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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.

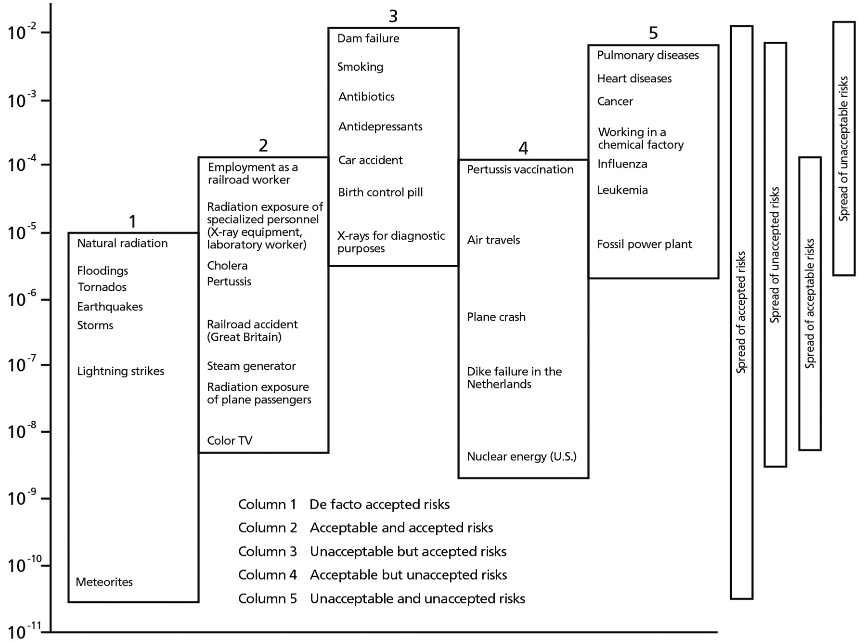


Figure 1: The spread of accepted (unaccepted) and acceptable (unacceptable) risks Histogram of individual risks of death for various risk sources

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).

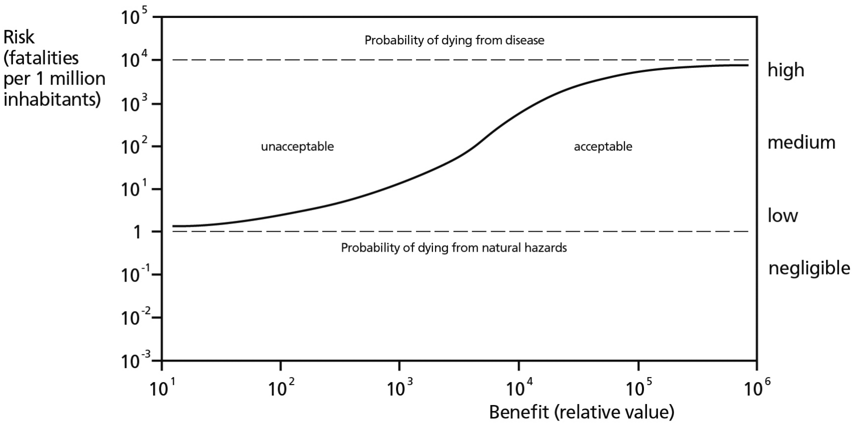


Figure 2: Revealed preference approach for technologies

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.

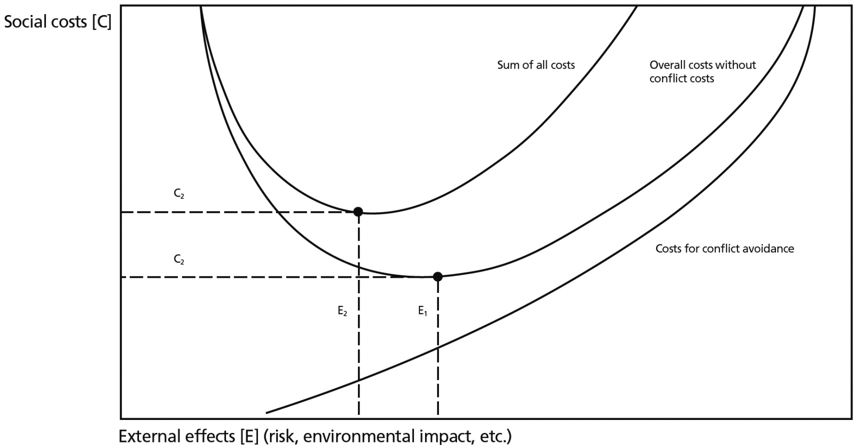


Figure 3a: Cost efficiency according to Starr for typical technologies including social costs

Source: Based on Starr 1979.

