METHODOLOGICAL APPROACHES TO THE ASSESSMENT OF SOCIAL AND SOCIETAL RISKS

O. Renn

Programme Group Nuclear Energy and Environment, Nuclear Research Centre, Jülich, Federal Republic of Germany

ABSTRACT

Risk Assessment and Cost-Benefit Analysis are the predominant methods of evaluating the consequences of technologies. Since both methods rely on the aggregation of various types of consequences and on the creation of objective yardstick to obtain criteria for systematizing different dimensions of hazards, we suggest a new methodology of risk analysis which is based on the basic need concept and a graduated optimization procedure.

KEYWORDS

Decision Analysis, Cost-Benefit-Analysis, Risk-Assessment, Multiattributive Utility Measurement, Systems Analysis, Energy System Optimization.

INTRODUCTION

The increasing significance of economically and technologically induced risks results in a similar growth of the need for a comprehensive assessment of the implications for the future involved in the consequences of the technological age. Since the future as such is of an indeterminate nature, it is a question of using plausible assumptions to develop models with which to identify the possible consequences and to quantify the probability with respect to each consequence. An ideal example of a risk analysis of this kind would be a process where the decision-maker received a list of future benefit growth factors together with the associated risks, in quantified form, so that he (or the authorities democratically legitimized for this purpose) could weigh up these positive and negative consequences for each innovation on the basis of his/their value system. This process would result in the development of only those forms of technology which promised the highest net benefits. As yet, no process has been able to fulfill the function of providing an objective yardstick for the future consequences of a particular technology. The ideal solution described above can never be realized, even in the case of refined and improved models for two basic reasons:

- Room will always be left in any calculation of future consequences for uncertainty and discretion, irrespective of the complexity and comprehensive nature of the calculation design.

- In theory, evaluations and identifications can be separated. In practice, however, these two fields of consequence analysis are interwoven. In principle it is possible to separate "objective, scientific risk analysis" from "subjective, political evaluation", although it can only actually happen if there is a continuous dialogue-process between these two decision-making bodies.

In addition to these basic objections, reference is made in the literature to the following unresolved problems (cf: Lesourne, 75):

- Identifiying consequences from among the interminable variety of possibilities
- The lack of knowledge regarding interdependences during the process of consequence effects
- The aggregation of various types of consequences
- The absence of an objective yardstick for obtaining criteria for systematizing consequences (and possibly also for evaluating them) and for weighing up various dimensions
- The allocation of probabilities for the chain of consequences.

In view of these central problems, it is tempting to dispense with comprehensive risk analysis and, instead, to use existing processes, such as probabilistic risk assessment or cost/benefit analysis, as "more objective" criteria for decision-making. For this reason, the following discussion begins by asking wheter the conventional decision-making processes with respect to the implementation of technological equipment and projects can provide a substitute for a comprehensive risk analysis. It will also be demonstrated that although all these processes offer rational tools for decision-making within their assumptions, they are not suitable for use as the sole yardstick in an evaluation of technologies and projects. The discussion will continue by attempting to describe a proposal developed by the author for measuring social consequences, on the basis of the cost/benefit concept and the "basic needs" theory.

CONVENTIONAL METHODS OF EVALUATING TECHNOLGIES AND RISKS

Technologically Oriented Procedures

Probabilistic risk assessment: The objective of this process is to assess as accurately as possible the risks involved in a plant or a project, using probabilistic analyses, and to establish specific limit values for a detrimental consequence which is not to be exceeded. The individual possible detriments and their effects on health and life are estimated with the aid of special emission-dispersion models, of methods involving the average detrimental consequences to be expected or of damage indices, on the basis of collective exposition of consequences. Subsequently, multidimensional aggregation processes are calculated in order to determine the overall burden. Risk assessment is an excellent instrument to detect deficiencies within technical systems and to compare alternatives with the same benefit values, but it cannot be substituted for an overall cost-benefit analysis, for the following reasons:

- The determination of detrimental consequences depends very much on the strategies used, since different methods lead to different results.
- The aggregation of various types of detrimental effects will always remain a matter of subjective weighting.

- The theory of risk threshold values presupposes that the benefits of a system play no part in the acceptance of the risks involved. This premise cannot be justified either empirically or normatively.

- Even low threshold values yield no results if they can be adhered to by the appropriate safety conditions with little effort involved.

- In the preselection of uniform threshold values, too little consideration is usually paid to the interrelationship of various risk sources and their detrimental side effects, so that synergistic effects are underestimated.

Revealed preference concept: In this process, risk acceptance is assessed on the basis of the extent to which the expected value of a risk does not exceed the order of magnitude of risks so far accepted. In addition to the expected value, the author of this theory (Starr, 1977) also includes the voluntary nature of the risk taken as a determining factor for historical acceptance. The comparison of new risks with risks accepted in the past can, of course, be used as an illustration for risk acceptance within a society; it is not, however, suitable for indicating quality criteria for risk assessment. It is not merely that the concept is unrealistic, because it presupposes that all the consequences of a risk source can be seen before a decision is made with respect to that risk source, and that a rational decision will be made as a result of the awareness of these consequences; in the same way as was shown in the previous concept, this theory also bypasses the real view of risk, since risks with the same expected values can be evaluated completely differently.

