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Traditional and modern Technology Assessment. Towards a toolkit.

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Abstract

Technology Assessment (TA) as a discipline includes rather different approaches and methods. Traditionally, the discipline focused on forecasting, impact assessment and policy studies. Later more process oriented approaches were developed, such as Constructive Technology Assessment (CTA), which aimed explicitly at influencing the shape of new technologies. Although the new approaches have surely enriched the field of Technology Assessment, the scope and variety of the field has increased, particularly concerning its methods. These range from trend extrapolation and delphi's to interventions in innovation networks and consensus conferences.
This paper aims at classifying the approaches and methods of TA into a common framework. Distinctions are made between methods of analysis and intervention methods, and between methods functioning as project lay-out and mere tools. Moreover, some criteria are formulated for the choice of methods. In this way, the paper attempts to increase the coherence of the field of Technology Assessment, and to make it more transparent to non-practitioners such as scientists and engineers, government employees and members of civil movements.

Introduction

In the past decades Technology Assessment has become a broad field of activities, including studies about, and interventions in the development of technology and its social aspects. Most famous are the studies of the US Congress Office of Technology Assessment. The 1994 elections created a Republican majority in US Congress. Unfortunately, the Republicans decided to show their determination in keeping their "Contract with America" by cutting their own Congress services budget. As a result, OTA was abolished (Coates, 1995, Kunkle, 1995). However, this certainly is not the end of technology assessment. On the contrary, various TA institutions have been founded all over the world[2] and the ITA in Washington is

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[2] Some parliamentary TA organizations are: POST (UK), Rathenau Institute (Netherlands), TAB (Germany), Opecst

trying to keep the OTA spirit alive in the USA[3]. There are even activities in research organizations and strategic departments of corporations that could be seen as technology assessment. Moreover, various new and creative approaches have been developed to further democratic decision making on technology.

Recently, so called Constructive Technology Assessment initiatives belong to the field (Rip et al., 1995, Schot, 1992). Although objects and aims of the activities vary, they have in common that they concern current and future developments of technology, and that they aim at improving the alignment between technological and societal developments, whereby societal developments include the activities of corporations.

The methods applied in the field of Technology Assessment are as diverse as the field itself. They range from forecasting studies to interventions in stakeholders networks. This paper attempts to bring some order in this diversity. This may be useful for experienced practitioners of TA, but even more for new entrants and for educational purposes. The ultimate aim is to develop a methodology of Technology Assessment, specifying in which cases which methods are most appropriate. However, a necessary first step, taking the larger part of this paper, is to classify different methods according to the character and scope.

Approaches

The origins of the field can be traced back to **technology forecasting** studies in the nineteen-fifties. These studies attempted to forecast technological trends 'as such'. The studies were basically intended to help large corporations and government agencies to adjust their technological investment schemes. Large think tanks, like RAND and HUDSON, made many technological forecasts.

In the same period, public interest in the negative effects of technology grew. Sometimes these effects only appeared long time after the introduction of technology. These negative effects were often unintended and unforseen. A new kind of studies was developed in the U.S. to assess all of the effects of technologies that were still to come. These studies were called **Technology Assessment**. Various definitions were given, which differed especially on the question whether TA should be a neutral, fact-finding activity, or whether it should take a normative stand itself by assessing the contribution of new technologies to 'the public good'. Examples of definitions are:

- Technology assessment is *"a class of policy studies which systematically examine the effects on society that may occur when a technology is introduced, extended or modified. It emphasizes those consequences that are unintended, indirect or delayed."* (Joseph F. Coates, cited in: Porter et al., 1980.)
- *"Technology assessment is an attempt to establish an early warning system to detect, control, and direct technological changes and developments so as to maximize the public good while minimizing the public risks"* (Cetron/Connor, 1972).

This kind of TA was later called **Awareness TA** or Early Warning TA. The studies attempted to forecast societal effects of technological change in order to include these effects in societal decision making, or to be more precise, to create the possibility to make this subject to

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societal decision making.

