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CONSTRUCTIVE TECHNOLOGY ASSESSMENT: INFLUENCING TECHNOLOGICAL DEVELOPMENT?

1. Introduction

Since the late 1960s, technology assessment (TA) has been preached, and sometimes practised. Its institutionalization in the Office of Technology Assessment of the US Congress has been very visible; more recently, many other countries are experimenting with various forms of institutionalizing TA (OECD 1983). Methods of TA have, for a long time, focused in impact assessment. The idea of technology assessment, however, encompasses more than just studies to estimate the potential future impacts of technological developments. The coupled aims of anticipation of such impacts, and subsequent feedback into (relevant) decision processes, which has been called the "philosophy" of technology assessment, are increasingly also the practice of technogy assessment (Rip 1986b).

In general, one can distinguish four different TA strategies, with their corresponding clusters of methods and approaches. (1) The traditional TA consists of ex ante inventories of impacts, with their valuation and (hopefully) some feedback into relevant decision making. (2) The broadening of processes of design and implementation of technologies, as happens already within organisations for aspects of safety, but could perhaps also work inter-organisationally. (3) The orientation of technology toward (more) human/social/environmental goals is discussed in public arenas and pressure is exerted, e.g. by social movements and government agencies in terms of the undesirable impacts that would otherwise occur. (4) Ex post inventories of impacts, increasingly on the basis of monitoring (as happens for example with new medical drugs in a number of countries).

Such TA strategies can be taken up by firms, by non-profit bodies, by government agencies, by social groups, as well as used as guidelines in doing TA studies. Taking a government perspective, a TA strategy has to be followed by measures (constraint or incentives) in order to assure feedback into relevant decision making and make desired outcomes probable. Regulation and standard setting have been obvious choices. But there are also diffuse societal decision making practices, e.g. as a result of controversies, which can be used by governments (Rip 1984). And one

should not neglect the possibilities to influence design and development of technologies, their diffusion and their assemblage into working systems. This is especially important if one does not want to be limited to a so-called technology dulling approach, but introduce some technology transformation (Stewart 1981). Governments have approached this possibility primarily in terms of increasing the number of technological options, e.g. in energy technologies, or in programs on new technologies in the work place (Dankbaar 1986, esp. p. 52). They could, in principle, also try to influence the processes of technological development, as they happen within an across organisation.

Ideally, successful feedback of correctly anticipated impacts would allow the development of technologies without negative impacts, or at least with manageable negative and many desired positive impacts. This implies attention to technology transformation, and therefore use of strategy (2), and the realization of relevant incentives and constraints for the actors that develop technologies and decide upon them. To achieve such a situation is the aim of what is called (at least in the Netherlands) constructive technology assessment (CTA). It represents a mix of the four TA strategies with heavy emphasis on (2) and (probably) (4).

To entertain the goal of constructive TA implies at least two assumptions:

(i) that there are margins, or room for choice, in technological developments, and that it is possible to exert some leverage;

(ii) that future impacts can be estimated with some certainty, that is, that the so-called "control dilemma" (Collingridge 1980) can be to some extent overcome. (The control dilemma says that impacts become recognizable only by the time the technology is so entrenched that changes are difficult to introduce.)

This paper will focus on assumption (i), its plausibility, and the implications for constructive TA. As soon as technology transformation is envisaged, a variant of the "control dilemma" arises, because it is difficult (for a government agency) to realistically specify the desired performance beforehand (Stewart 1981, pp. 1266 - 1268). On the other hand, in corporations that develop technology, setting performance (or safety) standards is a common way of directing the design process. Thus, at this lower level the problem can be overcome in practice. One might speculate that the "control dilemma" can at least be softened by involving the technology developers (and appliers and users) in the TA process.

The work of economists and historians of technology, and recently also sociologists of technology (Bijker, Pinch, Hughes 1987), has shown that the "inner logic" of technological development is a socio-logic (to coin a word, inspired by Callon 1980). Thus, the assumptions of constructive technology assessment (CTA) can be transformed into research questions in a productive way. For instance, what can we learn from recent studies of technological development about the dynamics of development and their social and institutional location? How important are technical communities (cf. Constant 1984)? If concepts from Nelson and Winter (1977) are applicable, can one then influence technological development only through modification of selection environments, or is it possible to modify the heuristics making up the technological trajectory? How can practices of design and development (Clark 1985) be modified, and modified with an eye to improve the future balance of positive and negative impacts? Are government incentives possible (directly, or by influencing other actors), and which would be most effective? Not all of these questions are answerable, but they indicate an approach to technology assessment and CTA that is promising, more promising anyway than the elaborate methodologies for impact assessment and their evaluation.