Expressed preference concept: Using this method, evaluation criteria for risks are determined on the basis of the results of surveys among the general public. Suitable questionnaires and experiments are used to determine the intuitive dimensions of the evaluation of risk sources, and these inherent patterns of evaluation are applied consistently and systematically to the evaluation of new risk sources (Fischhoff, 1978). This process presupposes that the public will have a clear view of the consequences of a risk and can only be accomplished where fixed opinions and assessment criteria are already in existence. A second precondition is that these dimensions can be transferred to all possible risk sources. Both these prerequisites are disputed at present.

Economically Oriented Procedures

Market separation: In our economy, the market forms a selection mechanism which provides a process evaluation in accordance with the criterion of economic viability. In other words, it ensures the most economical and most rational management of the production factors. However, it can only fulfill this function in the presence of complete competitiveness (which may be partially simulated), total internalization of all aspects of indirect costs and benefits, and transparency of consequences and preferences. Collective, meritorious, semi-public and public goods can be supplied only in part, incompletely or not at all by the market (criteria of exclusiveness and non-rivality). In addition, the following problems distort the results of market separation:

- Absence of supply with reductions in average costs or with zero level marginal costs,
- Inability to internalize external effects or to attribute them to external sources,

Systematic Balancing Procedures

Cost/benefit analysis: Cost/benefit analysis is the most commonly used process for comparing the costs and benefits of projects with external effects. In spite of all the criticisms levelled at the conversion of various cost/benefit dimensions into monetary units, it must be borne in mind that only a multidimensional aggregation process will permit a meaningful comparison of the advantages and disadvantages of a project. The premise that is used as a basis is the precondition that either a new project will improve the position of a number of people without harming others (pareto-optimum situation), or, more realistically, that new objects can only be introduced if those harmed by them can be compensated by those benefited in such a way that those benefited are still left with a net surplus of benefit (Kaldor-Hicks criterion). Although the theory of cost/benefit analysis is economically elegant, the problems of practical application are also evident:

- Some detrimental effects (e.g. death) cannot be compensated for at all;
- Some dimensions of benefit and damage cannot be measured against each other;
- Some dimensions of benefit and damage cannot be quantified;
- The problem of relative income distribution is not considered;
- The basis of comparison between different dimensions cannot be derived objectively;
- The distribution effects of benefits and damage are not taken into account;
- The individual detrimental or benefit dimensions are not independent of one another but usually have a substitutive interrelationship.

Multiattributive decision-making processes: Multiattributive decision-making processes attempt first of all to present quantitatively individual dimensions of benefit and risk as probabilistic functions of the possible damage, subsequently setting up preference functions for the different variants on the basis of the value concepts of the decision-makers. The combination of quantified consequences and value preferences takes place by means of the allocation of benefit values to each dimension and the allocation of weighting factors with respect to readiness to take risks (for example, risk propensity, fear of risk, etc.). The ideal decision-making process would be one where the decision-makers input the information used to obtain values, while the decision-making theoretician translates these values adequately and logically into the selection of variants. This process takes the form of a constant dialogue. The following criticisms can be levelled at this decision-making process:

- The subdivision into value and empirical statements (assessment and weighting of assessments) is often difficult to carry out.
- Preference functions presuppose certain mathematical pre-set properties in the preference structure of the decision-makers (e.g. transitivity). This is probably unrealistic in many cases.
- The aggregation of multidimensional consequences to form an index is always partially determined by mathematical, formal models, even when preference and utility functions are included (for example, the question of additive, multiplicative or logarithmic relations).

- Multiattributive decision-making models presuppose a single decision-maker, where no contradictions are involved. When value conflicts arise among the decision-makers it is almost impossible to set up a preference function.

- Adapting the preference function to suit a single decision-maker is often regarded as undemocratic and authoritarian; it is, however possible that preferences are only established after a democratic or participative dialogue has taken place (a sort of compromise).

Critical Summary of the Traditional Methods of Evaluating Risks

What general conclusions can be derived from the description and evaluation of the decision-making processes in use today, and how can these conclusions be converted into a meaningful collection of criteria?

- Theoretical risk concepts are not suitable for the establishment of acceptance threshold values in an objective manner or for setting up meaningful criteria for the evaluation of technologies and projects.

- The economic processes of market separation, welfare theories and marginal utility theories are either based on an application framework which is too narrow (cost-effectiveness) or they can only be used for certain purposes (minimization of risk) or under conditions which are extremely unrealistic (e.g. setting up social utility functions).

- Political instruments place the focus of attention on the decision-making process and on the selection of the decision-makers. The manner in which decisions are prepared and in which their contents are balanced is either ignored completely (black box idea) or is seen as a resultant force in the interaction of individuals and institutions who are working to maximize their own interests (political economics concept). These processes cannot be considered as the normative basis for a rational assessment of consequences.

- Cost/benefit analysis or other analyses balancing the advantages and disadvantages do represent more comprehensive possibilities for the comparison of benefits and risk; however, they lead to the problems of universal comparability, the incommensurable nature of the various dimensions and to doubts as to the objectivity of the bases of comparison. The functional dependence of the various consequence dimensions also results in serious methodical difficulties.

