering), some of them acted as scientific "entrepreneurs," attempting to use their scientific authority and formal methods to counter criticism of the risks and consequences of the increasing technologization of society (Nelkin 1987). Fields of problem-oriented and applied research emerge that differentiate themselves from the hard core of basic research and develop independent orientations, career patterns, and forms of organization.

This development is intensified and takes on a new quality as the environment becomes a scientific political issue and at the same time a social field of action. It is becoming clear that environmental policy cannot do without scientific analysis. Politics depends constitutively on scientific knowledge both in defining problems and in designing solution strategies. Only with the help of science can environmental changes be measured, environmental quality determined, and causes and possible solutions to environmental problems formulated. In this context, science is not only involved in diagnosis, but also assumes the role of admonisher – either voluntarily or ascribed to it by society. The warning of unintended consequences and forecasts of future dangers and risks becomes a legitimate part of its activities. It becomes an early warning authority for society (Bechmann/Gloede 1991; Bechmann 1994).

The fact that society has been addressing ecological issues for a good twenty years now means two things for science: First, new fields of activity are emerging that require interdisciplinary cooperation, new topics are being created and, last but not least, large amounts of funding are being made available. Secondly, the need for scientific advisory capacity is increasing. Not only politicians, but also companies and associations, insofar as they deal with environmental policy and ecological regulation, need to draw on scientifically-generated knowledge. The rise of the scientific community to a new elite in social decision-making processes is, as it were, an expression of the new and complex tasks facing society as a result of its own development, namely the regulation of increasingly complex social relationships and the regulation of environmental and nature-related issues.

However, as science has taken on this new role, it is confronted with two problems that call into question the traditional self-image of science as rational and value-free:

- It is advancing into areas of application in which even those interdependencies that can still be recorded or even technically generated are no longer controllable. In contrast with "normal science," where science only asks itself questions that it can answer with its own resources, it must be recognized today, particularly clearly in the field of environmental research, that science is reaching the demonstrable limits of its analytical and forecasting capabilities. Known non-knowledge is emerging in a new way.
- With its integration into the political regulatory process, science loses its innocence, which it had propagandistically defended for so long through the norm of value freedom. Value freedom also means, among other things, objectivity of knowledge. What is known scientifically is indisputable knowledge that applies to everyone until proven otherwise, i.e., until refuted. The consensus of the scientific community is the criterion here. It is precisely this that can no longer be maintained in the new areas of application. Knowledge, although produced by scientists using scientific methods, quickly turns out to

be context-bound, unsystematically acquired, quickly in need of revision and, above all, selective. In other words: It is controversial.

These observations raise the question of how the new and expanding field of science can be understood. There are a number of important studies that attempt to define the phenomenon of "problem-oriented research" in more detail.

3. Characterization and delimitation of "problem-oriented research"

The emergence of "problem-oriented research" can be seen as the science system's response to new demands placed on science by society (Nowotny 1993). More and more problem areas are emerging that have been defined by science, or with its help. "Transdisciplinary" research teams are emerging, i.e., research teams that can no longer be described within the scientific disciplinary structure and that develop knowledge-based solution strategies in cooperation with social groups. But what are the characteristic features of this problem-oriented research, which to a certain extent represents a new type of research?

A look at the literature reveals terms such as "mandated science" (Salter 1988), "postnormal science" (Funtowicz/Ravetz 1993), "science in action" (Latour 1987), or "science for policy" (Jasanoff 1990). As different as these descriptions may be in detail, they agree on the fundamental characterization of problem-oriented research.

First of all, problem-oriented research must be distinguished from *basic research*. Problem-oriented research is centered on problems that arise in the realm of society, while basic research, whose model is knowledge about itself, responds to no other stimulus than that of research itself (de Bie 1973). This definition implies several things.

Problem-oriented research is issue-dependent. Depending on how relevant a problem is considered to be by politics, the public, or the economy, research capacities, funding, and the number of positions increase. Problem-oriented research is therefore directly dependent on social values and their transformation. It must strive to ensure that its definition of the problem is prioritized on the agenda of the major systems. This has an impact on the role and scope of action of the researcher. Not only is the scholar required, but scientists are becoming managers. They generate public attention and know how to direct it toward their field of research (Ingram et al. 1992, p. 46). In some cases, science becomes a political venture with a high risk of failure. In addition, this type of research is conducted under time pressure and in project form.

Problem-oriented research cannot wait until the fundamentals of this field have been clarified in order to collect data and give advice based on well-established theories. On the contrary, even if the theoretical basis is unclear, it must attempt to arrive at sufficiently plausible and argumentatively justifiable solutions using scientific methods. Where basic research has time, problem-oriented research is under pressure to make decisions.

Problem-oriented research is necessarily interdisciplinary or even transdisciplinary. It cannot be expected that social problems can be adapted to the scientific disciplines. This is precisely where the high selectivity of disciplinarily-organized science becomes apparent. In the individual disciplines, more and more highly specialized knowledge is being accumulated through the constant progress of "normal science," but the reaction to interdisciplinary questions is usually helpless, with problems being narrowed down. The expectation of problem-oriented research, however, is to translate social problems into scientific questions and to organize their solutions in an interdisciplinary manner.

However, problem-oriented research also differs from *applied research*. Although the differences here are not as clear at first glance as with basic research, it is evident that applied research is more strongly related to the criterion of useful application. Application means that acquired knowledge is used to solve problems that are given in practice and that can also be expected to provide solutions within the framework of proven practice. In most cases, this a simple repetition: Analytical models, conceptual schemes, techniques, and instruments are applied to a specific problem situation. Furthermore, in applied research, knowledge is prepared in a client-specific way and there is no reference to the public. Direct relationships between client and researcher still prevail here. One could almost speak of an instrumental relationship.

4. The characteristic problems of problem-oriented research

The dependence of problem-oriented research on the political-public decision-making process and its relation to the identification and penetration of social problems creates specific prerequisites that characterize this new type of research.

4.1 The inherent uncertainty

The first and perhaps most important characteristic is dealing with uncertainty. Uncertainty can relate to several dimensions in dealing with knowledge. Uncertainty can initially mean *uncertainty of the knowledge base,* and this is where the most difficult problems arise (Salter 1988, p. 199).

Phenomena such as forest dieback, climate change, but also genetic engineering or AIDS are new, complex, variable in their effects, and still poorly understood. In these cases, there are no well-founded theories or proven findings that problem-oriented science can fall back on. In this case, the basis for robust argumentation must be created with the help of our own research design and by drawing on other disciplines. The preferred means here are computer simulation or expert surveys, statistics, and ad hoc theories (Funtowicz/Ravetz 1990). Nevertheless, this uncertainty remains inherent, as problem-oriented research is not only confronted with complex and new questions, but is also involved in a consultation and decision-making process. It is therefore also under pressure of time and decision-making. It cannot wait until all questions have been scientifically clarified, but decisions must also be made in unresolved situations (Collingridge/Douglas 1984).

This compulsion to make a decision gives rise to a second uncertainty. It can be called *practical uncertainty*. In many cases, science cannot give a clear answer to practical questions. Whether a certain pesticide is causally responsible for an allergy or whether CO_2 emissions contribute significantly to forest dieback cannot be decided unequivocally. Especially when clear causalities are demanded by decision-makers or judges, research usually has to remain silent or refer to further research (Ladeur 1995).

A third uncertainty can be characterized as *methodological uncertainty*. Methodologies usually arise within disciplines in relation to the development of theories or the generation of data. In both cases, there is a chronic shortage in the field of problem-oriented research, so that it has to develop its own methodological standards (Fuller 1993).

A fourth uncertainty is *ethical or normative uncertainty*. Decisions about risks, hazards, and public problems are not only decisions about the content of knowledge but also set standards that determine how people are affected (Ungar 1992). In addition to setting levels of protection, limit values also define the burdens to be endured. If science is involved in this process of standardization at a decisive point it also determines normative patterns. However, values and preferences are controversial in society and cannot be clearly defined. Which threshold value should be followed and what implications does it have for people's lives? Who is disadvantaged, who is favored? These are both cognitive and normative questions to which there are no certain answers. Depending on the state of scientific research, different solutions are found (Beck 1986; Jamieson 1992; Jasanoff 1987).

In summary, the inherent uncertainty of problem-oriented research can be characterized, in the words of Funtowicz/Ravetz, by the fact that the facts are uncertain, the values are disputed, the dangers and risks are high, but the decision is urgent (1993, p. 744).

4.2 The hypotheticality of knowledge

Another feature that distinguishes problem-oriented research from traditional research is the role it plays in the political regulation and decision-making process. The usual understanding of the relationship between politics and science is based on a clear separation of the two areas. Science provides the factual knowledge, politics makes the value-based decisions. Science is characterized by its neutrality and freedom from values, which extends to the establishment of facts and the generation of causal or legal knowledge, while politics makes the assessments and decides on value conflicts. This cozy image of separate worlds that harmonize peacefully with each other has become obsolete, at the latest with the debate about unintended consequences of technological developments and since the controversy about ecological precaution. What is now required of science is not only specialist knowledge, but also predictions about future events that need to be prevented. Sheila Jasanoff gives a precise description of this change:

> These preventive policies placed unprecedented demands on the capacity of science to predict future harm. Fed by images of impending environmental disaster, the public turned to science for more sophisticated methods of identifying and measuring risk. Science responded with a new emphasis on toxicological testing and increased use of predictive mathematical models. But this shift of scientific attention to the unknown, and possibly unknowable, effects of technology highlighted the intuitive, subjective and uncertain underpinnings of much of the advice that scientists provide to government. Moreover, the increasingly adjudicatory style of decision-making in the United States forced scientists to articulate their reservations about their technical assessment and generated questions about the coherence or reliability of policy-relevant science (1987, p. 201).

