THE CONCEPT OF TECHNOLOGY ASSESSMENT – AN ENTIRE PROCESS TO SUSTAINABLE DEVELOPMENT

Bjørn Ludwig

Technical University of Clausthal, Germany

The ‘widespread agreement’ for sustainability requirements concerning any future development is an expression applicable only to the abstract level of the discussion. Due to the huge number of aspects of sustainable development considered after the Rio Earth Summit, it is difficult to find the same agreement in a more detailed form. Focusing on the chief aspects of the discussion about sustainable development, namely the global problems that have progressively developed since the 1960s, the concept of technology assessment (TA) is obviously based on the same origins, although developed separately. TA is a powerful strategy with which to generate the appropriate technologies necessary to achieve any sustainable development.

In this contribution, TA studies are introduced as sustainable feasibility studies, a tool to help sustainable development become operational. In order to unify the discussion and achieve increasing application of TA, a description of TA is presented that readily includes all instruments, such as life cycle assessment, environmental impact assessment or environmental audit, and makes the interactions between them visible.

INTRODUCTION

Global problems, for instance environmental pollution, population growth, anthropogenic climate change, and increasing energy demand, expected to double in the next 20–30 years, have become more evident in recent times because of the increasing industrial use of natural resources during past centuries (Duchin and Lange, 1994; Global 2000, 1980).

Today, global activities are governed by the competing goals of environmental maintenance and increasing welfare, which is used synonymously with economic growth. The demands not to abuse the nonrenewable primary resources, on which our quality of life is based, have recently led to increasing discussions about sustainable development as a possible solution to this dilemma. To guarantee a global carrying capacity for 10–12 billion people (as forecasted for the year 2050), increasing application of technology is necessary.

This situation arises from vast technical applications, made to ease the conditions of human life. Technical systems have become more complex, and
more difficult to understand and to control. Undesirable effects can have cumulative environmental impact, which increases with space and time. Thus, as more people benefit from technological progress, they are also affected by more accidents and incidents of technological failure. In order to minimize the undesirable effects of technical application, the idea of technology assessment (TA) has been developed since the 1960s. One of the main issues of TA is to develop appropriate technologies to sustain future development. Thus, making the paradigm of sustainable development operational is indisputably linked with the strategy of technology assessment.

SUSTAINABLE DEVELOPMENT

Global development has disclosed what has been called the collision between civilization and the ecosystem (Gore, 1993). Many problems have occurred because of an incomplete perception of the term 'capital', by ignoring the necessary input taken from nature. Thus, if development is understood economically, the goal should be to keep capital intact in order to avoid impoverishment by overconsumption. This is expressed by the term Hicksian income, that is, maximum sustainable consumption (Daly and Cobb, 1990).

The concept of natural capital was overlooked prior to the notion of sustainable development (Pfister and Renn, 1996). It is now generally accepted that we should integrate the activity of human beings into our patterns of nature, rather than regard the Earth and nature as something separate from human civilization.

The meaning of the term 'sustainable development', left rather vague in the Brundtland report, has been more precisely defined by Daly. It is necessary to distinguish between growth and development that is on the one hand, the quantitative expansion but, on the other hand, the qualitative change of a physically nongrowing economic system. Furthermore, weak and strong sustainability are distinguished. Although weak sustainability aims at the maintenance of the total capital, which implies the substitutability of natural capital by humanly created capital, strong sustainability requires maintaining both kinds of capital separately, 

"on the assumption that they are complements rather than substitutes." (Daly and Cobb, 1990, p. 72)

The paradigm of sustainable development means the logical requirement – because of the competing goals of a nondecreasing level of welfare within a society, and environmental protection. Several definitions of sustainable development exist in order to specify what is meant. A considerable conceptual gap exists between any definition of sustainable development and the detailed policies required to make it applicable. However, there is overall consensus on the following core sustainability rules:

- the exploitation rate of renewable resources must not be greater than their regeneration rate;
- the environmental load should not exceed the loading capacity of ecosystems;
- the exploitation of nonrenewable resources is to be permitted only if future generations will not be concerned.