- Multiattributive decision-making processes have managed to solve the problems of value allocations and benefit perception among different consequences by developing models which involve dialogue between decision-makers and scientists; however they presuppose consistent and unanimous preselected objectives and are highly dependent on strategy, according to the aggregation model used.

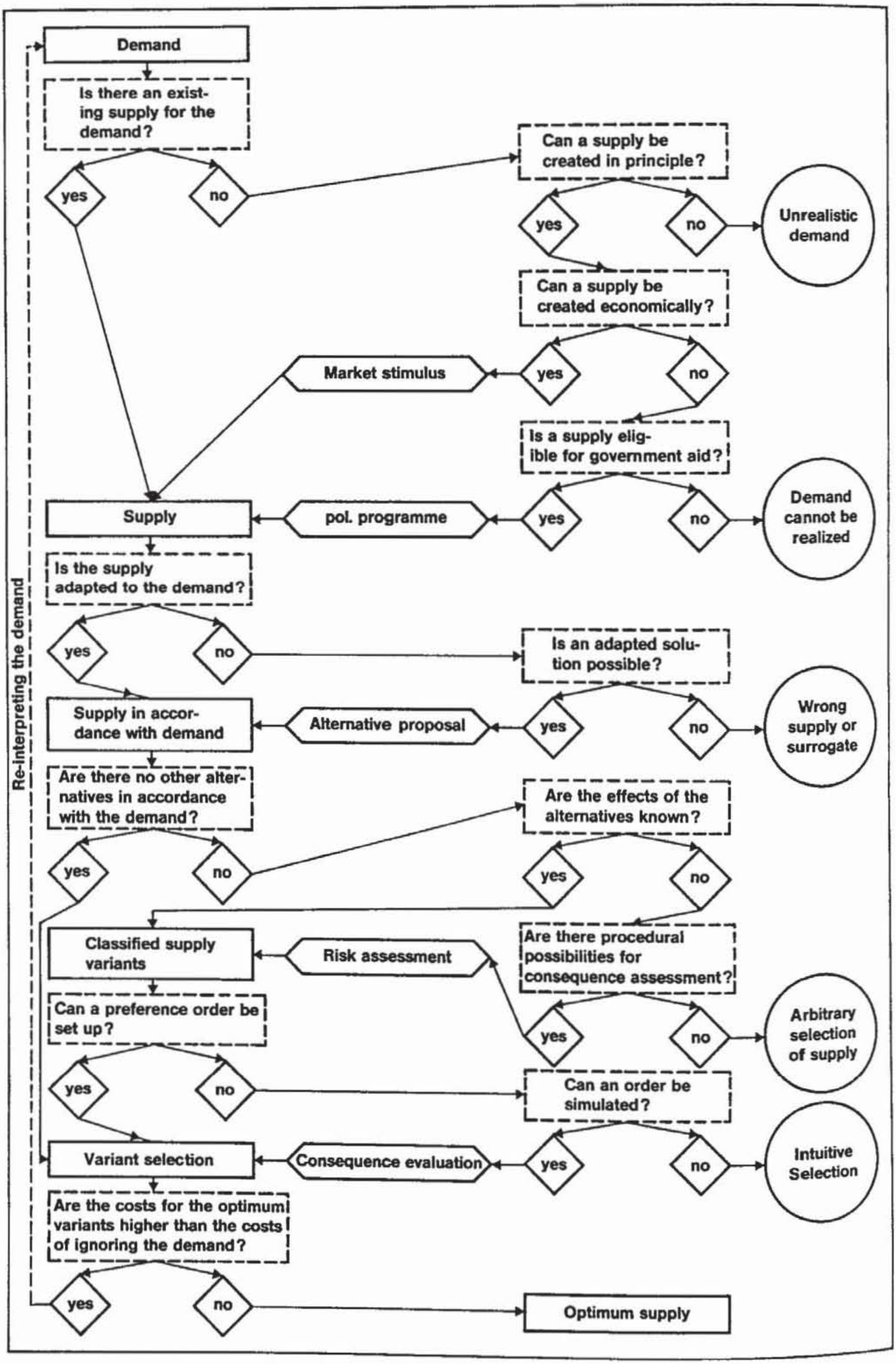

Fig. 2 Systematic framework for the satisfaction of demands

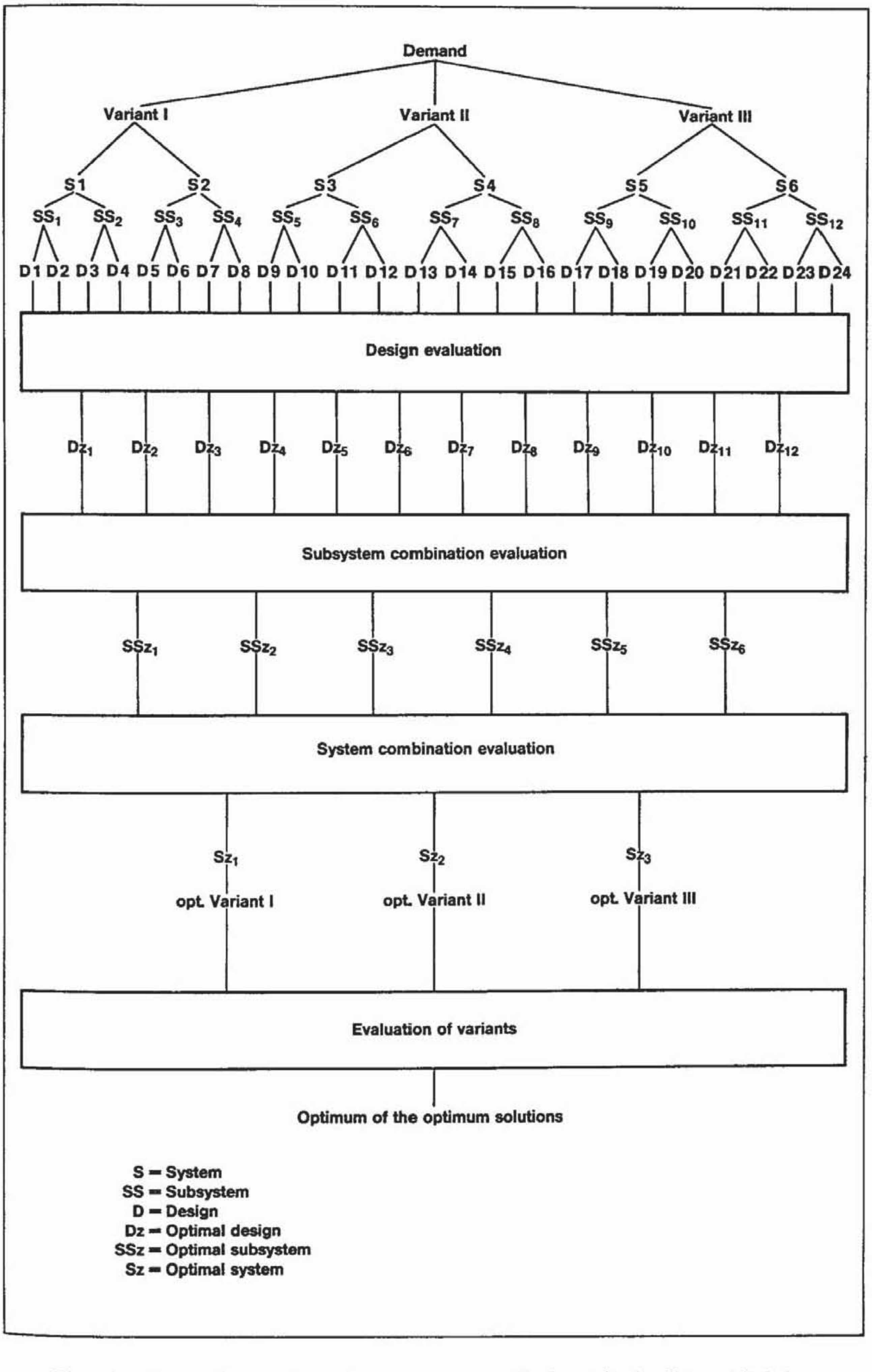

Fig. 3 General procedure to construct optimal variants for satisfying complex demands

If these four assumptions are made, then a decision-making course can be determined which includes, step by step, an optimum strategy for meeting the requirements pertaining at any one time. This decision-making process is shown in Fig. 3 where, initially, static conditions are assumed, that is to say, the time factor and the uncertainty resulting from it with respect to behavioural reactions or availability are explicitly excluded.

The Development of a Static Multi-Level Concept for Differentiated Technology

Assessment

At the start of the analysis, a specific need is converted into differentiated supply possibilities. Deductive variants are developed which can, in principle, cover the need assumed to be present. The variants can be made up not only of supply possibilities on the market at the time, but also of new innovative forms or the improved use of existing systems (e.g. rational energy modelling). These elements making up a variant and described here as a mix of systems, from the first subcategory for each variant. They should be distributed among the individual variants in such a way as to ensure that the basic need is covered. A detailed plan of supply and demand structures has to be worked out in order to include in the analysis specific regional