When investigating the side effects of large-scale technologies and determining the environmental risks of major projects and long-term planning, science comes up against limits that it can prove to be insurmountable in principle. The complexity and diversity of overlapping causal relationships and circular processes cannot be dealt with analytically because the problem orientation prohibits ceteris paribus assumptions, which basic research can use if necessary. The smallest deviations in the initial data, which are unavoidable due to measurement inaccuracies, lead to completely different quantitative and qualitative forecasts in the case of non-linear relationships. This fact, which has been known for a long time, is only now being recognized in its full extent in the context of problem-oriented research, in which the scientific tradition of working with linearity assumptions is losing its value. Such evidence of the fundamental limits of analysis and prognosis means that the certain awareness of scientifically proven factuality is increasingly being replaced by an awareness of the fundamental hypotheticality of science (Häfele 1993). Although scientific methodology can limit arbitrariness, it can never really be reduced to certain statements. Neither with simulation models nor with statistical methods will it be possible to analyze all possible causal relationships.

The belief in the reliability of knowledge, which is used instrumentally for political decision-making and which relieves the burden on politics, is thus questionable in three respects:

From a factual point of view, problem-oriented knowledge is under the sword of Damocles of hypotheticality. The increasingly long decision-making horizons of today's planning and decisions as well as shorter innovation times are leading to the replacement of traditional trial-and-error procedures, which allow technical systems to be successively adapted to situational requirements. They are being replaced by scientifically elaborated long-term planning and probabilistic risk analyses that can only make hypothetical assumptions about reality.

Practical experience and empirical research are increasingly being replaced by models, scenarios, and idealizations. Empirical knowledge is being replaced by subjective assumptions of probability. Damage potentials and damage probabilities can no longer be determined through experience, trial and error, but must be anticipated mentally, as tests cannot be carried out to a sufficient extent, and observations or experiments cannot be repeated at will or may not even be carried out.

In social terms, it is clear that science is losing authority as a result of the dispute between experts. The products of high technology are increasingly giving rise to a socially relevant syndrome of mistrust and insecurity, which is a source of political conflict. With every new accident, the pent-up tensions are released and cause public opinion to explode. Over the last twenty years, technical risk has become the focal point of social insecurities and fears. Belief in progress itself has reached its limits and is turning into mistrust of the supporting institutions of the scientific world.

The delegitimization of experts is only one consequence of this development; another is the loss of legitimacy of state decision-making procedures. The credibility of state decisions is threatened by the decline in reliable knowledge based on personal experience in favor of scientifically-generated hypothetical knowledge, where one must be prepared for revisions at any time. Those who are legitimized by our constitutional norms to make decisions in the name of the common good depend on expert committees to form their opinions; those who possess decision-making knowledge are not legitimized to make such decisions. The result of this process is the loss of a clearly defined responsibility structure, which makes it impossible to clearly attribute responsibility in the event of wrong decisions.

In terms of time, scientific and technological progress creates an excess demand for knowledge compared to the actual generation of knowledge. To the extent that technical development is accelerating and constantly causing changes, every decision – due to the increased involvement of different authorities and the inclusion of ever more complex side effects – requires more and more time.

While this time elapses, the data that gave rise to the need for a decision in the first place changes. If you still want to reach the conclusion of the decision-making process, you have to largely ignore this constantly changing data. The decision is made on the basis of fictitious facts. Marquard sees this as a general feature of our technical culture: The increase of the fictitious (Marquard 1986). Where everything is in flux, any adherence to a decision forces us to flee into fiction, and the boundary between reality and fiction becomes blurred (Marquard 1986, pp. 85–86). For the observer, this leads to a loss of trust in the public decision-making systems, as he can see through the fiction from the outside and denounce it as such. The decision-maker is denied such a perspective.

Dealing with non-knowledge thus becomes a decisive variable in decision-making (Frederichs/Blume 1990). Since we cannot know the future, it is all the more important how this non-knowledge is processed in public decision-making systems; the fact that this problem is still relatively new can be recognized by the fact that there are as yet no elaborated theories for this, let alone procedures or routines that can cope with these new uncertainties.

4.3 The fusion of facts and values

The traditional fiction of a separation of facts and values is difficult to maintain in the context of problem-oriented research: Normative aspects are so obviously intermingled with factual aspects that in many cases, due to strategic argumentation fraught with uncertainties, even the most gullible can no longer adhere to the assertion that science is value-free and neutral. The close relationship between uncertainty in the field of scientific expertise and ethical implications has been mentioned above. Particularly in the case of decisions on risks or environmental problems that have to take into account the impact on third parties, the assumptions of profit or harm to others cannot be separated from the scientific factual analysis. This is especially true when no clear statements can be made about the expected extent of damage and possible opportunities. The question of social and environmental compatibility, a normative criterion, is therefore an inevitable part of the scientific investigation. Just as with limit value conditions, there are no objective markers of the necessary exposure below which it is possible to determine whether something is harmful or harmless. Risk definitions and limit values are the results of consensus/dissent processes in which cognitive arguments must be used to reconcile conflicting interests and decide uncertain facts (Colglazier 1991; Jones 1991; Funtowicz/Ravetz 1993; Jamieson 1990).

There is another factor that blurs the clear distinction between values and data: The inability to predict the effects of new technologies or human intervention in nature. The risk debate has opened up the broad field of hypothetical risks, possible damage that is not known but can nevertheless be assumed. The debate on genetic engineering is one example, the problems of the consequences of possible climate change another in a long series of examples. The discrepancy between knowledge and the consequences of action has only recently become fully apparent. Whereas in the past it was said, first knowledge, then action, today this has been reversed: Action first, and then perhaps knowledge later. This priority of action over knowledge leads to a peculiar reversal of the burden of proof in the environmental debate. It is no longer identifiable dangers and their prevention that play the central role in precautionary policy, but dangers or damage that lie in the distant future, that are unknown but cannot be theoretically and logically ruled out. These arguments are based on theoretical assumptions and possible empirical observations, which are by definition provisional and thus open to falsification by future research (Wynne 1988). Scientific expertise then becomes speculative, and under the conditions of a lack of knowledge, an uncertainty that cannot be resolved, it becomes apparent that scientific knowledge is also tainted by the flaw of being merely conjecture and ad hoc plausibility. It is not for nothing that experts appeal to the trust of their audience (Fischer 1990).

5. The political function of problem-oriented research

The characteristic problems of problem-oriented research mentioned in the previous section are not generally recognized in their fundamental nature. On the contrary, scientists and politicians involved in problem-oriented research often propagate an idealistic image of science that asserts objectivity and freedom from values (Salter 1988, p. 5). This is presumably based on the view that the scientific legitimization of risky decisions is only possible in this way. It is true that no one can deny the insight that science is burdened with the aforementioned problems of uncertainty, hypotheticality, and the normative content of its statements. However, it is assumed that these are deficits which, if not eliminated, can be marginalized by increased research efforts to such an extent that they become negligible.

However, to the extent that science tries to maintain this fiction, it loses credibility. This occurs in various forms, for example, when predictions are made that then fail to materialize. Or when there is talk of value-free research whose implicit values are then proven by lawyers in court. The error also occurs in the form of disciplinary hegemonies, when the claim to interdisciplinarity is undermined by a project organization in which the discipline of the project leader is decisive: The research results are then very quickly relativized by counter-reports in which the perspectives of other disciplines dominate. The loss of credibility is the worst prerequisite for the scientific legitimization of decisions under uncertainty.

The counterfactual idealization of science will be all the less tenable the more urgent and complex the problems that are to be decided. But what then is the point of scientific policy advice? Surprisingly, the starting points for answering this question arise from the radicalization of the previous diagnosis of the problem:

(1) To the extent that scientific statements refer to the future, they can at best only provide estimates of the certainty of their statements. This is why rhetoric, the moment of conviction, takes on an important role in scientific debate. However, this devalues scientific statements to opinions (Luhmann 1991, p. 228f.)
(2) Problem-oriented science is reflexive in a counterproductive sense, in that the conditions, contexts, and consequences of decision-making are changed by feeding scientific knowledge back into the practical process, so that new situations constantly arise to which research must refer. Therefore, one cannot expect that an increased research effort will create more certainty, but rather, on closer inspection, more uncertainty (Giddens 1990).

Scientific statements that can only be regarded as opinions and which, moreover, only increase the uncertainty of the political problem – these are findings that make the claim of scientific policy advice appear completely meaningless. The fact is, however, that scientific policy advice diagnosed in this way is an everyday practice that nobody can do without. The contradiction is resolved when the propagated expectations of scientific policy advice are distinguished from its actual functions. These, in turn, can only be understood if one grasps the full extent of the uncertainty with which political action is confronted.

It is the hallmark of modern society to become increasingly aware of this degree of uncertainty and to look for ways to make legitimate decisions nonetheless. The two deficits of problem-oriented research – the devaluation of the scientific statement to a contribution to the discussion, which could also look different, and the change in the political discussion through precisely such scientific statements, describe exactly what problem-oriented research does: It continues the political and social discourse with scientific means and thus sets up an indispensable barrier against the danger of fatalism spreading in the face of seemingly insurmountable uncertainties, either against the arbitrariness of particular interests or against lethargy and inaction (Stehr 1993, p. 15). For example, we can know almost nothing about the social effects of climate change in the second half of the next century, but we still have to deal with them and do so in a qualified and meaningful way.