The operation of these rules is unresolved, because nonrenewable resources form the majority of our material standard of living. Sustainable development has so many aspects that the diversity of interests hinders the establishment of a unitary strategy, even after the efforts since the Rio Summit in 1992.

Discussions on sustainability have identified the following main problem (Freeman, 1993). Equal rights of use of nonrenewable resources and general pollution limits implies quantifiable and measurable criteria, so as to be able to answer questions of the kind: how much is too much? To make sustainable development operational as well as to consider methodical deficiencies, sustainable development indicators (SDI) are needed to check quantified goals for compliance, as required in Agenda 21 (Mitchell, 1996).

Looking at the strategies to make sustainable development operational, it is possible to distinguish different levels of aggregation. A very basic level might contain operative methods and applicable plans and measurements; another level that could be considered is one which enables agreement on the strategic procedure to achieve sustainable development. This latter is the concept of technology assessment. Global problems are consequences of extensive utilization of natural resources by increasing technical application. The quality of life achieved in the industrialized countries cannot be transformed to the last and least developed countries (LDC and LLDC), nor can it be maintained in the industrial countries, without more use of technologies. To avoid increasing resource use and risk, these must be appropriate technologies (AT), that
have yet to be developed as being ecologically acceptable.

Technology assessment is a necessary concept with which to achieve sustainable development and environmental protection. In the evolution of environmental protection three stages can be identified:

1. conventional environmental protection;
2. integrated environmental protection;
3. sustainable environmental protection.

Modern industrial countries are on the threshold of the second step. The LDC and LLDC, without much experience of conventional environmental protection, now have the chance of leaving out at least one step. It is possible to start directly with sustainable environmental protection, by using technology assessment and appropriate technologies.

Comparing our efforts towards sustainability with a global scale LCA, we are still standing at the beginning of the phases of goal definition and inventory analysis. The intention of this paper is to identify the invariants and connecting elements in all of these procedures, and to strengthen the paradigm of sustainable development by a systematic approach to the instruments of TA.

STRATEGY AND CONCEPT OF TECHNOLOGY ASSESSMENT

General remarks

The global problems of today are the consequences of technical progress, because overall systems were not taken into account. Undesirable side effects cannot always be recognized during the phases of planning, development and production. However, they can have cumulative environmental impacts. Increasingly, more people benefit from technological progress, but they are also affected by the accidents and incidents of technological failure. However, the perception that the solution to global problems is only possible through technology, has led to the requirement of the appropriate technologies.

In order that the development and application of technical solutions becomes more objective, transparent and safe, and in order to minimize undesirable side effects, the idea of technology assessment has been under development since the 1960s. It was given an official start in 1972 with the founding of the Office of Technology Assessment of the Congress of the United States (Schevitz, 1993). However, this mother of TA institutions was shut down in September 1995, because of the political situation within the US congress. Nevertheless, several other governmental and nongovernmental institutions have been founded, especially since the mid-1980s, essentially in the OECD countries (Ludwig, 1995).

Technology assessment is a strategy that has to provide information and knowledge on technical systems. This knowledge encompasses development and application of technical systems and the connections between economic, social and political systems, and impacts on the environment. Such knowledge should be used when evaluating existing or new technologies within decision support systems.

Ideally, TA satisfies the highest requirements of timeliness, comprehensiveness, participation and transparency. However, it is mostly because of these criteria that TA is criticized — because these criteria are usually not fulfilled. But the only alternative to TA is making unwise and unfounded decisions. All of these requirements on TA are subject to various interpretations, implementations at differing steps, and criticisms in the methodology.

A TA study should start as early as possible, but the earlier an investigation starts, the greater is the lack of knowledge and data about the process under examination. The decision of what qualifies as timeliness is one that should not wait to be reached by general agreement, due to irreversibilities of the common nonlinear systems. It is often too late to eliminate negative impacts when the definitive answers are in. Apparently it is best when several TA studies run parallel to the development process.