requirements and quantitative effects which would not be given sufficient consideration in a comparison of systems using average values. With respect to energy supply, it is, for example, not sufficient to compare one kilowatt-hour from an atomic power station with one kilowatt-hour from a conventional power station. It is much more important to consider the use to which this kilowatt-hour will be put, as well as the extent of utilization of the power station, the possible location or the specific form of the stated load sector. The use of electrical energy for night storage heating can of course be evaluated in a number of different ways, depending on whether the intention is only to equalize fluctuations in the demand for electricity or whether this method of heating would involve creating additional power station capacities. The advantage of the analysis carried out here lies in the fact that a given need for heat, mechanical energy, light, etc. will have to be covered by a combination of various systems, the applications specific to the particular need being a necessary precondition. As a rule, there will be a variety of possibilities for combining the systems in order to cover the final need.

Each possibility, called a variant, is divided into systems, subsystems and designs as the final links in the chain. The differentiation involved here can be briefly illustrated using the example of motor traffic. In this instance, private and public transport would be the systems; subsystems of public transport would be buses or trams, for example, and the design variable would refer to the fittings of individual buses or trams.

Selection of the best variant would, therefore, take place according to a four-stage process:
- optimization of the design,
- optimization of the subsystems,
- optimization of the systems,
- selection of a favourite from among the variants.