The scientific discourse is not the only one that serves this function. Salter (1988), for example, describes a close interweaving of scientific and legal discourse and sees this as a characteristic of problem-oriented research ("mandated science," loc. cit., p. 6). However, the special prerequisite of problem-oriented research for social discourse lies in its scientific nature. For the fundamental lack of knowledge does not lead to arbitrariness in the spectrum of opinions, in which every horoscope maker could appear with the same legitimacy as a scientist. It is not a matter of absolute knowledge, but of provisional, revisable knowledge, which is, however, obtained according to rational methods that can be explicated and argued. Scientific knowledge is characterized by the fact that it is obtained using recognized methods and that it can in principle be understood by anyone who uses the same methods. This does not yet produce unambiguous knowledge – think of the expert disputes – but it does produce knowledge that can be communicated according to democratic rules.

6. Uncertainty and discourse: Structures of "problem-oriented research"

The development of "problem-oriented research," as described in the previous sections, is still relatively recent. Nevertheless, structures can be recognized that are an indication of the direction in which the development is heading in order to guarantee the functional requirements of a meaningful social debate on uncertainty.

In modern society, "uncertainty" is increasingly becoming a topic of new dimensions in various contexts and especially in scientific discussions. This is particularly associated with environmental problems, the coalescence of global society, the risks of technological progress, and other contemporary issues. While the traditional understanding of science saw the reduction of cognitive uncertainty as the scientific goal, this goal is increasingly losing its orientation function with the realization of the insurmountability of many uncertainties. It is being replaced by another goal, the creation of "consensus knowledge," which is not compatible with the traditional understanding of science. This term arose primarily in the context of international climate research – out of the necessity that climate researchers were unable to meet the demands of politics with unambiguous information.

The decisive point in the scientific examination of uncertainty is how the mixture of knowledge and ignorance is structured in the respective situation. This is why factual knowledge and value knowledge are intertwined, and their separation is only carried out pragmatically under the respective conditions of action, and preferably only for a limited period of time. Conversely, this also shows that value judgments cannot be made in a purely normative, so to speak decisional way, but also have cognitive components that are accessible to rational argumentation (Fuller 1993). Problem-oriented research is not merely "applied research," but always also interpretation and evaluation (Ravetz 1987).

Another aspect points to the intrinsic value of scientific expert knowledge. When analyzing complex problems, different disciplines are always involved that do not have a common research approach or a uniform view of the problem. Even the formulation of the problem depends on which scientific disciplines are considered relevant. Which questions are prioritized requires a decision, as otherwise an endless discourse would be set in motion.

Expert judgments are also necessarily based on a conclusion of the analysis in order to reach a decision in the practical problem-solving process. The results essentially depend on the time of this closure, i.e., on the stage at which the research process is then at. Facts are thus generated qua decision and can be changed by new research as soon as the discourse is reopened. Thus, what is considered a fact or recognized knowledge essentially depends on the consensus of the participants that the discourse is concluded. When new participants enter, the situation changes, new facts are discovered, and reality changes. Knowledge in the context of problem-oriented research is always constructed knowledge based on consensus and incompleteness.

The problem is therefore not only scientific uncertainty but also ethical and normative uncertainty as to the criteria according to which hazard and risk management should be carried out. Both uncertainties create a fundamental social contingency with regard to what is possible and what is necessary. As there is neither certain knowledge nor general and binding standards for making recognized and acceptable decisions, it is necessary to generate consensus knowledge. In more recent times, a proceduralization of knowledge generation is often resorted to.

Procedurality refers to the rationality of procedures in the sense that the chosen processes and procedures guarantee the rationality of their results. The connection between such procedures and the rationality of their results can be understood in different ways. The fulfillment of certain procedural conditions can be regarded as conducive to the achievement of rational results, or it can be regarded as a necessary but not sufficient condition for the acceptability of procedural results, and finally it can also be regarded as a sufficient, constitutive condition of rational decisions per se.

It would go too far here to take up the entire discussion on the procedurality of rationality, but what is important for our question is how a way out can also be sought via procedurality against the background of the debate on risk management. Discourse is highly regarded as a procedure for generating consensus knowledge. Without rashly advocating one or the other discourse theory, discourse can be understood as social processes or interactions, which in everyday language are called discussions or – somewhat more scientifically – topic-centered communication.

Central to discourse is the exchange of arguments to answer questions, to solve problems, or to clarify controversial claims. In other words, argumentation is at the center of discourse. Discourses are regulated partly by symbolic rules of operation and partly by pragmatic rules that apply to communication in general or specifically to particular forms of communication. Discourses do not create or set obligations that are relevant to action. They can serve to discover or gain insights of an empirical-cognitive or normative nature.

According to Rawls, scientific discourse can be described as a “quasi-pure” process (Rawls 1979). This means that arguments can be structured by reasons, but due to cognitive uncertainties – whether due to a lack of information or a lack of knowledge of causal processes – arguments must be made consistent by assertions, plausibility assumptions, or evaluations. Two forms of discourse can be distinguished in the context of these procedures: Truth discourses, in which it can be stated under what conditions truthful statements can be expected (Habermas 1973), and epistemic discourses. René von Schomberg has vividly explained the structure of this second type of discourse:

> The discourse around the acquisition of new knowledge can, in my opinion, be reconstructed within the framework of a specific concept of discourse in which arguments have precisely no consensus-enforcing force. I refer to this as an 'epistemic' discourse. Here, the disputing scientists can only refer to arguments that, like analogies, attestation arguments, and counterfactual arguments, articulate an uncertain and insufficient knowledge: Plausibility. Consensus in the strict sense is not reached here because the truth conditions of individual statements cannot be explicated due to the background of uncertain knowledge. In an epistemic discourse, it is not so much the truth of statements that is controversial, but rather the plausibility of theories and hypotheses with which we can assert the recognizability of certain areas of knowledge. The typical arguments of epistemic discourse do not directly serve the argumentative fulfillment of truth claims, but rather the coherent construction of theories, hypotheses, and assumptions with which we can first and foremost reliably open up areas of knowledge. In epistemic discourses, the plausibility of knowledge claims is therefore controversial (Schomberg 1992, pp. 262–63).

If it is precisely epistemic uncertainty that constitutes the actual difficulty of scientific discourse, one must first and foremost ask about the social-organizational form of knowledge-producing or knowledge-mediating discourses. One can, as Habermas does, primarily reflect on the "quasi-transcendental" preconditions of a truth discourse. According to Habermas, only communication in which a problematization of the validity claim of propositions and an argumentation with the aim of verification takes place is worthy of being called a discourse (Habermas 1971). Validity can only be determined by recourse to an "ideal speech situation," the only motive of which is the cooperative search for truth, i.e., communication that is in principle unrestricted and unconstrained, in order to reach an understanding. Understanding here is a normative concept that must be determined counterfactually (Habermas 1971, p. 201). This peculiar mixture of descriptive characterization with the normative stylization of discourses has been criticized many times (Schnädelbach 1977; Giegel 1992): From the perspective of epistemic discourses, which have to struggle with conditions of uncertainty, it becomes apparent that the dissent that occurs there cannot be explained exclusively as a violation of rules of argumentation, but that incommensurable systems of orientation clash here, whose divergence can be traced back to the logical and correct adherence to different rules and norm systems. Even concepts such as communication, understanding, and argumentation are still controversial in this context (Lueken 1992). In principle, it must be left to the participants in the discourse to decide what conditions, rules, and norms they must or want to base their argumentative actions on. Nevertheless, if we do not want to adhere solely to an ideal justification of the discourse, whose idealized conditions can only be followed with an oblique upward glance and a guilty conscience as a norm in the factual events, we must also ask about the practical conditions of the empirically perceptible discourse. There is no doubt that discourses are conducted in society, sometimes even with astonishing success and in a few cases are concluded by consensus.

A real discourse must fulfill two essential, albeit contradictory, conditions: openness and closure (cf. Bühl 1984, p. 95ff.). On the one hand, the discourse must be so open that it allows room for new ideas and the expression of different views; on the other hand, however, a certain amount of pressure must be exerted for theoretical integration and the continuous working through of shared knowledge. Based on this understanding of the problem, some organizational criteria can be specified.

Firstly, a fruitful discourse should allow for a broad diversity of topics, people, and viewpoints. This determines its adaptive capacity, namely the extent to which the discourse is able to process uncertainty and variety. At the same time, a high degree of variety requires a structured discourse community that is organized according to rules. Secondly, there must be a willingness for variable interaction; the participants must be prepared to communicate with everyone and on all topics. Interdisciplinary perspectives and interpersonal understanding are essential prerequisites. Diversity has its limits where the collective identity and constitutive factors of the members' common orientation are called into question (procedural rules). Here too, a reciprocal relationship between openness and closure is an essential prerequisite. Thirdly, knowledge discovery and knowledge verification must be separated in discourses, an old theme in the philosophy of science (Popper 1966, p. 6f.). Knowledge discovery is about discovering and constructing new elements of knowledge, regardless of the methodological level at which this occurs. Knowledge testing is about integrating the newly acquired knowledge into the existing body of knowledge, that is, about logic, consistency, generalizability, theoretical relevance, i.e., overall about cognition and acceptability.

These three organizational principles – diversity, variability, and separation – can be found in different forms and combinations in the various types of discourse – practical discourse, scientific discourse, and cultural discourse. The idea of discourse makes an essential insight of problem-oriented science its fundamental principle: That scientific knowledge is always only valid under hypothetical conditions, that it can be changed at any time, and that the mutual increase of consensus and dissent is to be regarded as an essential motor of knowledge expansion.