The Dutch government is interested in CTA, and thus in these questions, because it has established a program to stimulate technology assessment, not just in the traditional sense, but broadened to the issue of the integration of science and technology in society. One of the implications is that public understanding of science and technology, and increasing appreciation of their nature and role in society, are among the aims of the program. Another implication is that the hoped-for effect of technology assessment, the introduction of better, safer, and more humane technologies (besides the containment of negative impacts of existing ones) is actively sought. For this reason, they have introduced the notion of CTA, and they have commissioned studies to explore the questions related to CTA.

In this paper, we focus on those aspects to CTA that build on the insights of the new sociology of technology. The question raised by CTA require us to pay more than usual attention to aspects like diffusion of technologies, processes at a more aggregate level than the firm (e.g. branch), and strategic actions and reactions of the actors with regard to attempts at influencing technological developments. In our opinion, these aspects are very important in their own right, and deserve a much fuller treatment than we can give it here. Thus, our paper is exploratory.

2. A sociological model of technological development

When naive views of technological determinism were replaced by market pull models of technological development, this implied a view of technology as an undifferentiated reservoir, without any prestructuring or dynamics of its own. In reaction, a number of economists, historians and sociologists have taken up the challenge to study and understand processes of technological development. The present situation can be characterized as one in which much work has been done on the cognitive structuring of technological developments (compare key notions as 'dominant design', 'technological regime', 'technological paradigm', 'design hierarchy'), but where sociological aspects have been alluded to, but not systematically addressed. This can be understood as a consequence of the unsatisfactoriness of earlier economic or social-institutional determinisms: neo-classical or marxist economic determinism of technological development and industry evolution has been criticized for its neglect of technological uncertainty (by neo-Schumpeterians and by Abernathy, Clark and Kantrow 1983), while adding an important dimension, certainly tend to jump to hasty conclusions. In addition, the relation with technological development remains an exogenous one. What is necessary is an endogenous theory of the emergence of cognitive and social structuring, constraints, imperatives, regimes. (Note that no fundamental distinction between cognitive and social is implied. Latour (1986) and Callon)1987) have emphasized the importance of not making this distinction. We think it is sometimes harmless to use the terminology, especially if it is clear that one is looking at the emergence of such distinctions, not their being given as such.)

To show the possibilities for a sociology of technological development, we shall briefly discuss two approaches: Abernathy et al.'s work (1983) on design hierarchies, and our own sociological extension of Nelson and Winter's model of technological regimes and selection environments (Van den Belt and Rip 1984, 1987). Two aspects will be highlighted: the fact that technological imperatives are always "quasi-imerpatives", i.e. have to be maintained as such, do not exert force independently; and the interactive processes with environments.

Abernathy et al. (1983) (see also Abernathy and Clark 1985, Clark 1985) analyze the automobile industry in the United States and emphasize how technological products and markets are not pre-given, but emerge: "Producers gradually learn to distinguish the relevant product attributes for which they must supply technical solutions acceptable to the market.

(...) Taken together, these attributes constitute an industry's basis of competition - that is, they define the arena within which different producers stake out their distinctive positions. (For such an arena to emerge some stabilization has to occur of ...) a process of iterative searching and learning (...) among producers and buyers alike." (Abernathy et al. 1983, p. 26, 25)

It is in such an agonistic field, in which struggles for its definition occur continually and make it impossible to specify its character independently, that a dominant design emerges: "When Henry Ford began to tinker with the idea of making an automobile the industry (if one could call it that) was young and its future direction ill-defined. Dozens of budding entrepreneurs labored in sheds, small shops and garages to turn out a bewildering variety of what they called automobiles. (...) As search and learning behavior proceeded on both sides of the market, some concepts won general acceptance - internal combustion engines fueled by gasoline, for example, and front-mounted engines, direct drive shafts, and left-handed steering. In 1908 Henry Ford synthesized these concepts into an overall design, the Model T, that was to dominate the industry for fifteen years." (Abernathy et al. 1983, pp. 44 - 45)