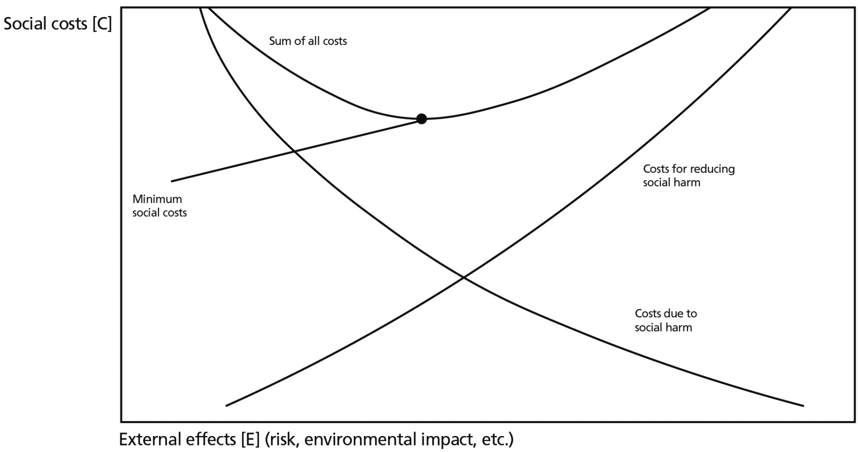


Figure 3b: Cost efficiency according to Starr including costs for conflict avoidance

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).

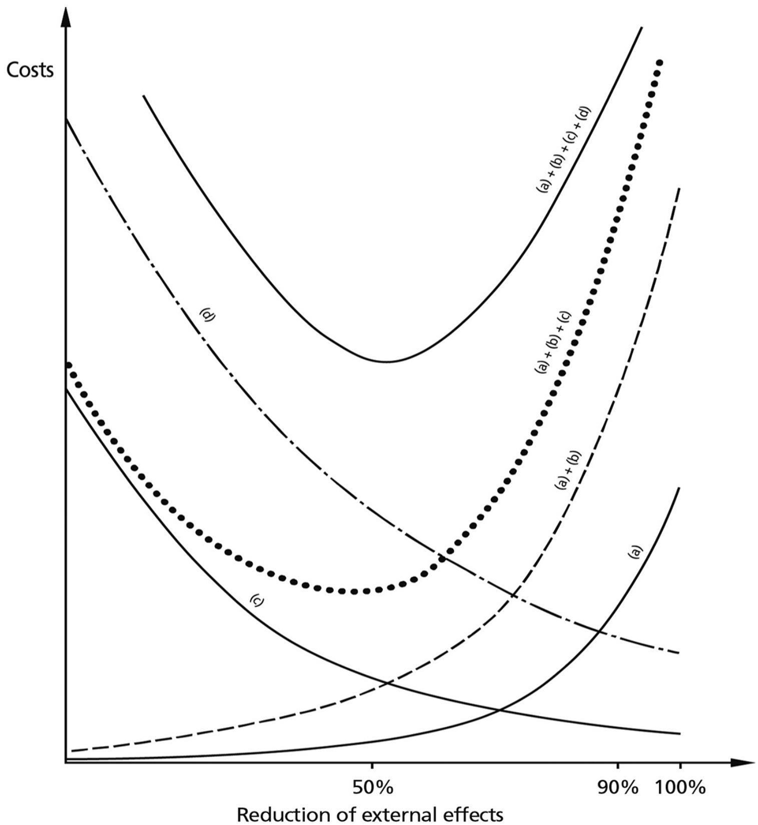


Figure 4: Cost efficiency according to Steiger Cost trends of the individual social cost components and total social costs

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).