Discourses are aimed at the cognitive prerequisites of decisions. Here, interpretation and evaluation divergences are at the center of the process. Agreement must be reached on the validity of empirical results, the plausibility of theories and propositional systems, and on stringent argumentation and interpretations (Bora/Döbert 1993; Hennen 1994).

The difficulties in the discourse can be seen in the meaningful termination. When is a debate over? Who concludes it and with what arguments? What is characteristic, however, is the self-reference of the discourse, i.e., its capacity for self-transformation. The capacity for self-transformation consists in the fact that in the process – and nowhere else – both the learning conditions under which new assumptions of reality arise and the specification of consensus-building structures, consensus content, and problem-solving strategies are generated. In this respect, it can be said that the process is both the path and the goal.

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Fritz Gloede

Rationalization or reflexive scientification? On the debate about the functions of technology assessment for technology policy

Preliminary remarks: The boom and criticism of a label

In the twenty-odd years of its existence, "technology assessment" has had many children – with changing partners. Technology assessment (TA), technology research, or constructive TA have enriched the spectrum of relevant hybridizations, especially in recent years. However, this seems to be due less to plurality than to arbitrariness. Elementary terms are recombined in every conceivable way and given attributive definitions. The recently launched "ex-post technology assessment" could be seen as a temporary crowning achievement, creating a smooth transition to technology genesis research (Gloede 1991).

If we examine the current debate on technology, technology research, and TA more closely, we can make the diagnosis that "the 1980s reinvented criticism of the TA paradigm once again" (see Petermann [1992] in this book). The fact that today more participants and communities have entered the arena of technology science and technology policy controversies than in the 1970s does not sufficiently explain the "retreading" of arguments. Rather, unresolved and unsolved problems of technology development and technology policy regulation still seem to be responsible for this.

The first indications of this thesis can be found in the self-referentiality of many criticisms of the concept and practice of technology assessment. They ignore the relationship between TA and its social framework conditions and concentrate on the scientific deficiencies of the concept, which can only be remedied through basic disciplinary research or through a TA concept of the nth generation. The subsequent articulation of the need for research and funding is openly self-referential. In this way, the critique paradoxically participates in the boom of the criticized label without referring to the problems and possible solutions of the subject area in a comprehensive way.

Before we break the baton in this way about technology assessment as a "strategic framework concept" (see Paschen & Petermann [1992] in this book), it seems appropriate to take a look at the "classical" TA concept against the background of the political perceptions of problems at the end of the 1960s and the beginning of the 1970s. The dilemmas of this TA concept are – it should be made clear – to a large extent a reflection of the ambivalence of state technology policy (Sec. 1). The "new" TA concepts either ignore these correlations or fail to provide a fundamentally new solution (Sec. 2).

However, if the contradictions of social technology policy cannot be resolved at the level of a general TA concept, the question of the conditions and reasons for the practical continuation of technology assessment becomes all the more pressing.

A programmatic plea is made for TA to be recognized as the subject and object of a "reflexive scientification" (Beck/Bonß 1989, p. 29). In this perspective, reflective and self-reflective technology assessment has a strategic character both cognitively (as produced knowledge) and institutionally (as an actor in the technology policy arena) (Sec. 3). Some implications of this (self-)understanding are then outlined. From a cognitive point of view, the consequences that a conceptualization of the subject of TA should have for the implementation of TA studies will be discussed (Sec. 4). Finally, from an institutional point of view, some conditions for the realization of reflexive technology assessment with strategic intent will be addressed (Sec. 5).

1. The "classic" TA concept and its dilemmas

1.1 Problem-oriented research and the genesis of the "classic" TA concept

The concept and institutionalization of TA in the late 1960s and early 1970s were part of a general upswing in "problem-oriented research" (de Bie 1973; cf. also Lohmeyer 1984). The problems of problem-oriented research already discussed at that time were very similar to those of TA institutionalization. Parallels can be found down to the last detail if we take, for example, "social indicators" research (Bechmann 1976) or policy research in program and practice (Ukeles 1977; Jann 1985).

Problem-oriented research with the intention of providing policy advice must be understood as an expression of the political system's specific perception of problems. Thus, the TA concept did not originate as an offer from the sciences to politics, but was developed by politicians in conjunction with policy-oriented advisors (Dierkes 1987a, p. 191). In this context, it was noted early on that the label of *technology* assessment in the U.S. was actually intended to describe an assessment of *political programs*, i.e., specific policy research rather than (a new form of) technology research. In the German reception, on the other hand, the focus on technology seems to have been decisive from the outset. The dominant orientation in the 1970s toward "technology policy as active structural policy" (Hauff/Scharpf 1975) on the one hand and the experience of initial conflicts over major technical projects on the other may have been responsible for this.

There are many problems, but very few of them are recognized by the political system. Possible selection criteria are those that in one way or another indicate a threat to the existence or functioning of the political system.

Crises, such as reproduction crises, control crises, legitimation crises (Habermas 1981, Vol. II, p. 364ff.), not only represent problem pressure and a need for action for the political system. If they appear to be sufficiently serious, they are indications for the political system that established social and political forms of regulation, which are normally intended to and actually do manage "disturbances" and conflicts, are inappropriate, or no longer sufficient (Dierkes 1987a; Dierkes et al. 1988).

This is always the hour of scientific policy advice. The development of the TA concept was not only about researching the development conditions and control problems of technologization, but also about making a virtual contribution to *changing or supplementing* the coordination of social action and political decision-making procedures.

In general, many concepts of problem-oriented research were based on two fundamental assumptions:

- There is no alternative to technical-industrial modernization. Reproductive disorders and crises are not caused by internal contradictions, but by the "wrong" treatment and care of the "cow that you want to milk" (Willy Brandt). At the core of these ideas, industrial society appears as a (highly networked and complex) "machine" that needs to be "controlled."
- The sheer extent of technologization and scientification of society means that the production of suitable control knowledge is required for control purposes. And since it is about society as a whole, scientific and technical knowledge must be supplemented by human and social science knowledge – widely understood as "social technology" (Beck/Bonß 1989, p. 8ff.).

Basic assumptions of this kind also shaped the early TA concept (Wynne 1986; see also GW 1975). Science and technology as axial principles of society were to find their equivalent in the production of political control knowledge in order to bring about "rational" decisions. This almost inevitably closed the technocratic circle.

The tasks of TA formulated at that time show what qualitative progress was to be made compared to conventional (predominantly disciplinary) policy advice:

- Completeness of the analysis with the aim of taking into account previously unnoticed correlations and, accordingly, interdisciplinarity in the *factual dimension*;
- Early warning for the purpose of anticipatory consideration of problems that would otherwise be perceived "too late" and therefore concentration on "consequences" in the *temporal dimension* that are not immediately recognizable;
- Comparative evaluation of technologies or options for action (possibly with the participation of those affected) to maintain consensus or to reach compromises in the *social dimension*.

This phase can be characterized as a "simple" as opposed to the "reflexive" scientification (Beck 1986, p. 259). In any case, politicians and scientists alike rhetorically shared considerable expectations regarding the certainty of the forecasts and evaluations to be obtained in the context of an "instrumental-technical knowledge" paradigm.

The further course of "rationalized" modernization of industrialization and technological development showed that the underlying assumptions of the concept were fragile. The economic cycle could not be "shaped" without crises, environmental destruction remained a pressing problem, and social and political conflicts were not resolved. Problem-oriented knowledge was neither "instrumentally" successful nor context-independent in a technical sense, but was highly open to interpretation and therefore controversial.

This experience can be seen in attempts to reformulate the TA concept (Menkes 1983; Paschen et al. 1978). A more instrumental concept became a more strategic one, the need for selection and scoping was emphasized over the claim to completeness, and one-off scientific efforts became an iterative and recursive "process." The institutional history of the OTA can also be interpreted as a process of pragmatic adaptation – from a primacy of politics via a primacy of science to an unstable balance between science and politically controversial factions.

Nevertheless, considerable discrepancies remained between a pragmatically reformulated "strategic framework concept" and the practice of TA.

1.2 Ambivalences in technology policy and the dilemmas of TA

The historical reconstruction of German research and technology policy from the post-war period through the phase of planning and reform euphoria to the programmatic return to a "reactive" technology policy (Briefs 1991; Stegmüller 1990) reveals two fundamental contradictions:

- Although state research and technology policy (similar to industrial and infrastructure policy in general) is based on deficits in the self-regulation of the market economy system, it must not run counter to its logic for structural reasons.
- Their orientation toward the logic of market processes and capital accumulation creates – in relation to controversial social interests and needs – a specific weakness of legitimacy, which is confronted with an increasing need for public legitimization due to growing funding measures (Urban 1982).

As a consequence, this constellation means that politics must also legitimize such technical developments (or deal with their "consequences") that it has neither initiated nor can significantly influence (Fach/Grande 1988, p. 385).

The contradictions in the relationship between the political system and its environment correspond to internal contradictions. In fiscal terms, for example, a dilemma arises from the state's interest in promoting growth because of the tax *revenues* that depend on it and the state's fear of the "consequences" of growth because of the tax *expenditure* required for repair and compensation services (Ullrich 1988), for example in the form of the problem of contaminated sites. In terms of legitimization policy, on the one hand there is the insight to withdraw the exaggerated claim to political omnipotence (Engholm 1988; Momper 1989), on the other hand the obvious withdrawal of general responsibility rhetoric (Beck 1988) clashes with the functional imperative of securing social reproduction. The fact that "politics" is also and above all made outside the political system and leads to a "dissolution of boundaries" of social subsystems (Beck 1986, p. 300ff.) raises problems of continuity. On the one hand, environmental complexity and problem networking suggest overarching internal coordination of the political system, but on the other hand they are counteracted by – also functional – segmented processing and small-scale working structures.