When a core concept has emerged, it becomes the top of a design hierarchy. "Standardization of product design changes the basis of competition. Battles in the market place are no longer fought over the kind of thing a product is or even the kinds of things it should be able to do. The locus of competition shifts to what the product costs. (...) This is not to say that product innovation disappears entirely of that it ceases to be of value altogether. The point, rather, is that what product innovation there is tends to be localized toward the bottom of established design hierarchies and, as a consequence, to enjoy little market visibility." (Abernathy et al. 1983, p. 24)

The concept of a design hierarchy is a powerful tool for the analysis of processes of technological development within a firm and across firms. Clark (1985) shows how interaction with 'customer concepts' (at the beginning still hardly articulated) produces a particular route through the design hierarchy. Abernathy et al (1983) discuss how the maturity of an industry is related to the standardization of the production technology ('production paradigm'), note how competiton then tends to conserve design concepts already in place, but also show instances of increasing 'market niche versatility': "As the work of refinement proceeds (...) the range of

performance available from a given design tends to increase, and this permits a firm to cover a broader set of market segments from the same or even a narrower technical base. In the post-World War II application of piston engines to commercial aircraft, to cite one example, the same manufacturing resources - tooling, equipment, and so forth - satisfied the requirements of small planes like the DC-3 and larger planes like the DC-6 and Lockheed constellation. Such versatility was simply not possible during the prewar days of industry evolution." (Abernathy et al. 1983, p. 112) (A similar point is made by Sahal (1981) about the versatility of the general purpose tractor.)

The existence of design hierarchies within firms (and their similarity across firms in a mature industry), including their concrete social embedding, allows influence to be exerted by broader customer or societal concepts, at least in principle. That other criteria than cost and performance can be included is clear in the examples of safe design, for example in automobile, aircraft and space industries. Volvo Car company has an elaborate formal and informal system to improve safety and reliability, including monitoring of performance and feedback into the design, development and production processes (Sevenson 1984). Volvo Car has been a leader in this area, but other companies are known to follow their "hazard management routines". For the actual production of safety, it turns out to be important that safety targets are set, safety prototypes developed, and that the formal review and accountability procedures are supported by a company culture accepting safety as a goal. Comparable conclusions follow from case studies of American companies (aircraft, space, elevators, chemicals) done by Flores (1983). There is little or no empirical material about the incorporation of other criteria into design and development, but one might argue that similar routes could in principle be followed: as Svenson (1984, p. 494) indicates, general organizational theory predicts that organizations create routines to cope with external (societal) demands.

Limitations of the approach via design hierarchies derive from its focus on firms, and consequent neglect of the transformations of technology during the adoption and diffusion stages. The agricultural sector, with the important role of agricultural extension services, deserves analysis from this point view. Recently, it has been argued that also manufacturing technologies depend, for their success, on solving design problems anew for the concrete "application" in each individual firm (Prakke 1986). In fact, each of these "applications" can be termed an innovation. More generally, one can note that assemblage in concrete situations will raise its own problems of design, and that the 'solution concepts' emerging in this way may find wider application, and may feedback into the design processes of the firms producing the component technologies. Such processes have been documented already for scientific instruments and medical technology (see e.g. Blume and Finkelstein 1985) and may become increasingly important in information technologies and automation.

Another limitation of a focus on firm is the neglect of horizontal interactions, especially those at the level of the technical practitioners. In principle, Nelson and Winter's (1977) evolutionary model of technological change takes such interactions into account, although the sociological aspects often remain implicit. The basic concept is that of 'technological routine' and learning processes to produce such routines, which will themselves be guided by 'search routines' or 'heuristics'.

"It may be that there are certain powerful intra project heuristics that apply when a technology is advanced in a certain direction, and pay-offs from advancing in that direction that exist under a wide range of demand conditions. We call these directions 'natural trajectories'. If natural trajectories exist, following these may be a good strategy. (...)