Comprehensiveness and participation lead us to the ethical dimension of the problem. Responsibility is a key notion in ethics, which itself is important for TA. Research in TA is mainly motivated by the following dilemma. As the complexity of today's technologies increases, so does the responsibility carried. Yet it is hard to assign responsibility of immense impact to any one person because of the little visible causality between the results and the activity. The actor is not necessarily identical with the carrier of liability. We can say, this is the estrangement of the individual from responsibility. Earlier, the liability was distributed, or taken over in a political or superficial way. This has led to a reduction of responsible behaviour. Therefore, the concept of individual responsibility alone is no longer sufficient.

This insight results in expanded conceptions of responsibility. In addition to the expansion of the domain of responsibility, those responsible are often removed in place and time (intragenerational and intergenerational responsibility). Jonas (1979) called this the genus responsibility of mankind. TA raises...
consciousness for responsibility by bringing out values that are decisive but that have remained undiscussed.

Methodology

The most common claim made against TA is that it lacks sufficient methodology. The following discussion copes with procedural aspects of TA. The proposed methodical procedures for TA, all of which consist of various numbers of steps, have been summarized using the guidelines of the German Association of Engineers (VDI, 1991):

1. problem definition and structuring;
2. analysis and estimation of consequences;
3. assessment;
4. decision.

The first step is to align the problem and recognize the boundary conditions. The system boundaries have to be fixed. Procedures and variables as well as the data and information to be acquired, then have to be fixed. Time constraints and evaluation criteria have to be stated. In the second step analysis of the consequences is based on experience and assumptions on future development. The assessment phase requires the laying down of the desired positive, but also the negative consequences that have to be accepted. Eventually, reasonable and conscious decisions should be made. Any presuppositions with respect to the value system have to be documented. Thus, several subjective decisions have impact on and influence not only the assessment phase but the whole TA procedure.

Additionally, each step requires the application of operative methods not treated here (Ludwig, 1996).

The types of TA can be categorized as problem induced and technology induced. Problem induced TA is primarily aimed at providing technical solutions for societal problems, such as insufficient energy supplies or transportation capacities. Technology induced TA checks for application possibilities and consequences of known or yet to be developed technologies, such as a renewable-based energy supply technology. To a lesser extent one can also speak about project induced TA and product induced TA.

Another classification criterion is the initiation of a TA study, with respect to the state of development of the considered technology. The most important types of TA in this category are innovative and projective TA, which focus on possible future aspects. With projective TA one looks for likely consequences before application, whereas with innovative TA one starts very early in the research and development phase, trying to guide the process using feedback. Other types of TA in this category are back-directed: reactive TA is used to examine consequences after market introduction, whereas retrospective TA is used to search for critical points in the development of past technologies. The achievements of old technological implementation are often applicable to today’s problems and can help to avoid negative results in cases of historical analogy.

These classifications help to provide a systematic overview of TA. However, almost every applied TA examination, including the tools of TA such as lifecycle assessments (LCA), requires a specified procedure, due to the individual nature of each problem. Therefore, a unique conceptual notion of TA encompassing these tools has not gained acceptance yet.

As an option for strategic technological decisions are usually important and far reaching, yet only rarely applicable to methodical solutions. The problem of assessment can be taken as the optimal arrangement of a set of possible alternatives, with respect to the relevant aims and the according preferences of the decision makers, considering given restrictions. Thus, it is the aim of an assessment to determine a particular value of any alternative, so that its advantages are represented in only a single expression. Such one-dimensional aggregated indicators are needed as supports in the decision-making process, for instance by entrepreneurs. The solution to this selection process will be especially difficult, if the following problem structure holds:

- many objectives are to be considered;
- different assessment scales emerge;
- objectives are weighted differently;
- information is at least partially uncertain;
- the problem is time dependent;
- many are to participate in the decision-making process;
- no unique criterion exists for decision making.