The Optimization Process

Design evaluation: The problem of design evaluation is one of arranging a piece of equipment in such a way as to minimize the overall costs. According to the assumptions of our main concept each design has to meet some basic requirements which are regarded as essential. So in the first step all solutions will be excluded which do not meet the minimum conditions. The remaining solutions run through an evalution process described as cost-effectiveness. In a primary analysis the expected losses from several proposed designs are levelled out by the expected losses caused by the incorporation of safety measures. This procedure ensures that each design variant is optimized in respect of hazard minimization. Since every design has a different cost structure (basic costs and safety costs), it is necessary to find the most efficient solution with reasonable costs. A design which meets both requirements best, can be chosen as optimal equipment. Cost-Effectivness and Cost-Efficiency are the two steps taken for the comparison of designs. Both methods are illustrated in Fig.4.

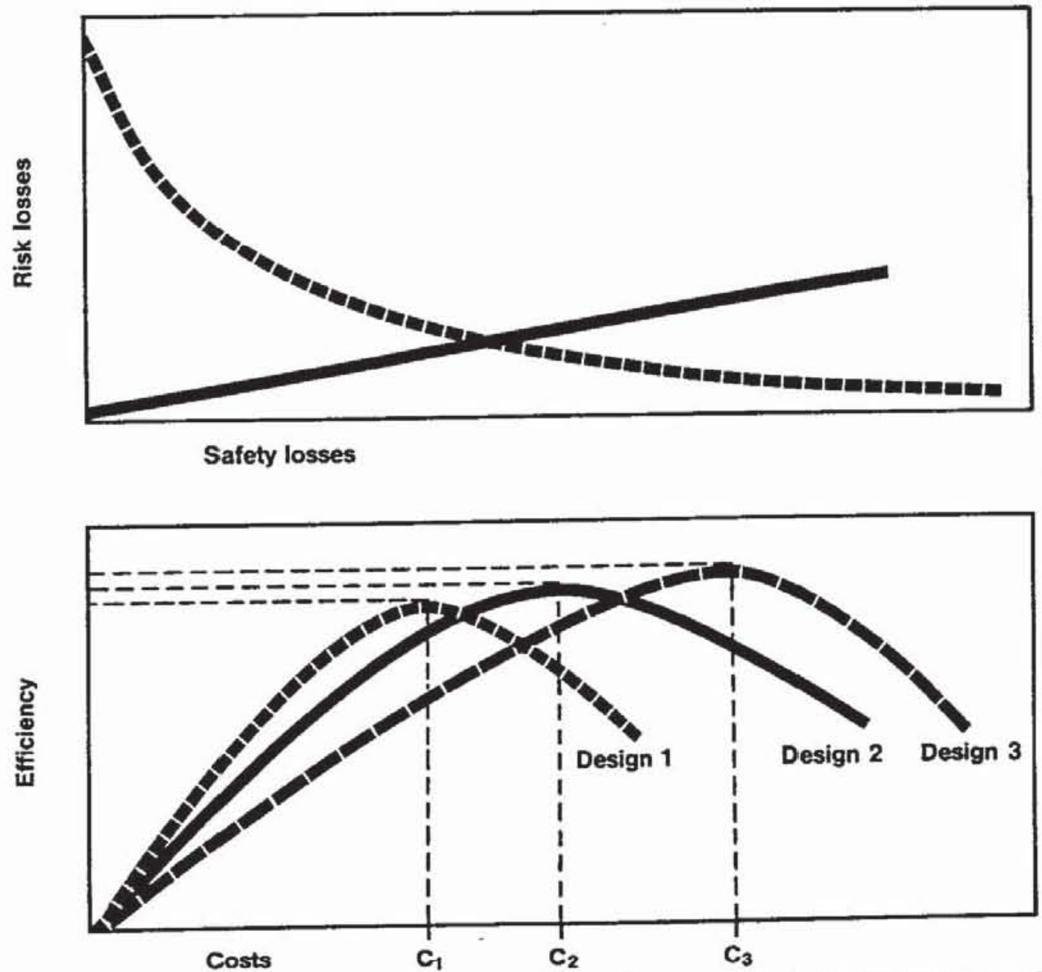

Fig. 4 Optimization of the design structure by a two step process: cost effectiveness study (upper figure) and cost efficiency analysis (lower figure)

As the selection of designs does not determine the social cost of subsystems and systems, it is sufficient to limit the evaluation to the analysis of health hazards, efficiency and costs.

Subsystem and system evaluation: In the same way as the procedure of selecting the appropriate design the first step in optimizing subsystems and systems is again to exclude all variants which do not meet basic requirements. The remaining solutions are all eligible, but will create costs and other detrimental effects depending on the relative frequency of their implementation. Therefore the object is to combine various systems in such a way that most of the evaluation criteria are fulfilled. For this purpose it is necessary to consult the legitimate decision maker and deduce evaluation criteria from his value systems (A promising methodology for this has been developed by v. Winterfeldt, Edwards and others, 1980). But since we object to the multiattributive utility measurement we do not make use of these value implications to construct preference functions. Instead we sort these criteria into an order of priority, in pairs, and ask for a tolerance range for the indicator of each criterium to calculate areas of overlap. Fig. 5 shows this selection process.