(... these trajectories are not determined by technology as such, but are couled to 'technicians' beliefs about what is feasible or at least worth attempting'. When such beliefs and corresponding design and development practices are entrenched, one can speak of a 'technological regime' determining technological decisions. As Example:)

... the advent of the DC3 aircraft in the 1930's defined a particular technological regime: metal skin, low wing, piston powered planes. Engineers had some strong notions regarding the potential of this regime. For more than two decades innovation in aircraft design essentially involved better exploitation of this potential; improving the engines, enlarging the planes, making them more efficient." (Nelson and Winter 1977, p. 56, 57)

From these quotations it is clear that there are similarities to Abernathy at al.'s concept of 'design hierarchy'. A technological regime, however, is carried by practitioners and can extend across a sector of industry. In addition, it is important to retain the notions of heuristics, beliefs about their success, and the way such beliefs are maintained by individuals and groups within and across organisations. These aspects are captured by speaking of a 'technological paradigm', in the sense that Kuhn used the

concept in his postscript (Kuhn 1970): the combination of an 'exemplar' (an exemplary achievement that is further articulated) and a 'disciplinary matrix'. Dosi (1982) uses the same terminology, but does not fully exploit the analogy.

In our own work on technological development (Van den Belt and Rip 1984, 1987), we emphasize that in those cases where technological developments shows such focusing or regimentation, one should speak of a technological paradigm as the combination of (a) a set of heuristics clustered around an "exemplar" or a "dominant design" (compare Nelson and Winter's example of the DC-3 airplane), and forming the cognitive backbone of the trajectory; and (b) a (sub)cultural matrix of expectations about the success of the exemplar and its heuristics. In our case study of synthetic dye chemistry in the 19th century, both components can be traced in the emergence and stabilization of technological trajectories. The (sub)cultural matrix of expectations is carried by technical communities, but also (at least in this century) by organisations or groups in organisations (eg. R&D management, production engineers, board of directors). Through these actors, the content of the (sub)cultural matrix can be influenced, and thus the choice and shape of heuristics. Sometimes, the environment of the organisation provides incentives (e.g. when production processes of anilin red were changed to avoid the use of arsenic). In other cases, the internally held expectations about a (potential) technology are maintained in the face of frustrations and an unresponsive environment (e.g. when Philips Company continued their development of the Stirling motor between the 1940s and the 1970s).

Nelson and Winter (1977, 1982) introduced technological trajectories as part of an evolutionary theory of technological change, in which selection environments (markets as well as other environments, e.g. government institutions and regulations) weed out all those "technological variations" that cannot survive. (The circularity in such statements should be noted.) Nelson and Winter argue that "selection works on what exists, not on the full set of what is feasible" (1982, p. 142), and what exists in their model are the 'routines' or heuristics of firms (e.g. innovation strategies) and of technical practitioners, as well the products of following such routines. The important point of an evolutionary model is that "there is no choice that is clearly best ex ante" (1982, p. 276): the success of the heuristic has to be won against the selection environment.

Although the evolutionary approach has clear advantages, the further elaboration of the sociological aspects indicates that independency of trajectories and selection environments should be seen as a particular case, not as a general feature. The case study of synthetic dye chemistry showed that the distinction between selection environment and technological trajectory may become blurred, when the heuristic (or the technological development in general) incorporate features of the environment. This can occur at the level of heuristics, e.g. when the search for new azo-dyestuffs is guided by heuristics about ease of handling during the dying process. There is also "internalisation" of the selection environment: dyestuff companies establish application laboratories, where they test new colouring materials. This work may become so important, that the roles are reversed, and the dyeing and textile companies come to depend on the dyestuff producer for instructions how to use the new dyestuffs. Formulated in abstract terms: the trajectory may influence the selection environment to increase its own chances of survival - but only by incorporating enough of the needs and requirements of this selection environment.

The point of this argument for CTA is twofold. First, technological development is not a purely Darwinian evolution of random mutations and blind selection of the "fittest". That is the way that Nelson and Winter (1982) have modeled, and economists in general tend to model technological change: an independent market selects and market growth of a technology, or of the firms using it, is the indicator of success. But actors try to anticipate potential selection effects, and to avoid, or at least counteract them. This may extend to the inclusion of further criteria (of safety, environmental viability, humaneness) into the design and development of technologies. Economic-strategic arguments alone will make at least some actors adopt such a strategy: it is recognized that product life cycles are often shorter than is necessary, because secondary negative impacts (becoming visible after the first growth phase) appear and lead to public criticism and government regulation. To avoid such losses, companies will anticipate such selections for economic reasons alone, and attempt to design safer, cleaner, and more humane technologies - especially if they can put these attempts to publicity use. (After determined resistance of automobile companies and organisations against measures to reduce emissions contributing to the acid rain/deposition problem, there recently appeared advertisements of Opel in the Dutch newspapers, presenting their cars as being environmentally friendly because they could easily run on lead-free

patrol, and stating that it was a good thing that the government had taken measures against acid rain.)