Summarizing the observable contradictions, this results in fundamental ambivalences of the political-administrative system toward TA as problem-oriented policy advice.

From a factual point of view, the political system ultimately expects scientific advice to ease the burden of identifying problems and the need for action. Heterogeneous information should be organized, evaluated, and external demands on the political system reviewed. However, in view of the problems and issues that TA has to deal with and which it can only process as "interpretative" research, it usually fails to meet the expectation of reducing complexity. In contrast to technical instructions, it does not lead to easily manageable recipes, but rather to an increase in choices and future options (Luhmann 1990, p. 634; cf. also Beck/Bonß 1989; Weber 1989).

In terms of timing, the ambivalence of the need for advice is reflected in the fact that scientifically reliable information is expected at a time when problematic developments are not yet apparent, i.e., when the political system does not yet have an immediate need for action. It is precisely for reasons of research methodology and pragmatism that it is not possible to provide unambiguous indications (which are intended to facilitate or replace political considerations and decisions).

Finally, *from a social point of view,* political decisions are expected to be scientifically legitimized and made more "acceptable" through consultation. However, it is precisely the increasing scientification of social action and decision-making processes that has contributed to the dismantling of scientific authority (Weingart 1983). Even scientific-technical knowledge does not appear in a specific sense to be free of values and norms, but rather characterized by decisions and choices in several dimensions (Beck/Bonß 1989, p. 16f.; cf. also Halfmann 1988). It thus became increasingly clear to TA that the political consensus it was supposed to create was basically already a prerequisite (Wynne 1975).

These ambivalences can easily be found in the obvious contradictions of political rhetoric on TA. Here we need only refer to the "parliamentarian's fear of dealing with science" (Petermann 1988), which presents itself as a fear of technocracy and a defense of the primacy of politics. This is certainly based on fears of a loss of power and pragmatic restrictions on parliamentary work. But how is the articulated fear compatible with the simultaneous demand for "hard," unquestionable, instrumental knowledge, which is supposed to reduce uncertainty and complexity, and marginalize "soft" knowledge (such as that of the social sciences)? (Beck/Bonß 1989, p. 19). The political approach to scientific advice can only be understood from a "rationality" of the political, which – in contrast to science-centered assumptions – is highly contradictory in itself.

The contradictions of state technology policy outlined so far and the ambivalences of political expectations of TA are ultimately reflected in dilemmas and practical deficits of the TA process, which can only be understood with some blindness as those of a pragmatically reformulated TA *concept*.

If, for example, the "steering dilemma" of TA (Collingridge 1980) is seen in the fact that TA studies come either "too early" (due to unsolvable forecasting problems) or "too late" (due to irreversible social consolidation of a technological development), both the cognitively irreversible social framework conditions (Wagner-Döbler 1989, p. 177) and the ambivalence of instrumental consulting expectations in factual terms are addressed. The "implementation dilemma" (Paschen et al. 1992) between an orientation toward traditional "scientificity" without practical relevance, and an orientation toward concrete addressee premises without the prospect of acceptance of the results by other social actors, obviously paraphrases the aforementioned ambivalence of political expectations in social terms.

Such dilemmas cannot be negated by a reflexive TA concept, but from this perspective they appear in a new light. At the same time, they indicate boundary conditions and requirements that the criticism of "classic" technology assessment must face just as much as the proposed "new" concepts.

2. The "new clothes" of TA: Scientism, normativism, pragmatism

In my opinion, more recent critiques and counter-concepts of TA all too often miss the constitutive connections that exist in the relationships between problem situations and social perceptions of problems, between the political system and its environments, and between problem-oriented research and its "embedding." Sometimes the focus is only on the scientific quality of TA (scientism), sometimes the institutional deficits and limits of state policy are blamed on the TA program (normativism).

2.1 Scientism

It is typical of a "*scientistic*" criticism of TA that the "control dilemma" or the "forecasting problem" (Frederichs/Blume 1990) are *reduced* to "basic methodological problems." The "aggregation problem" (the relationship between national accounts and the operational "realization" level) also appears to be one that can be solved through scientific creativity, instead of seeing it primarily as a systemic problem of market-based self-management in relation to political global management.

Naschold notes a "standard reaction" to this view: the "relegation of such problems to the processing routines of the scientific system" (Naschold 1987, p. 17; cf. also Beck/Bonß 1989, p. 21). Since the scientific system is necessarily overburdened with such impositions, the scientivist critique is radicalized to the effect that TA cannot fulfil its claim to scientificity. The traditional boundaries between science and politics are called into question. This has two possible consequences:

- either the general renunciation of TA
- or the return to a decisional advisory concept.

The *general renunciation* of TA can take on several shades. On the one hand, we find tactically motivated pleas (Radaj 1988), which are actually concerned with preventing the public politicization of state technology policy – for example through TA capacity in parliament (Meier 1987).

Not for a second would most representatives of this position advocate a waiver of consulting and planning at company level.[1]

On the other hand, we find pleas for a retreat into the academic ivory tower, which refer to unresolved questions of disciplinary research, but in fact rather deal with disappointments about the "implementation dilemma" (von Thienen 1989; Knie 1990). What usually remains unreflected is their own science-centered understanding of practice and a concealed technocratic way of thinking, which considers scientific rationality to be the only "true" one and has long since left its future behind with the phase of planning euphoria (Beck/Bonß 1989).

The *return to a decisionist consulting concept* is demanded when the specific problems for TA are denied and reference is made to "controllable boundary conditions" of positivist science (Pinkau 1987).

Without repeating the criticism of classical decisionism (Habermas 1964) at this point, it is only necessary to refer to its current socio-political significance.

Its first implication *programmatically* amounts to the re-segregation of social subsystems from one another and is thus directed against a "dissolution of political boundaries," which Beck and Eder adequately consider to be a "risk society" (Beck 1986; Eder 1988). No matter how one judges such diagnoses of the present, the decisionist plea today certainly represents an expression of crisis warning and

1 Incidentally, a comparison between business-related and policy-related consulting is a good way of illustrating the nature of the supposed cognitive and conceptual dilemmas. (Coates/Fabian 1982a; Evans/Moussavi 1988). Under the premise of relative homogeneity of interests in individual companies and limited planning horizons, the strategic character of scientifically supported planning is accepted. Conversely, the well-known controversies about the meaning of risk analysis arise when actuarial and decision-theoretical concepts are transferred from the corporate sector to the socio-political sphere (Beck 1986; Evers/Nowotny 1987).

regulatory roll-back. In other words: the established modes of regulation (Dierkes et al. 1988) are (once again) considered sufficient (Evers/Nowotny 1987, p. 325).

Its second implication amounts *ideologically* to the wish for a restitution of scientific authority, whose statements would have to be valid ex cathedra (or ex Berlin) (Becker 1989; Gloede 1991). Although this wish is understandable from the point of view of established scientists and politicians in need of legitimization, it cannot even be fulfilled at Christmas (Weingart 1983; Beck 1986).

Its third implication *practically* amounts to an anarchic pluralism of scientific assessments, which conceal basic disciplinary assumptions and also very personal evaluations, are likely to correspond to complex problem contexts only by chance and would be just as functional for politicians seeking advice as an informational chaos – i.e., depending on the situation, either paralyzing or extremely helpful (Britsch 1989; Rasehorn 1989; Rautenberg 1989; Schatz 1989).

2.2 Normativism

The second fundamental line of criticism relates to the TA concept, which is accused of lacking problem adequacy (reified concept of technology or technology determinism) and incorrectly limiting itself to "consequences," when it is at least as important to analyze the conditions under which they arise.

This is usually followed by the argument that TA should be replaced by technology design, innovative or normative technology assessment, or even ethics (Ropohl 1985; partly also Fricke 1989; Lohmeyer 1984; Reese 1986).

It only seems plausible at first glance that this *normative criticism* of the TA concept is due to new scientific findings. Rather, the "discovery of the formability of society" (Evers/Nowotny 1987) and technology should be seen as the result of the crises and conflicts from which TA ultimately arose. Radkau has aptly pointed this out (Radkau 1988).

It thus becomes clear that normativist concepts tend to substitute science with politics (or social decision-making). This is illustrated by Meyer-Abich's concept of socially acceptable technology design as an answer to the question of "how we want to live in the future" (von Alemann/Schatz 1986; Bechmann/Gloede 1986). Ultimately, it is scientific elites who decide instead of (or even before the eyes of) the public where the journey should go (Evers/Nowotny 1987, p. 259ff). Philosophy in particular has recently discovered a long-missed area of business when it includes in its offerings overarching rationality criteria for the development of technical knowledge (Spinner 1989), professionalized ethics

(Zimmerli 1982), or even just the "rationalization of the obscure" (Gethmann et al. 1989[2]).

In their desire for a "rationalization" of the purposes of technology development and technology policy, the normativist concepts have technocratic implications. At best, they appear promising in the area of "interpretation" and "symbolic mystification" (Beck/Bonß 1989, p. 22). Their more or less hidden promises of public acceptance through "acceptability criteria" are open-ended.