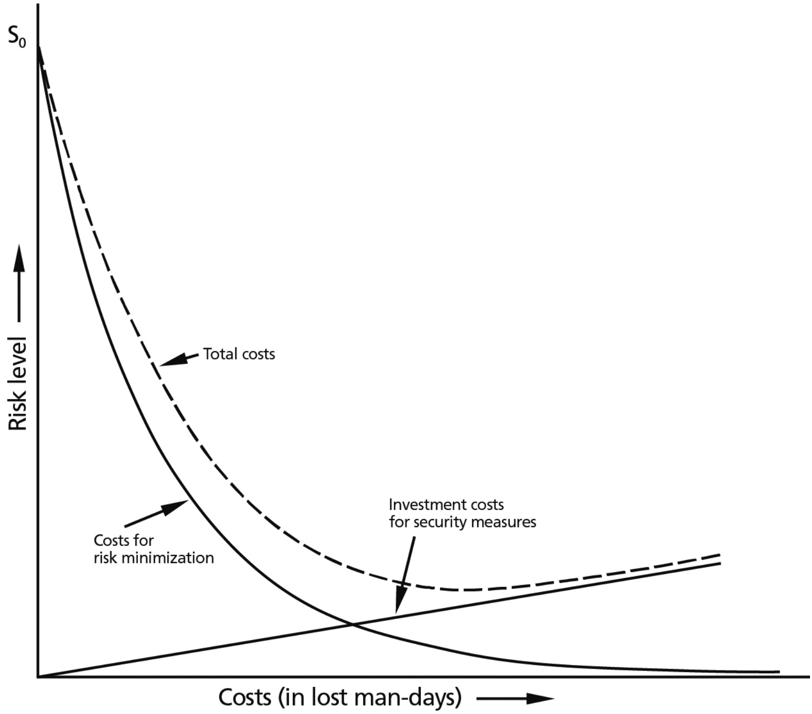


Figure 5: The marginal cost model of Black, Niehaus, and Simpson

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):

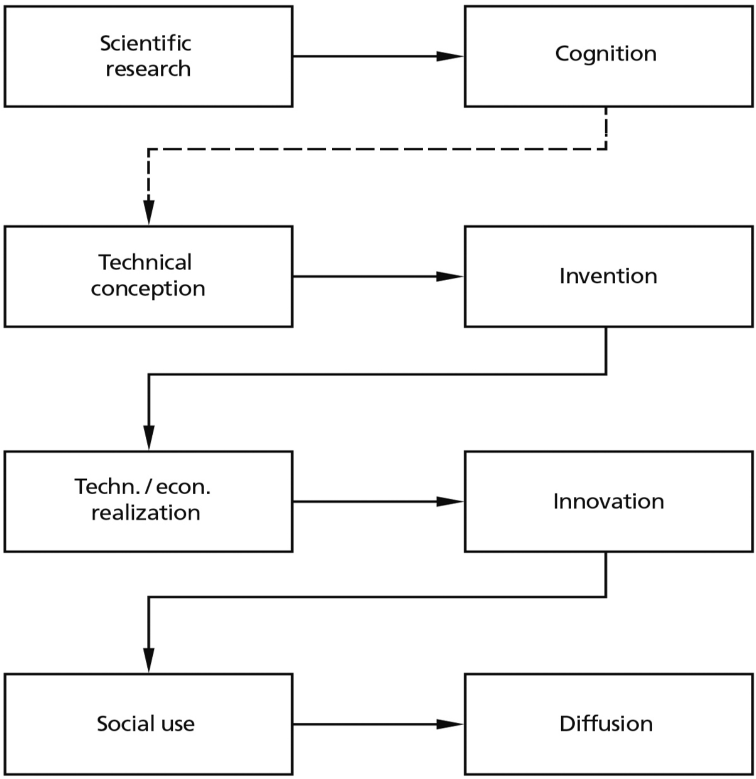
- Planning (definition of project objectives, operationalization of sub-steps)
- Program development (development of feasible alternative programs)
- Budget preparation (cost estimate, financing, etc.)
- Performance review (comparison of actual values with target values)