Second, although actors will try to influence the (selection) environment to protect their own interests, they can do so only by some accomodation to the demands of this environment, whether passively or in an attempt to exploit a strategical advantage (as in the example of the Opel advertisement). Thus, changes in the selection environment, e.g. through government measures, will have some effect on technological development. Because of the limited power of governments and strategical reactions from the actors, however, one can never expect full goal attainment. The example of enforcement deficits in environmental regulation is a telling one in this respect.

Technological development offers possibilities for external influence. So, for a government to propagate CTA is not futile. But it is necessary to consider the actual positions of actors (including the government itself) and the strategic games that can be played in order to turn the possibilities into reality.

3. The gap between decision practices and technology-development practices

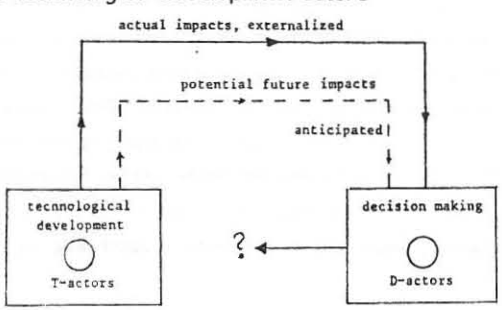
The sociological elaboration of Nelson and Winter's model of technological development requires one to specify the relevant actors (often corporate actors like industrial organisations) as well as their strategies, and provides a framework to trace their role in and effect on technological development. Such a perspective is a necessary addition to economic modeling, but also to traditional technology assessment.

In economic modeling, the focus is on the aggregated outcomes of actor strategies: the functioning of the market. Perhaps with some imperfections or some government intervention, but little or no attention to the emergence and maintenance of such an aggregate system from interdependent actor strategies. As the quotes from Abernathy et al. (1983) in the preceding section show, the problem of the emergence of a market is now recognized. Understanding of the historically contingent nature will in addition allow a better treatment of technological linkages across sectors. There has been analysis of such linkages in terms of filières (Dosi 1983, p. 95, and references given there), and some economists now speak of 'technological web' (Roobeek 1985). Such linkages or webs make sectorial input-output analysis of very limited value. A full treatment of this point will show that such technological webs, and their concrete embedding in industrial and social structures, is a form of development in its own right, in which trajectories could be found occasionally. Input-output structures between sectors then appear as the results of such developments, not as a way to trace them.

Traditional technology assessment has followed a problem definition in which it remained external to the actors involved in technological development. Future impacts of technology were estimated by research firms (like MITRE), reported to US Congress or some other government body, and some decision making would hopefully take place. Because of such an institutional (and often also cultural) separation between technological-development practices and decision-making practices, feedback of TA results becomes difficult, and in any case limited to the aggregate level of an industrial sector for which some regulation is devised.

The gap between the two kinds of practices is visualized in figure 1. For the specific issue of technology assessment, there is the additional problem that many of the negative impacts to be avoided are secondary effects, that remain external to the firm that develops and/or produces the technology, and so their burden can be shifted off to generalized decision-making practices (politics). Note that an institutional gap between the two kinds of practices need not imply a cultural gap. For example, the promotion of commercial nuclear energy was a goal shared by industry, utilities, and US Congress alike in the 1950s and 1960s. The potential negative impacts, as estimated in the risk analysis of the time, were considered avoidable by all actors, and decisions of Congress went in the same direction as the work of the developers of nuclear technology. Further elaboration of the example would show both that such a 'joint game' can be important for the transfer between T- and D-practices, and that it may be important to have some separation to allow independent evaluation.

Figure 1: The two externalities of present technological development: impacts remain external costs, decisions to reduce or avoid them remain external to the technologica-development actors



It is instructive to consider cases where there is no, or much less of a gap between decision-making practices and technology-development practices. When profitability and other investment criteria for a new technology or product are assessed in an industrial corporation, there are functional links with decision making, as well as with the technology developers. (This is not to say that there are no problems: the extensive literature on innovation and barriers to innovation has shown that there are many intra-organisational problems to be overcome.) Actually, this type of assessment ("Picking the winners") is thought of as technology assessment by many industrialists.