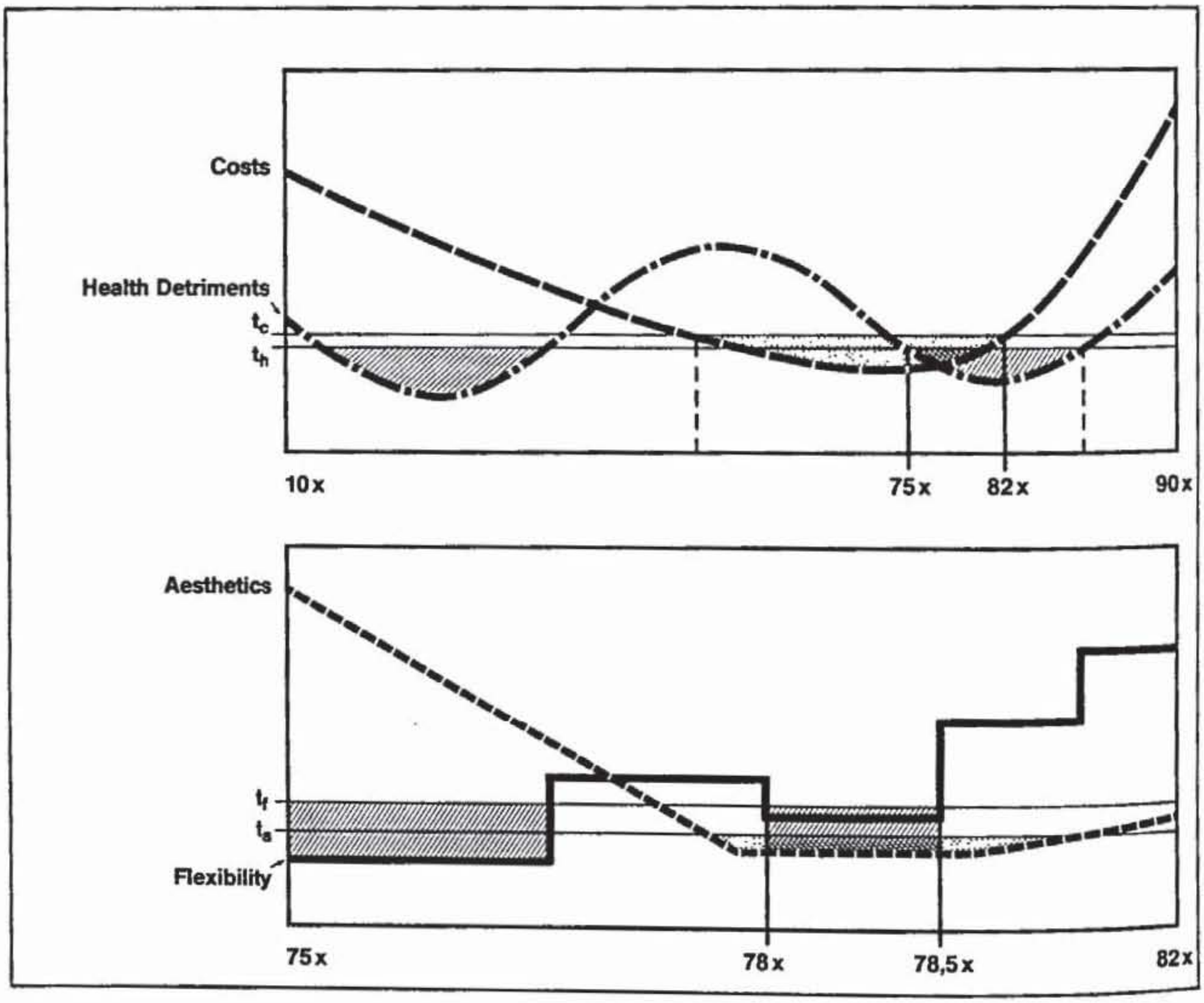

Fig. 5 The selection of optimal system mix: all solutions which fall into the tolerance range for the first two criteria (upper figure) are the starting point for the next step of finding areas of overlap (lower figure).

In Fig. 5 four criteria have been selected: costs, effects on health, aesthetics and flexibility. According to the decision maker the first two criteria have priority over the third and fourth. If we presuppose substitutive relations between two systems (like coal versus nuclear power stations), we are able to calculate the values of the criteria indicators for each possible combination (in Fig. 5 there is a continuous substitutive relationship from 10 to 90 percent variation). Drawing in the tolerance ranges for the two most important criteria a range of combinations can be determined which all meet the minimum requirements with respect to the primary yardsticks. This range of possible combinations determines the new border points for the next evaluation, in our example the criteria aethetics and flexibility. Again the tolerance ranges are drawn in so that the area of overlap can be calculated. The corresponding range of the combinations defines the set of acceptable solutions. This procedure can be extended (either by introducing new criteria or by narrowing the tolerance range), until just one point meets all the criteria. If there is no common area between two variables, the tolerance range of the criteria indicators has to be expanded.