However, they will certainly fail as *concepts* in practice if they lead to a change in real social and political forms of regulation. It is doubtful that companies will voluntarily cede decision-making authority to philosophers or technology evaluators. It is counterfactual that the political system is prepared to restrict the decision-making freedom of private economic units beyond the usual level (regulatory standardization) on a case-by-case basis (Traube 1988, p. 25f.). Finally, the hope for a change in awareness among engineers (via VDI) is also likely to be deceptive. All relevant studies in the past and present show that the influence of moralizing discourses remains marginal (Kohlstock 1991). At best, a certain influence arises from socially consequential conflicts in that it is not the morals of normativists but the heterogeneous values and interests of the public that become practical. In this roundabout way, normative shifts also penetrate companies – but slowly, very slowly (Coates/Fabian 1982; Evans/Moussavi 1988).

Recovery research, insofar as it does not operate exclusively within a disciplinary frame of reference, also falls victim to this verdict. Dierkes' concept of "Leitbild-Assessment," which at least attempts to build a bridge between "exciting" research and political problem perceptions (Dierkes 1987b; Dierkes/Marz 1990), is subject to two errors:

- It spreads illusions[3] about the influence of entrepreneurial or technical models on the ecological and social qualities of diffusing technology. Later

2 *Editors' note*: No bibliographic details were provided in the original publication.

3 In the first instance, Johannes Cross can be considered an unsuspicious witness: "The people who allow themselves to be celebrated as managers never talk about how they manufacture or sell a product, but about the philosophy on which they base themselves and their company" (FAZ-Magazin, December 1989). While the idea of "Leitbild-Assessment" was originally more in line with the postulate of early political influence on technology design (without, of course, having recipes for influencing mission statements in good time), today the virtue of "soft" social action coordination seems to have been made out of hard control theory necessity (Dierkes/Marz 1990, p. 39ff.). However, the arguments that guiding principles of all things could be promising for steering remain just as soft as the steering itself is recommended to be. On closer inspection, this

implementations and their consequences cannot be adequately deduced from the intentions of very early innovation activities. As empirical genesis projects show, these often break with social and political configurations (HACK 1988, 1989). The resolution of the Collingridge dilemma, as can be seen here again, is not scientifically feasible (Wagner-Döbler 1989, p. 149).

- In this respect, as with all normativist concepts, a fundamental insight that was already the inspiration for TA is ignored here: namely that intended purposes and measures can certainly have unintended "consequences." From this perspective, "finalized" science and technology development on the one hand and TA on the other represent complementary tasks (Rammert 1990, p. 347).

2.3 Pragmatic mediations

After scientism rhetorically sought to grant primacy to politics and normativism (with its technocratic implications) to science, we must now turn to the third perspective, which cannot be absent from the classical triad. *Pragmatic critique or TA concepts* of younger "generations" are based on a discomfort with the lack of consequences of impact assessments and explicitly reflect the practical experiences of past TA. However, in their criticism of the concept, they tend to refer to the old technocratic self-image (Rip 1987; Smits et al. 1987; Smits/Leyten 1988), which they contrast with a process-oriented concept that mediates between research, politics, and society. Many of the postulates mentioned here have long since been adopted by the classic TA *self-image*. This also applies to the "dragged along" claim to participatory TA (Naschold 1987).

However, it is precisely where the boundaries of traditional political responsibilities are to be exceeded in two respects (Schuchardt/Wolf 1990), namely by extending TA into the operational and social space as participation in "decentralized design" and by extending the participation of social actors in political TA – Naschold calls these "extra-paradigmatic" developments (Naschold 1987) – that the new pragmatic concepts come up against the very socio-structural and regulatory limits to which the reformulated TA concept also finds itself exposed. The *practice* of such concepts – be it "constructive TA" (Smits/Leyten 1988) or socially acceptable technology design (von Alemann/Schatz 1986) – is in fact

perspective is related to the radius of action of the creators of "organizational culture" (Dierkes/Marz 1990, p. 38) – which ultimately brings us back to Gross' scepticism.

subject to very similar restrictions. Without any malice, reference must be made here to the resistant conditions of good intentions.

Perhaps a more important aspect is the appropriation of operational mechanization and rationalization processes for TA. Here, too, scientific advice and support are only as effective as the respective interests and power relations of the participants allow. Trade union co-determination in the implementation of technology is still largely in its infancy (Briefs 1991; Weber 1986).

As much as the "extra-paradigmatic" inclusion of non-political areas in TA concepts could be programmatically in line with the trend toward social self-regulation of formerly "political" issues (Fach/Grande 1988, p. 385), two things must be pointed out:

- On the one hand, operational mechanization or technology design is usually a level in which "scope for design" is only given in relation to a basic technology that has already been introduced into society. In this context, the "designability" of technology, which is also a popular political claim, often conceals basic decisions that have long since been made, and structural rigidities (Hack 1988). The classical TA concept, on the other hand, is concerned with more fundamental problems of technologization that require general regulations.
- Secondly, the company level is not necessarily the place where the social actors involved are willing or able to assume "social responsibility" beyond corporate egoistic concerns. There is ample evidence of this (Coates/Fabian 1982; Evans/Moussavi 1988).

As long as new forms of mediating "decentralized" and "centralized" decision-making processes are not available, the political system in its function of framework regulation and global control hardly seems dispensable (Coates/Fabian 1982, p. 340). This is also the point of fundamental criticism of the decentralization and proceduralization discourse (Evers 1989; Seibel 1985; cf. also Dimmel 1989).

In my opinion, the new "pragmatic" TA concepts outline three interrelated aspects more clearly than was the case with the classic concept:

- the procedural character of TA processes as a scientifically mediated process of understanding and negotiation (Rip 1987),
- the necessary "strategic" or "communicative" character of TA knowledge in the context of such processes (in contrast to an "instrumental" or "science-centered" understanding of rationality) (Beck/Bonß 1989, p. 24ff.),
- the participatory structure of TA processes (Naschold 1987) as a necessary – not sufficient – condition for their virtual consensus-building function (in-

stead of acceptance studies in the context of “realization conditions” (Gloede 1987).

It remains to be seen which general “target system” (Böhret/Franz 1982, 1985a) will prevail as a result of social conflicts and power relations: whether the “maintenance of a generally acceptable technological and social change,” or “the socially adequate regulation of technological change.”

This openness of the TA concept, which does not apply equally to all aspects of the TA process, can perhaps even be regarded as one of its advantages (Conrad 1981).

3. Reflexive scientification and TA

After the overview given so far, it is no longer sufficient to simply fall back on problem perceptions of the political system in order to reformulate the TA concept.

Since almost all attempts to play off good “ideas” against a bad “reality” have failed historically, a self-enlightened TA concept must refer to the relationship between objective problem situations and political-social problem perceptions in a doubly reflexive way.

- At the level of *problem situations*, it can be assumed on the one hand that there is an objective substrate of natural processes or natural social processes whose characteristics and “consequences” are perceived by social systems (Landfried 1991, p. 104f.). From this point of view, the processes appear to be the most powerful opponents of themselves precisely in their naturalness (Beck 1988).
  On the other hand, however, there is no way around social and political perception if developments are to be controlled or shaped in a reasonably conscious manner. This also and especially applies to programs that seek a new “balance” between society and nature (Sieferle 1989, p. 193ff.).
- At the level of *problem perceptions* (which are mediated by social conventions and negotiations), any concept formation cannot therefore start naively from those problem situations, but must be based on a process of perception which – as indicated – is contradictory and fractured *in itself*.

TA as a program must focus on those contradictions within the political system and its environments that are both an expression of problem situations and indicate their modes of processing.

With regard to solving "factual" problems, TA can tie in with general efforts to ensure social reproduction. Such problems (such as the global climate) induce a dynamic that makes established reactions and regulations appear contingent or malleable (Böhret 1990, p. 260ff.). Despite the continuing context dependency of specific problem perceptions, mediating "themes" of social communication emerge here, which can be connected to (Luhmann 1990, p. 639).

With regard to problem perceptions *within* the political system, which are a direct point of reference for TA, it can reliably rely on the political system's interest in itself, which creates starting points for *options* for change even without normativist utopias.

It should have become sufficiently clear that, from this perspective, the hope of a standard line from "scientific rationality" to political decision-making is misguided. Rather, in its relationship to politics, TA is referred to complex strategic "games" that take place within the political system as well as in its environments (Beck/Bonß 1989, p. 30ff.). It should also not be deceived by supposedly sober self-assessments of internal actors who only consider a TA reception possible if the results confirm decisions that have already been made (Gries 1991; cf. also von Thienen 1989, p. 44). This is generally part of the game, as the results of social science research on utilization suggest.

If the diagnosis of strategic "games" between social actors in political arenas is correct, if these also characterize the handling of problem-oriented research, then TA itself must understand itself strategically in two ways:

- as a producer of "strategically" oriented knowledge[4], which is inevitably knowledge for action and sees its conditions of validity influenced by its use (Wingens/Fuchs 1989, p. 218);
- as a participant in strategic games, whose specific perception of problem situations and self-interests (as research) is functionally necessary (Lau 1989, p. 412ff.).

Public reflection on this function of TA could also increase the credibility of expertise in social discussions. After all, scientific policy advice is seen as compe-

4 Although arguing similarly in substance, Rip cites the term "strategic use" of TA results with a different meaning – namely as selective use to legitimize political decisions that have already been made (Rip 1987, p. 165). The corresponding counter-concept – "substantial use" – shows that the distinction adopted by Whiteman is largely based on scientistic premises (of one, "substantial" rationality). However, Rip correctly recognizes that "attempts to prevent strategization" in fact lead to a reduction of learning effects in social conflicts (Rip 1987, p. 166).

tition in the struggle for power anyway (Mayntz 1983; von Thienen 1989, p. 43). The corresponding mistrust cannot be dispelled by assertions of a scientistic self-image.