Recently, it has become customary, at least with big firms, to pay some attention to environmental aspects at an early stage of development (to select out the more troublesome technologies and/or to introduce them as design criteria - e.g. in re-thinking a process in order to have more recycling of wastes, by-products, water, and heat). Again, T-practices (to introduce a handy abbreviation) are linked to D-practices within one organisation. Such a broadening of the scope of T-D-practices in a corporation may well go further and include more aspects than environmental impacts and compliance to environmental regulation. And governments wanting to spread the technology assessment philosophy could attempt to do so through incentives to broaden internal T-D-practices.

The challenge of CTA must thus be addressed at several levels. The final goal of having "better" technologies must be reached by changing the relevant practices. Broader criteria have to be introduced, either directly within relevant organisations (at the T or the D side), or indirectly, in external D-practices, provided the gap with respect to the T-practices can be bridged.

4. How can CTA be stimulated?

From the discussion in the previous section, a number of possibilities for government stimulation of CTA can be derived already. Combination with the analysis of section 2 makes a systematic approach possible. An important condition for successful stimulation of CTA is understanding of the processes and their dynamics, both of the technologies and of the actors and their strategic games.

Understanding is required of three kinds: insight in future impacts; knowledge of the specific socio-institutional and technical dynamics of the technological developments at issue; some idea of the dynamics of behaviour and interaction of the relevant actors (the "games" they play). The last requirement can be illustrated for the case of safety and environmental risks and the response of corporations to them. When there is explicit regulation, standard setting and/or inspection, there may well be an enforcement deficit: not (only) because firms find non-compliance or limited compliance profitable, but also because of the interactions between them and enforcement agents, in which both parties accommodate a bit in order to continue to play a joint "game" (Rip 1983, see also downing and Hand 1984). There are other factors influencing actors' strategies; in the chemical industry for instance, credibility pressures and, in a very different way, insurance companies (who sometimes refuse to insure) shift the behaviour of the firm to anticipate and avoid possible negative impacts of its production process and products. In addition, there are internal pressures, especially from staff groups (like environmental and safety staff) that are professionalizing and claim a certain responsibility for such issues (Rip 1986a). At the level of corporate actors, processes can be traced. It is not a priori certain that a full analysis at the societal level is possible, or that governments can obtain (and usefully apply) enough understanding.

Stimulation of CTA (or further improvement of existing CTA) implies that practices have to be changed. Thus, knowledge about potential future impacts of ongoing or planned developments, however necessary, is not enough to reach the goal of CTA (Cassandra's fate has become proverbial). Formulated in economic terms: the preference functions of the actors have to be changed, or the balance of their cost-benefit equations. (It may be necessary to add sociological and psychological categories, but the economic terminology is sufficient to make the point.)

A change in the cost-benefit equation can be produced by introducing sanctions (and perhaps rewards) externally, regulation and its enforcement being the traditional one, with taxes taking second place (a more flexible instrument, but less visibly asuring the avoidance of undesired impacts - cf. the unacceptability of counteracting murder by putting a tax on it). Apart from the problems of enforcement deficits and the present trend toward deregulation, the approach of regulation and/or selective taxation is less effective in the case of CTA because not the actual impacts, but the potential future impacts have to be regulated. The uncertainties inherent in estimating future impacts imply that some way of modifying sanctions/rewards in the light of accumulating experience has to be found. (An example would be the way the risks of recombinant-DNA research have

been addressed.) Such a learning strategy, however, requires some cooperation from the actors. Thus, one might consider the possibilities of more decentralized and more open measures.