The mathematical calculation for finding appropriate solutions is very simple and similar to the "satisficing" strategy proposed by Simon (1976). It is, of course, more fascinating and rewarding to an analyst to construct cardinal preference and utility functions which take into account the marginal differences between the preference ordering of criteria and the expected utility. Working with decision makers has taught us, though, that only simple, unsophisticated and easily understandble methods of combining value statements with analytical processing guarantee an effective cooperation between analysts and politicians and decrease the distrust and misunderstanding on both sides. It is essential that the decision maker is totally aware of the mathematical procedure, i.e. of what the analyst will do with his input. He also has to acknowledge which input is required and which output he can expect. The more complicated the analytical tools are, the greater is the chance that unrealized biases and personal strategies will disturb the results.

Variant evaluation: The final step is the most difficult, methodologically speaking. The separate variants, which have been optimized in themselves, must be compared with each other, so that a selection can be made as rationally as possible. Three problems must be overcome here:

- The search for suitable selection criteria
- The operationalization of these criteria
- The comparison of results for each dimension.

These will be explained in the next sub-chapter.

Incorporating the Indicator Model for the Selection of Variants

In the description of the indicator models, mention was made of the fact that objective criteria for the assessment of variants can never be scientifically obtained, but can only be founded on the basis of systematic estimation and selective choice. The following conditions should be mentioned as meta-criteria for the creation of criteria:

- Distribution of dimensions as completely or at least as representatively as possible,
- Exclusiveness of dimensions (no redundancy),
- Possibility of operationalization, in principle,
- Practicability.

A model for energy supply is presented here, as an example of the process of obtaining criteria from the systematics stage right up to the operationalization stage (Figs. 6 and 7).

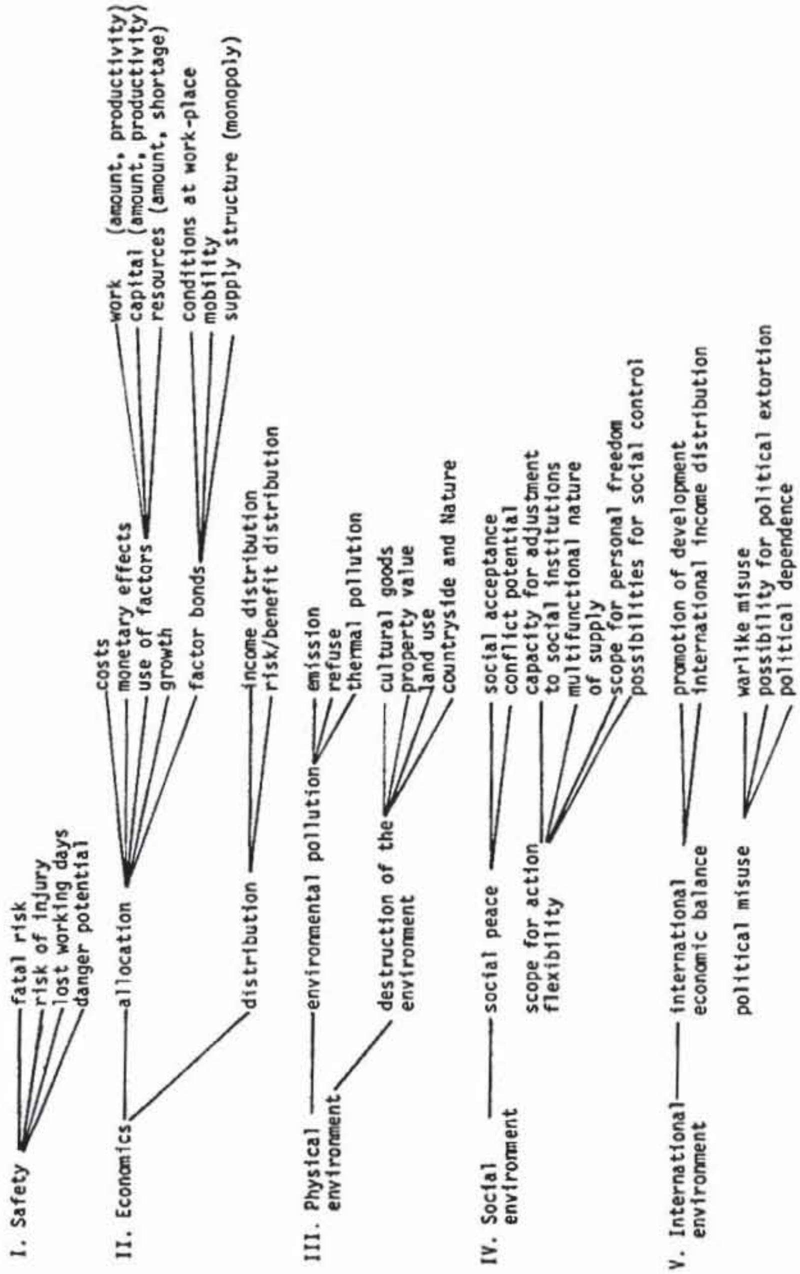

Fig. 6 Categories and subcategories for evaluating energy systems

Operational Indicators

Quantitative features

- Deaths (accidents, noxious air, extension of conflict)
- Lost man-years caused by damage to health (accidents, noxious air, restoration of private pollution of the environment,etc.)
- Monetary losses (costs, property values, compensatory pollution, losses due to insufficient flexibility, provisory expenses, etc.)
- Consumption of raw materials (energy resources, other raw materials)
- Changes on the employment market (labour potential, progress in productivity, competitiveness)
- Distributive national and international effects on income