A multidimensional assessment problem can be considered as a logical measurement operation. One usually has to deal with complex and nonlinear systems, where many unmeasurable qualities occur and interactions are at least partially uncertain. Behaviour prognosis for such a system is inherently valid only for limited time spans, because the boundary conditions, in contrast to most other problems of natural sciences, cannot be considered constant in time.

Due to the complexity and the diversity of concepts it is not surprising that the TA concept is
controversial. The four TA phases named above are categorized as scientific-cognitive (steps one and two) and political-normative level (steps three and four). This distinction leads to strained working relationships between scientists and politicians who’s competence outside their field is denied by the other.

Technology assessment is actually based on well known and self-evident ethical principles. It has entered the discussion due to the rapid progress of science and technology. Simplified cause-impact relationships are no longer adequate to spell out the consequences of technical applications. The scope of technical-political decision making has increased. Earlier standards for decision making are insufficient. Entirely new tools have to be implemented, such as TA studies which are sustainable feasibility studies. Compared to the paradigm of sustainable development, the strategy of TA has less abstract operational problems, if the following instruments are considered.

**Instruments of TA**

Technology assessment is aimed at generating sustainable structures for technical applications. In the recent past several instruments have become important in the discussion of entire procedures. Since they are discussed separately among the participating groups dependent on the sciences and interests involved, each position is weak, which is not very helpful in achieving a unitary understanding (Neitzel, 1996).

All of the discussed instruments for entire examination of technical systems are essentially systematic procedures with which to register the environmental and social impact of products, processes, companies and their sites. Fundamental to all instruments are material and energy balances. Essentially, differences are only distinguishable due to different system boundaries for an examination and for scales of application. This also holds for different definitions and personal perceptions of terms, for instance ‘environment’. Thus, these instruments are named differently, such as product life cycle assessment, life cycle assessment, life cycle analysis, environmental impact analysis, environmental performance analysis, ecobalance or environmental management system.

If products are considered it is the unitary opinion that the whole ecological life cycle has to be analyzed, from the cradle to the grave. That means scrutinizing all stages of a product’s life: raw material production, production itself, utilization and consumption, as well as disposal, with the ubiquitous transport between each pair of stages. From this point of view, ecobalances of products can be taken as restricted life cycle assessment studies which consider, in addition to energy and materials flows, economic and social criteria.

For the investigation of processes, enterprises, or their sites, appropriate instruments could be ecobalances, environmental impact or performance analysis. Again, it is worth pointing out that only the system boundary and the point of view has changed. From the point of view of an enterprise, such an investigation is the methodical answer to the question of the ecological success of a venture, analogous to the economic success stated by balances of trade (Beck, 1993).

All of these instruments are based on methodical procedures very similar to the above-mentioned procedure of TA studies, although in the literature each step usually is named differently. In each case problems arise from different delimitations of the approached topic of investigation. This is due to the lack of guidelines, directions and standards for a unified strategy. Thus, the results of such studies cannot usually be compared with each other. This holds especially for impacts caused by transport and byproducts. It is important to identify the functional equivalent of the considered features that are to be compared. This issue becomes evident in the expression ‘utility unit’ or ‘service unit’, as used in new trials of aggregated indicators, for instance, material intensity per service unit (Schmidt-Bleek, 1994).

The first instrument of TA to be established in environmental legislation in Germany is the environmental impact assessment (EIA) due to the initiative of the European Communities (CEC, 1985). It is an instrument of preventative environmental protection, aimed at supporting the decision-making process about activities with potential impact on the environment. These impacts should be registered systematically and entirely before licensing. Here, the principle of prevention expresses the conviction that avoiding of harm is more effective than subsequent repairing and rehabilitation. At least in the German transition into national law (Kippels, 1990) the project-oriented EIA is described. Other kinds of EIA are applied to cities or counties, facilities, or to merchandise and services. Again, interfaces are to be stated with the instruments discussed above, life cycle assessment and ecobalance for products and enterprises.