A change in preference functions of actors implies that the actors will work toward the desired goals by themselves, provided their preferences are now of the "right" kind. Thus, government incentives could be provided that would enhance the effects of credibility pressures on firms, or support the attempts of professional staff to be less dominated by short-term profit orientations of other groups within the firm. Again, there is the obvious problem of what would constitute the "right" kind of preference. When there is enough dissatisfaction with present practices (of technological development and decision making), it is easy to specify the direction towards which the preferences should change (e.g. humane, socially viable technologies, less ecological disruption, etc.). The difficulties arise as soon as it has to be decided whether enough humaneness, social viability, and environmental friendliness has been achieved. One could argue, however, that this is not a matter of providing some "absolute" answer beforehand, but a learning process in which all actors, including the government wanting to stimulate CTA, participate. This perspective allows the recognition of further types of incentives, for instance public display of good examples of CTA, rewards for firms that can be considered to pioneer CTA, etc. Accepting the broader, more decentralized perspective also allows the recognition of the role of third parties: insurance companies have been mentioned already in the example of corporate response to risk issues, professional societies are another example (compare the issue of whistle-blowing, where dissenting professionals now sometimes get external protection if their action is in the public interest - an example of the expanding literature on this issue is Weil 1983).

Two final remarks. First, the above considerations do not specify concrete measures. They indicate certain categories of government action and initiatives, and indicate some of the conditions of effectiveness. Second, the problem of producing reliable estimates of future impacts at an early stage of technological development has not been solved. Thus, the control dilemma cannot be resolved. Technological development and diffusion has, however, been painted as a process that gets entrenched. CTA envisages to modulate such processes, and it is more important to improve learning and feedback processes than have fully valid information about future impacts - which may in fact become invalid because of the activities of the actors (including CTA).

Instead of a control dilemma derived from an information problem, there now appears a control dilemma based on a participation problem. Outside pressure or intervention is necessary to shift actors from original strategies potentially disadvantageous to society. Participation in technology development processes is important to broaden criteria that are taken into account, to open up search and learning processes. But too much pressure, too much participation, will make T-actors retract to their strongholds - which will be quite powerful in many cases. The give and take of such processes cannot be analysed in a general way. History shows that they do occur, and that one need not be completely pessimistic about improvements. Moderate pessimism might be the motto for constructive technology assessment.

Notes

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TECHNIKBEWERTUNG UND TECHNISCHE ENTWICKLUNG

Der Begriff Technikbewertung, lose aus dem englischen Technology Assessment übersetzt, wurde in den USA geprägt und entspricht - zumindest in seiner ursprünglichen Bedeutung - amerikanischen Bedürfnissen. Technikbewertung entstand aus der Erkenntnis, daß nicht alle Technik für die Gesellschaft wertvoll ist. Gegen Ende der 60er Jahre wurden viele Stimmen laut, die vor den Gefahren des unbedachten und ungebremsten technischen Fortschritts warnten. Insbesondere der Raubbau an den nicht unerschöpflichen Rohstoff- und Energiereserven und die überhandnehmende Verschmutzung und Vergiftung der Umwelt gaben Anlaß zur Besorgnis. Das US-Parlament sah aber noch ganz andere Gründe für die Bewertung der Technik. Der Technikgehalt der Gesetzesentwürfe und die Kosten der staatlichen Technikförderung stiegen stetig an, während das technische Wissen des durchschnittlichen Abgeordneten immer gleich niedrig blieb. Die Abgeordneten suchten einen Ausweg aus der Wirrnis; einen Ausweg zu dem ihnen Expertengutachten nicht verhelfen konnten. Denn jeder Experte sieht das Problem aus seiner eigenen Sicht und manchmal widersprechen einander sogar Experten aus dem gleichen Fach. Wie soll also ein Politiker aus einzelnen Fachgutachten schließen können, ob ein Vorhaben gut oder schlecht für Amerika ist, ob es sein Geld wert ist oder nicht und ob vorhaben A wichtiger als Vorhaben B ist? Mit anderen Worten, wie soll der Politiker Technologiepolitik betreiben - also Prioritäten setzen und Regelungen treffen - ohne einen wahren Überblick über ein technisches Problem zu haben, geschweige denn über die Entwicklung der Technik im allgemeinen.

Die öffentliche Hand war berufen, die Technik zu regulieren, um sie möglichst umweltschonend und menschengerecht zu gestalten. Sie war aber auch berufen, tief in die öffentliche Tasche zu greifen, um die technische Innovation zu fördern und damit die wirtschaftliche und militärische Macht des Landes zu erhöhen. Doch das öffentliche Auge sah nicht deutlich, worum es bei der Technik ging. Um Technologiepolitik zu gestalten, muß erst das notwendige analytische Wissen geschaffen werden. Die Technikbewertung versucht, die Folgen einer Technik schon während der Einführungsphase vorausschauend und umfassend abzuschätzen. Die Analyse