There are some indications that the renunciation of an instrumentalist self-image of TA called for here and also invoked elsewhere need not remain a pious wish. At the European Commission (EC) level, for example, it is at least proclaimed that one cannot wait until there is certainty about the validity of one or other global climate forecast (Hasselmann 1990). In the reformulated "classical" TA concept, conditional forecasts are increasingly being replaced by the formulation of political options by relevant decision-makers, whose "impact assessment" (e.g., with the help of constructed scenarios) is not measured by the certainty of their occurrence, but primarily by the structural/qualitative implications of a comparative consideration of those options (Paschen 1992, Böhret 1990, p. 179; cf. also Frederichs/Blume 1990, p. 26ff.). *Every* subsequent decision (which is made within the horizon of what is desired, of the probable implications, of what is possible in terms of power politics) already changes the basis of the previously constructed scenarios. Even if the TA studies understood in this way only (should) offer "orientation knowledge," a political discussion of their results may shift accents, change justifications, or open up new possibilities. Even on this rather "immaterial" mediation path, the social development and decision-making conditions do not necessarily remain the same (Beck/Bonß 1989, p. 27ff.; Roßnagel 1989a, p. 51).

In my opinion, the implicit "forecasting burden" (Paschen 1992) that still exists with such an approach takes on a different status. Certainly, even if it is not a matter of predicting the future, but of a "critical examination of future wishes" and the identification of starting points for political action (Roßnagel 1989a, p. 51), justified assumptions must be made about the connection between action goals, boundary conditions, and possible "consequences" of action, which can include causal relationships in the subject area of the options analyzed[5].

5 The most tangible reversal of questions of social communication processes into those of objectifying analysis (with the corresponding "forecasting problems") seems to me to be the consideration of society's future values in TA studies. In fact, such values can change "unexpectedly," and this in turn could be of some interest for an anticipatory consideration of the consequences of political decisions. However, in view of countless complaints about the – problem-related – inadequate time horizon of political calculations (legislative periods!), this uncertainty appears to be of little practical relevance. The postulate of a prognostic inclusion of value change processes becomes completely absurd if it serves to declare political decisions illegitimate according to *today's* value standards as long as no statements can be made about future ones (critical: Tribe 1973).

However, the “uncertainty” of such assumptions *no longer* appears here *primarily* as a *limitation of knowledge*, but *rather as a problem of understanding* between the actors involved in the TA process (including the TA researchers) about the possibilities and problem adequacy of scientific operationalizations (Frederichs/Blume 1990, p. 32ff.; Landfried 1991, p. 96ff.; Rip 1987, p. 168ff.; Roßnagel 1989a, p. 52).

Such a “strategic” turn in the pragmatic (self-)description of TA is further supported by the results of eco-systems research, which in perspective no longer allows even the most hard-nosed decisionist to claim causally fully determined prognoses (Halfmann 1988; Frederichs/Blume 1990, p. 38ff.). At best, individual aspects of development and “impact” assessments – such as the results of substance-related impact research – can still be examined in terms of a positivist understanding of science (Wagner-Döbler 1989, p. 145). Overall, however, statements generated in this way by those involved (science, politics, society) are always in need of interpretation. In my opinion, such a perspective should be represented offensively instead of defensively conceding the limitations of knowledge.

The problem- and practice-oriented reflexivity of the TA concept should be accompanied by actor-oriented reflexivity. In direct discussions with addressees and, above all, in public discourse, it should be made clear where the virtual benefits of strategically understood TA could lie for individual users and for social development as a whole. The accusation of arbitrariness (or even venality) of TA results frequently used in immunization strategies could be countered with reference to suitable control procedures (publicity of the generation of TA knowledge enables both scientific and political-social review) (Frederichs/Blume 1990, p. 67) – an advantage that is at least much less given with decisionist concepts (Richter 1989, p. 166).

Such an understanding of TA as a program is of course itself subject to socio-political discourse and can only become practical to the extent that the relevant decision-making processes allow. At the same time, it contains implications for cognitive and institutional implementation, as can already be seen from the imperative and voluntary formulations.

4. Implications for TA as problem-oriented research

Implications for the cognitive implementation of “strategic” TA are obvious insofar as the conceptual foundation is already on the problems and perceptions of industrialization and social technological development.

In terms of content, the reflexivity and self-reflexivity of TA must be directed toward the subject area to which it belongs (as an institutionalized process). At this point at the latest, namely with regard to the question of the appropriate conceptualization of technology development and technology "consequences," the aforementioned criticism of the "technology-deterministic" understanding of TA must now be taken up.

4.1 "Impact" assessment as technological determinism?

It cannot be a criterion of *problem*-oriented research per se whether and to what extent it analytically neglects certain aspects and dimensions of technology development. Selection is always necessary, but must be justified with regard to problem situations and not disciplinary claims. Thus, scientistic criticism of TA must also miss its object in cognitive terms.

Just as it likes to criticize the concept and practice by ignoring the problems and socio-political framework conditions, it usually attacks the concept of consequences without reflection.

Instead, a distinction should be made between the three most frequently used meanings of "consequences" in the TA discussion:

- At the *object level*, which is most easily accessible to scientistic criticism, the concept of consequences seems to imply causal or stochastic connections between "technology" and "non-technical" facts, although it would be better to speak of "effects" here, while the softer concept of consequences actually only implies a temporal succession of events (Böhret 1990, p. 35). In the criticized one-sidedness of technology assessment, the "autonomy of technology" is seemingly postulated – a "symbolic field" that only began to dominate social discourse in the 20th century (Gloede/Bücker-Gärtner 1989).
- At the *level of socio-political technology regulation,* the criticism of the concept of consequences amounts to a criticism of "reactive technology policy" (Ropohl 1985, 1989) and thus concerns the relationship between social subsystems (economy and politics) with regard to *the course of time and the influence* of technological development. Implicitly, in this context of meaning, considerable concessions are already made to the image of "autonomous" technology. In the same context, however, there is also a warning against overestimating the possibilities of political control, thus partially rehabilitating the "consequence orientation" (Knie 1989).
- Finally, at the *practical level*, the term "consequences" appears completely unsuspicious insofar as it is only a description of anticipatory social action.

> Trivializing characterizations of TA that point to the “praxeological” ordinariness of impact assessments (Adam 1987) operate in this context of meaning. What is essential is that the anticipatable future consequences, effects, “consequences” of action are included in a consideration that precedes the act of action itself (Böhret 1990, p. 27f.; Roßnagel 1989a, p. 52).

Connections can be shown between these three contexts of meaning of “consequences” for the concept of TA. In the context of “reactive technology policy,” the almost self-evident consequence orientation of policy in the practical sense must set different priorities and make different demands than in the case of active framework control or even finalized detailed control. The practical impact orientation gains a specific substantive concretization insofar as policy is not only confronted with the “consequences” of its own actions, but primarily with the “consequences” of others’ actions. However, such a statement is linked to further-reaching assumptions. For which actor “reacts” to the “consequences” of which action can only be decided by choosing a certain temporal, spatial, and social frame of reference (Böhret 1990, p. 35). In the context of the socio-political regulation of technology, this statement therefore means “on balance” a dominance of other social subsystems over politics – a conclusion that is perhaps true overall (Briefs 1991; Stegmüller 1990), but by no means for all areas of technological development (Keck 1984).

Finally, it can be assumed that the dominant regulatory mode of “reactive technology policy” (Dierkes et al. 1988) has contributed to a not inconsiderable extent to the formation of the “symbolic field” of autonomous technology. The process of advancing technologization, which is difficult to explain in detail, accelerated by self-referential internal relationships of technical innovation, but above all hardly accessible for political control from “one point” due to decentralized social self-regulation (Hack 1988; Rammert 1990), supported the myth of a reified technology to which political action only had to adapt (Gloede/Bücker-Gärtner 1989). Only to the extent that this process threatens to jeopardize not only particular interests, but also the conditions of reproduction for society as a whole, does the question of recovery factors and control conditions find sufficient social resonance (Dierkes/Marz 1990, p. 13f.).

4.2 Consequences of a social science concept of technology

If, on the one hand, it must be noted that “impact orientation” in technology assessment is unobjectionable in a *practical sense* (albeit unfortunate due to the overlapping contexts of meaning) and is at least realistic *in terms of regulatory* *policy* (which does not contradict limited attempts at intervention and design), then, on the other hand, we must take seriously the attempt to draw consequences from the more recent insights of technology research *at the subject level*[6]. Here we can tie in with the approaches of Joerges and Rammert, which in my understanding are complementary (Rammert 1990, p. 339). Joerges focuses more on the reification of action contexts in technical artefacts in terms of action theory and, by discussing such changing "connection conditions" of social action, points to the social implications of successfully used technologies (Joerges 1989) – a dimension that is definitely neglected in TA practice. Rammert's concept of "technicization" focuses on the social conditions and functions of innovation processes in a more system-theoretical context (Rammert 1989). Both concepts aim to integrate technology as a social category stringently into social science theoretical traditions, but for disciplinary reasons tend to neglect the reference point of a technologized appropriation *of nature* (and its sedimentation in the technical artefacts/processes) despite better intentions (similarly: Hennen 1991, p. 105ff.). Ultimately, this distortion can only be corrected through interdisciplinary cooperation (Landfried 1991, p. 101).

What are the consequences of this for directly problem-oriented TA? As a question about the sociological redemption of sociological desiderata, it ultimately appears unanswerable if one does not want to remain with the demand that TA practitioners should also rhetorically adhere to "largely shared objectives."