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

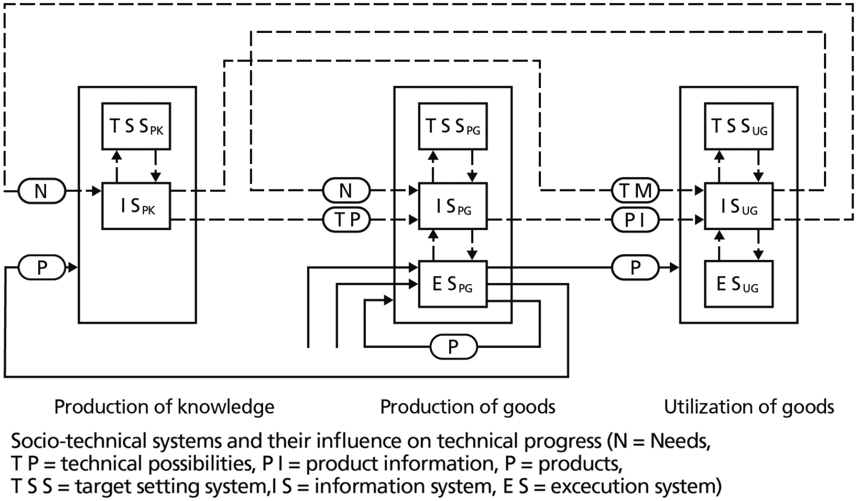


Figure 6: Simple diagram of a system-theoretical model of technology assessment

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.

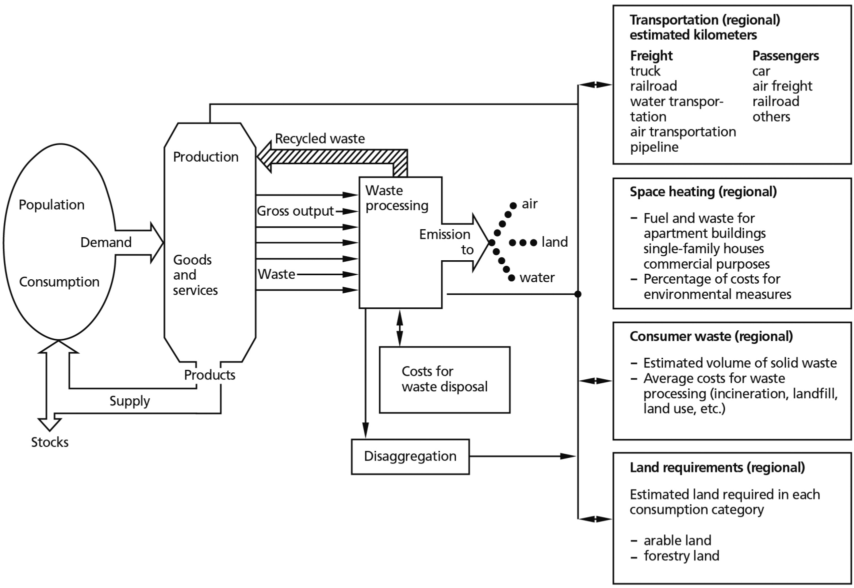


Figure 7: Diagram of the "Strategic Environmental Assessment System" (SEAS)

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.

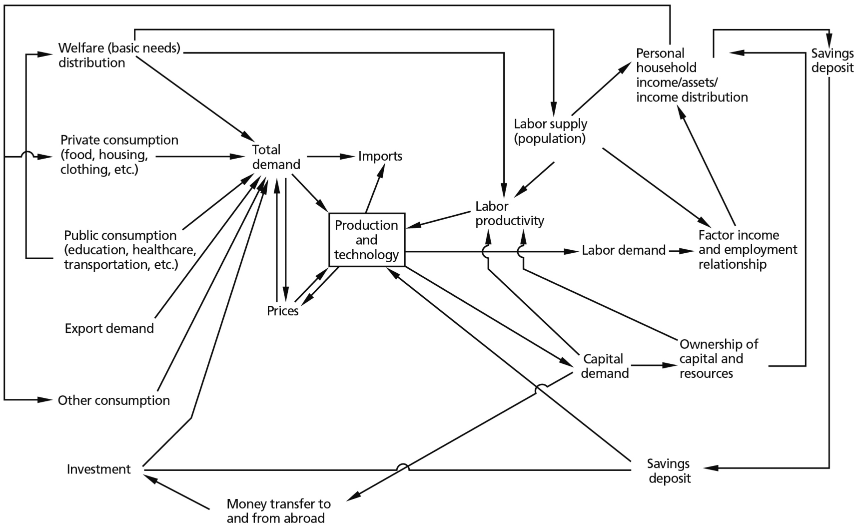


Figure 8: Basic elements of the basic needs concept

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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