In 1972 the US Congress created the **Office of Technology Assessment (OTA)**. Emilio Daddario, who introduced the bill for the foundation of the OTA, defined TA in part as a **policy instrument**:

> *"Technology Assessment is a form of policy research which provides a balanced appraisal to the policy maker. Ideally, it is a system to ask the right questions and obtain correct and timely answers. It identifies policy issues, assesses the impact of alternative courses of action and presents findings. It is a method of analysis that systematically appraises the nature, significance, status, and merit of a technological program."*(US Congress, 1968)

The main function of these forms of, what is now called **'traditional TA'** has been promoting **'awareness' of future technological developments and societal impacts, and the development of policy options**. A wide scope of aspects of technologies may be involved, pertaining to different disciplines such as risk and safety analyses, economic and environmental impact assessments, labour impacts, etc. It is not the task of Technology Assessment to perform all these studies, but to integrate different types of impact assessments. This is of course a highly subjective and normative task. A solution may be to do the integration in different ways, taking different value systems as a basis. The OTA has often taken this 'neutral' approach, developing different policy options based on different value systems (for instance aimed at more government intervention or more market oriented) (OTA, 1993).

In the 1970s and 1980s, the basic presupposition of Technology Assessment, i.e. that it is possible to predict the course of development of a technology and *all* of its societal effects, became more-and-more problematic. Many important developments, such as for example the oil crises, were not only unforseen, but made lots of assessments (which were often hardly recognized as being related to the energy field) completely worthless. As a consequence, more focused objectives were formulated for TA. Choices had to be made concerning the effects that were considered most relevant in a specific case. Consequently, TA became more a strategic tool rather than a neutral and objective input in the decision making process. TA studies now often aimed at strengthening the position of specific actors in a complex process of socio-technical decision making. The output of this new form of TA not only entailed a report, but also a discussion with relevant actors. Moreover, expectations as to the results were more moderate and the claim of objectivity was dropped. Smits and Leyten (1991) defined this **'new-style TA'**, as they called it, as:

> *"TA is a process consisting of analyses of technological developments and their consequences as well as a debate on the bases of these analyses. TA should provide information that could help the actors involved in developing their strategies and that might define subjects for further TA analysis"*[4].

One of the approaches of new-style TA was **Strategic TA**. Strategic TA involved studies and activities to support a specific actor or a specific group of actors in the development of their technology policy or technology strategy. Mainly research institutes could perform this type of consultive TA. In fact, also many activities of the governmental TA institutes mentioned above can be considered Strategic TA, since they aim at supporting the parliament or government in developing a technology policy.

Another example of the new-style TA is the **Constructive Technology Assessment**

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[4] Translated from Dutch by the authors. The Dutch quote reads: "TA is een proces bestaande uit analyses van technologische ontwikkelingen en hun consequenties en discussie naar aanleiding van deze analyses. TA heeft tot doel informatie te leveren, die bij technologische ontwikkelingen betrokkenen helpt bij de bepaling van hun strategisch beleid en met behulp waarvan het mogelijk is onderwerpen voor verder TA onderzoek te definiren."

(CTA) approach. CTA has its origins in modern approaches in the field of Science and Technology Studies, which entail that technological development is heavily influenced by societal processes. As a consequence, the practitioners of this approach, which are mainly public and academic research institutes, explicitly aim at shaping the course of technological development into socially desirable directions. CTA can be defined as: broadening the decision making process about technological innovation by including as many relevant societal actors as possible, aiming at an optimal alignment between technological and societal developments. Whereas traditional TA was mainly directed at government interference to enforce specific solutions for government defined problems, CTA tried to influence strategies of different actors involved in order to have them develop common perceptions of a specific problem and develop and adopt joint strategies for solutions.

Recently a new type of activity has emerged that can also be considered a type of TA: **Backcasting**. Backcasting is a form of normative forecasting, in the sense that a normatively necessary scenario of the future is constructed (in German: 'Ziel-scenario'). An example is the Dutch STD (Sustainable Technological Development) government research program, in which scenarios are constructed of a sustainable society on a global level on a time span of 50 years. The boundary conditions are: not exceed the ecocapacity of the earth; no diminution of welfare in the north; equity between north and south. Combined these conditions require a factor of 20 eco-efficiency increase of technology and/or human activities. Based on these scenarios a number of technological options are generated. Research is stimulated or started to develop these options. Backcasting thus provides a starting point for incremental actions in the present in the direction of the desired situation. The effects of these actions have to be fed back into the future picture (Robinson, 1988).