As problem-oriented research, TA *cannot* declare the development of technology theories to be its task in an independent manner – just as it is not capable of

6 To clarify and at the same time correct a widespread misunderstanding, it should be noted once again that the "impact orientation" of TA is to be understood primarily in the aforementioned practical sense. This distinguishes it fundamentally from "impact research" or, more recently, "technology assessment research" (Gloede 1991), which is understood in interdisciplinary terms and primarily refers to the object level. Accordingly, a "memorandum on social science technology research" from 1984 already called for the addition of the perspective of "recovery research" (Memorandum Verbund Technikforschung 1984; cf. Dierkes/Marz 1990, p. 17). However, here as elsewhere, the object-related *perspective of research* is erroneously associated with the *modes of technology policy* (regulatory policy level).
The TA *concept* has never adopted the subject-related dichotomy of perspectives of disciplinary research, but has always focused on analyzing the conditions *and* consequences of technology use. Even in the context of regulatory policy, TA was never exclusively related to the anticipatory management of the consequences of already developed lines of technology, but always *also* to political decisions on the promotion of technologies – i.e., apparently to mechanization strategies in early phases of development (Rammert 1990, p. 345).

driving genetic research or the sociology of science. Work in these areas must ultimately justify itself by recourse to specific problems and perceptions of problems. Essentially, however, TA can and must actually observe its research environment, identify any need for further research in the context of its problems, and use the existing academic research findings for its project-based problem-solving.

This use can and must consist of a heuristic control of the conventional operationalization of problems. In this way, the hitherto mostly rhetorical postulate of also considering social "consequences" (including the dimension of psychological processing problems) could be taken seriously (e.g., Clemenz 1987). The transformation of the social consequences of mechanization into questions of acceptance should not be allowed to continue (Gloede/Bücker-Gärtner 1989, p. 236).

However, the fundamental consequence of an understanding of technological development as "technicization" is that innovation processes, entrepreneurial technicization projects, state funding and regulatory programs, and social and cultural adaptation efforts must always be understood as social "strategies" whose normative (e.g., "guiding principles") and factual implications must be taken into account (Wagnerdöbler 1989, p. 142ff.). As "strategies" they are by no means obvious. Social actors need not be aware of the strategies they implicitly pursue in the context of the mechanization of nature and self-appropriation (Böhme/Lutz 1987), nor are these strategies readily apparent to an observer. *Insofar as* the problems of TA studies relate, for example, to state funding or the regulation of technological innovation itself, an attempt must indeed be made to reconstruct the social implications of these technicization efforts without neglecting the nature-related implications. The most recent attempts of this kind can be seen in the TA studies on genetic engineering (van den Daele 1991).

At the *regulatory policy level*, too, a reified understanding of technology cognitively misses the problems that lead to the awarding of contracts. With regard to the problem perception of individual clients, a technology-fixated TA becomes blind to the political implications of interests if it forgets the strategic aspect of the mechanization in question. TA as research can only really fulfill its corrective function if it questions the *articulated* problem formulation from its perspective in the light of overarching considerations of the problem situation.

TA misses its function even more clearly if, for factual and social reasons, it has to examine technological developments in the context of *conflicting social interests and orientations* and is limited to an "objective" assessment of technologies in the sense of an assessment of "natural processes." The TA process should not only take these strategic implications into account at the end of the analysis (i.e., in the controversial assessment of the "consequences"), but from the very beginning. It must therefore be examined whether a problem formulation capable of reaching consensus can be achieved at all through controversial negotiation processes (von Thienen 1989, p. 41f.). In case of doubt, parallel assessments are to be carried out here, the certainly controversial results of which are to be subjected to a mutual review. Either way, this constellation obviously describes the point of application of "participatory TA."

In my view, it would therefore be too little to call for "more" problem-induced TA, both in terms of the subject matter and in terms of regulatory policy (for technology impact research: BMFT 1989, p. 11). Rather, an understanding of "technology" as the result of social technicization strategies means that *only* problem-induced TAs should be carried out, i.e., even if individual technology lines or projects have been the reason for consideration in the sense of "technology-induced" TA studies. This is the only way to systematically open up the view for functionally equivalent problem-solving options (e.g., Gill 1991). In this way, the evaluation of the "consequences" of the technology lines under consideration, which is usually carried out in the light of alternatives and comparisons anyway, can be made accessible for explicit assessment. The *initial situation*, which is usually shifted to the consideration of "realization conditions" (e.g., Coenen et al. 1988), was then no longer neglected, but itself became an essential object of the assessment.

If a substantial problem orientation cannot be enforced with clients, it should at least be made clear which initial restrictions the study is subject to and what consequences this has for its results. In cases of doubt, it should even be considered whether it makes sense to accept the commission at all under the given circumstances. In some cases, *all* parties involved may be better served by rejecting it than by tolerating problem-adequate specifications.

The last consideration already addresses the consequences for institutional program implementation.

5. Institutional conditions

TA as a mediator between problems, their political treatment, and scientific research has "implementation problems" – in both directions, as we have seen. As wrong as it would be to try to resolve the dilemmas reflected in the concept of TA by *adapting* it to external socio-political conditions, it would also be inadequate to simply *withdraw* to academic research and only seek a contemplative relationship to social problems (von Thienen 1989, p. 44f.).

If, under these conditions, it must be part of TA's programmatic self-image to generate a specific form of strategically oriented knowledge and to see itself as a participant in strategic "games," then such a program is only promising under suitable institutional conditions.

Because TA is necessarily part of a more or less broad technology policy discourse or manifest conflicts in society, it is sometimes demanded that this discourse as a whole be seen as a "TA process" (Kollert 1984; cf. also Lohmeyer 1984). It seems to me, however, that the work of the Öko-Institut or the IFEU is also clearly different from the immediate "raging of the technology policy opinion war." Even though it is part of this social decision-making process, problem-oriented TA research nevertheless requires a relative distance from politics, disciplinary science, and the public.

Relative *distance from politics*, while at the same time demanding proximity, cannot be guaranteed by relying on science alone. Accordingly, institutional (financial and legal) independence must be ensured in such a way that political guidelines cannot have an unfiltered impact on research. Sufficiently high basic funding in conjunction with discursive management and supervisory structures are necessary but not necessarily sufficient prerequisites in view of practical experience. As a supportive flanking measure, circumstances should be sought which grant pluralistic social forces approximately equal influence on the processes of problem formulation for TA (van den Daele 1991, p. 40f.; Naschold 1987, p. 21ff.).

Relative *distance from disciplinary science* and simultaneous proximity appears to be less of a problem under the given circumstances. At first glance, the establishment of relative proximity to disciplinary research is much more urgent. Insofar as TA has to keep in touch with disciplinary concepts and procedures and seeks to implement them in a problem-oriented and problem-adequate manner, it must necessarily face disciplinary discourses for the examination and control of its results.

As the discussion of the scientivist critique of TA shows, it would nevertheless be misleading to disciplinary programs from the point of view of problem orientation. In this context, TA should not see itself as a "dirty" derivative of "pure" research, but should strive for an independent specific achievement with regard to problem orientation as well as – important in this context – multidisciplinary problem *solving* (van den Daele et al. 1979, p. 57). Crossing disciplinary boundaries and transferring conceptualizations (from one discipline to another) has sometimes proved to be extremely fruitful for disciplinary developments. At the same time, from such a perspective, specific disciplinary blindnesses and conditions of validity (e.g., of impact research) come into sharp focus (Becker 1989).

Relative *distance from the public* and simultaneous proximity as a requirement of TA practice should certainly be reversed at present. Participatory TA hardly takes place under the current conditions, and active participation in public discourse also leaves much to be desired.

On the other hand, it is obvious that TA cannot be absorbed into public discourse. Without relative distance, TA cannot perform a corrective function vis-à-vis the public. Here, both against conservative arguments (Adam 1987) and against "green" expectations (Gill 1991, p. 19f.), the qualitative difference between political and scientific technology *assessment* must be pointed out (van den Daele 1991, p. 44ff.).

The relative distance of TA from its environment outlined in this way (Beck 1986, p. 280) ultimately raises the question of what legitimacy the "strategic" participation in technopolitical interactions and communications called for above can have.

From more academic experiences with political consulting, Daxner postulated that a "new" science, taking into account its functions in the industrialization process, could not avoid

> [...] opening up and conquering a position of power whose goal would have to be the generation of problems rather than the solution praxeology. [...] The new science had to start where it was a matter of *enforcing methods that were already largely known* (Daxner 1988, p. 55).

Such a postulate can only *be legitimized* against the background of objective problem situations and socially shared problem perceptions that include the functionality of TA (as a "new science") (Daxner 1988, ibid.). *The necessity* is derived from the fact that most of the modern problems of the "risk society" can only be understood incompletely or not at all without the contribution of the sciences (Beck 1986, p. 254ff.). However, *the possibility* for TA to conquer "positions of power" does not result from its own strength and will. It is crucially dependent on situational circumstances and strategically reflected coalitions (Bronfman 1991, p. 77; Nowotny 1980, p. 173ff.; Rip 1987, p. 168ff.).

However, Daxner's political plea also runs the risk of blurring the difference between politics and science. The results and opinions of TA must be aware of their "relative" validity, which goes back to their specific social *practice* as problem-oriented *research* (Beck 1986, p. 290; Wingens/Fuchs 1989, p. 217). They cannot dispense with overarching political decision-making processes and must reckon with their virtual "functionality" even if this does not appear plausible in a science-centered understanding of rationality.

The basis of "power-political" action of TA can therefore only consist in its *specific* contribution to the identification and processing of problem situations – this is where strategic TA finds its limits, but also its justification (similarly: Lau 1989, p. 415).

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