In the case of the Environmental Management and Audit Scheme (EMAS) the idea of an entire approach of environmental protection was applied to enterprises. The guidelines of the Commission of
the European Communities (CEC, 1993) or the British Standards Institution (BSI, 1994) concerning environmental management may be taken as analogous to the International Standard of quality management DIN EN ISO 9000. The new International Standard ISO 14000 on environmental management issues is expected to be issued in its final version during 1997. EMAS can be seen as a stocktaking of enterprises’ environmental protection. It is the trial to obtain voluntary participation of enterprises to environmental protection by economic encouragement through market forces, in contrast to the traditional environmental policy, achieving environmental protection by governmental legislation. It is, however, required that the market pressure would be of such an order that an enterprises’ participation in EMAS will be rather obligatory. Here, interfaces to the TA instruments ecobalance and life cycle assessment emerge, because they are at least part of an environmental management system.

CLASSIFICATION OF TA INSTRUMENTS

From the above discussion an integral view on TA can be taken. It is the general purpose of the described instruments to include fundamental ethical principles in future activities, in order to establish sustainable development. This could become visible by developing and applying appropriate technologies. An integral view of these instruments succeeds with the following classification criteria:

- temporal TA-starting momentum;
- factual TA-starting momentum;
- institutional target group.

The temporal and the factual classifications have been described above. The temporal alignment results from the starting point of an examination. The factual alignment ensues according to the relative importance and to the societal problem range. A third criterion could be the societal rank of the institution on whose behalf and interest an examination would be made. This rank would accord approximately with the number of persons identifying themselves with this institution. Now, with these features a three-dimensional classification space could be spread in which each instrument could be integrated easily.

These considerations should illustrate the common purpose among the instruments and could strengthen the position of all procedures (Figure 1).

The illustration shows, for instance, that LCA could start as early as the concept of a new product, which we call innovative; but it could also be applied to provide backwards perceptions of product developments for consumers and enterprises, which we call retrospective. LCA is always product oriented, whereas an ecobalance could be imagined also up to the technology induced or to the problem-induced area. EIA takes the central position according to all features. This instrument is applied essentially to premature examinations, which is why it is positioned on the left side of the diagram. In particular, the discussed interfaces to LCA and ecobalance become visible. Because of their tempo-

Figure 1. The classification space of technology assessment (LCA = life cycle assessment; EB = ecobalance; EIA = environmental impact assessment; EMAS = environmental management and audit scheme).
rally limited character one could describe EMAS and ecobalance as stocktaking, that their results could serve as a database for other premature instruments. The ordinal classification space of TA could be made higher-dimensional by including other characteristic features, but it would become less expressive and would loose its toughness of statement.

An indicator for the necessity of such an approach made in this paper may be the slight change within the discussion about LCA in Germany, that leads to the assumption that the expression ‘ecobalance’ will be substituted in the sense of LCA.

CONCLUSIONS

Technology assessment (TA) is a concept with which to generate sustainable structures in future technical applications. The instruments of TA are discussed separately among the participating groups, dependent on the sciences and interests involved. In this paper the different instruments are treated by relating them to accepted classification criteria. Through consequent application, a classification space is introduced, the reach of each instrument concerning each feature becomes clear, and common interfaces become visible. The exact position of an individual instrument inside the classification space is open to discussion, but the important point is that these instruments do not stand isolated – they have overlapping and connecting character. This approach should help to enhance the paradigm of sustainable development on its way to becoming operational and less controversial.

REFERENCES


BIOGRAPHY

Björn Ludwig is an assistant lecturer and researcher in technology assessment and fluid mechanics at the Technical University of Clausthal, Germany. He graduated as a process engineer and wrote his PhD thesis on Methods of Modelling in Technology Assessment. He is working on the methodical integration of human knowledge into assessment procedures by methods of soft computing, especially with fuzzy logic.

Dr. Björn Ludwig
Institute for Applied Mechanics
Technical University of Clausthal
Graupenstraße 3
D-38678 Clausthal-Zellerfeld
Germany
Tel: +49 5323 72 3126. Fax: +49 5323 72 2203.
e-mail: bjorn.ludwig@tu-clausthal.de