Qualitative features

- Risk and benefit distribution
- Subjective satisfaction / desirability
- Overall frictional losses (losses due to conflict resolution strategies)
- Possibilities for misuse (sabotage, terrorism, war, proliferation)
- Curtailing or enlarging scopes of action (No. of limited possibilities for choice, pressure of circumstances, time budget, social dependence, international dependence)
- Reducing natural habitat (area, variety of species, natural landscape)

Fig. 7 Set of operationalized indicators to measure the intention of the categories

The indicator model attempts to sort the criteria with respect to economic, environmental, social and international considerations. The general task can be divided into two parts. Firstly one has to develop a fairly exhaustive set of evaluation criteria and secondly these criteria have to be transferred to measurable indicators. Both tasks are prone to manipulative and ideological biases. Under ideal cirumstances the criteria which can be derived from value orientations should be chosen by elicitating the value structure of the decision maker and of interest groups involved. An interdisciplinary team of scientists is then asked to deduct evaluation criteria by investigating the various value systems and to develop approriate indicators. As a control process one could imagine a procedure whereby competing groups of scientists trace these indicators back to their original values. After this validation the indicators can be measured. It was not considered necessary to compile these multidimensional values in an index, since this implies that a large amount of important information would be lost, and that the weighting of the individual indicators cannot be achieved, unless personal or measured preferences are introduced. With respect to a large degree of freedom of decision among the democatic bodies, and in consideration of the legitimation problems in the case of economic projects, it seems to be imperative to limit the process to measuring the various indicators and, in the final analysis, to allow the decision-makers to select the variants by discussing the various dimensions of the decision and heading for a common preference order.

When the indicator model is used, special considerations should be given both to the question of allocation and to distribution. This leads to the fulfilment of both the principle of utilitarianism (the greatest benefit for the greatest number) and the principle of equality (egalitarian distribution). Neoclassical welfare theories, in particular, suffer from not having paid sufficient attention to the problem of distribution, especially of relative income distribution.

Question Regarding the Inclusion of Uncertainty

Until now, static conditions have been assumed for the social cost/benefit analysis described here. The need was unambiguously defined and the individual supply variants could be realized without any time lapse. If these two preconditions are dispensed with, and if the time component is included, the application of social cost/benefit analyses becomes still more complex. Since future needs cannot be predicted, assessment must be based on certain assumptions regarding behaviour and structure, which can no longer be made plausible by working from the allocation of probabilities or a priori. Therefore, it appears to be necessary to develop several alternative possible need situations.Instead of assigning probabilistics to each possible risk consequence we prefer to construct several scenarios of consequential analysis, i.e. we use different models to describe alternative future paths. For each path or strategy we try to calculate expected losses as well as the overall probability of their occurence. But more important than this we investigate the political, social and economic requirements and their implications, if one of our scenarios were to be implemented. So we end up with a description of the probable consequences of each scenario and of the frictions and social cost to achieve the scenario situation. It is vital that the need scenarios incorporate the availability of supply with regard to time, place and behaviour, i.e. that each situation is consistent per se and can be realized in principle. No new problems arise in the evaluation of the design and the system due to the incorporation of the time component. Only when the indicators for the optimum strategy are required, some new sectors have to be included:

- Flexibility of supply in the event of fluctuations in demand,
- Flexibility in the event of changes in structural or social parameters
- Flexibility in the event of behavioural changes among individual groups

- Flexibility with respect to the substitution capacity of resources in short supply
- Frictional losses in the conversion of technological systems.

In addition to the incorporation of flexibility in the indicator model, it is particularly necessary for the evaluation of different projects that it be able to adapt itself to various need situations. For example, a decision could be made so that the costs which would arise if a high need situation were to occur were added to the costs of a low need situation. These would include the conversion costs accrued in changing to meet high instead of low requirements, as well as the losses involved in the gap in requirements which would occur. Conversely, if the low situation were to occur, the costs for the necessary adaption to the lower requirement and the remaining costs for possible excess capacities and excess supplies would have to be added to the costs of strategies for a high need situation. This cost comparison leads to a point of reference for the selection of different strategies.

CONCLUSION

All the processes described here for risk or technology assessment and the corresponding decision-making criteria have their specific advantages and disadvantages. Whereas models of welfare theory have very little practical relevance due to their excessively restrictive assumptions, most other applied decision-making processes have limited explanatory values because they only permit partial application and, thus, ignore important aspects of consequence analysis. The model proposed here follows the path of earlier proposals for planning processes in trying to develop a graduated optimization strategy for economic and technological projects, on the basis of the "basic needs" concept. This strategy attempts to combine all the advantages of a graduated selection process and takes into account the objective of allowing the legitimate decision-maker as wide a scope as possible in evaluation possibilities, at the same time increasing the transparency of the consequences. However, the process is based on the dubious assumption that needs in a society can be considered as independent values. This is in no way to deny the social transmission of needs, but only to assume the legitimate nature of social and individual goods requirmements a priori. Furthermore, the process is very time-consuming and probably extremely expensive. Thus, it can only be considered as a possibility if truly elemental needs for the present and the future are to be satisfied in the most rational way possible. Examples of this would be energy supply, mobility and the structures of communication.

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