We may conclude that the field of TA is diverse, but that a common aim exists, which is to contribute to an optimal alignment between technological and societal developments. Both studies and interventions are part of TA. Four main types of TA can be distinguished:

- Awareness TA: forecasting technological developments and their impacts, to warn for unintended or undesirable consequences.
- Strategic TA: supporting specific actors or groups of actors in formulating their policy or strategy with respect to a specific technological development.
- Constructive TA: broadening the decision process about technological development, to shape the course of technological development in socially desirable directions.
- Backcasting: developing scenarios of desirable futures and starting innovation processes based on these scenarios.

Methods

The methods that are applied in TA are possibly even more diverse as the approaches mentioned above. Types of forecasting, impact identification and assessment, social science methods, interviewing and workshops are used as methods of analysis. In what follows, we attempt to systemize these methods into a common framework.

A first observation is that in different types of TA different types of methods are used. Three types of methods can be distinguished:

A. **Methods of analysis**, which are used to analyze a specific aspect related to a TA problem. These methods include forecasting, construction of scenarios, analyses of technological options, definition and analysis of impacts (such as life cycle analyses),

market studies, policy studies, etc. Part of them are text book methods (Porter et al. 1980, Porter et al., 1991). Such methods are used in the abovementioned studies, but can also support the decision process in more process oriented types of TA.

B. **Intervention methods**, which serve as heuristic for interfering in the decision process on technology development (for example methods for interventions in innovation networks). These methods are exclusively used in process oriented types of TA.

C. Methods used in **'reflective studies'**. Such studies concern the organization of the decision and development process itself. They focus on the optimal way to integrate societal influences in the development process and on ways to promote the development and implementation of technologies that respond better to societal desires than existing technologies. Moreover studies on TA theories and methods, such as the work that has resulted in this paper, belong to this type of studies. These studies are of a general socio-economic type, and have no particular repertoire of methods. Literature surveys, interviews and workshops are often used. However, many of the above mentioned intervention methods have resulted from these studies.

In what follows we restrict ourselves to the types of methods A and B. Thereby we have to note that the distinction between the two, methods of analysis and intervention methods, is not strict. For instance, the development of a scenario (a method of analysis) is a social process that may have an influence on its own. The same counts for backcasting activities; although the primary aim is to develop a view on the future, it may provoke important social processes. Reflective CTA studies even may purposely attempt to influence the decision process by means of specific methods of analysis. For instance, interviewing R&D managers may not only result in useful information for the CTA-analyst, but may also create new ideas with the manager. This counts even more for workshops. So, the analysis in a certain way may contribute to the dynamics of the problem.

	Method of Analysis	Intervention Method
ATA	+	-
STA	+	+
CTA	+	+
Backcasting	+	-

Figure 1. The use of different types of methods in different types of TA.

A second distinction concerns the scope of methods:

1. Methods that serve as **project lay-out**. These methods aim at integrating different perspectives of the subject of study or of the decision process to be addressed. They

mostly entail a complex set of actions to be performed.

2. Methods that serve as **tools**, mostly as parts of larger projects. These methods are generally well-described and can be executed in a relatively straightforward manner.

Most tools can be used within different approaches of Technology Assessment. As we will see, for some project lay-outs this is also the case. Others are only appropriate for a specific approach of Technology Assessment.

Based on these categories we have four types of methods:

- Lay-out of studies
- Lay-out of interventions
- Tools for analysis
- Intervention tools.

In what follows we give examples of each of them.

Type Scope	Method of Analysis	Intervention Method
Project Lay-out	Lay-out of Study	Lay-out of Interventions
Tools	Tools for Analysis	Intervention Tools

Figure 2. Types of methods

Lay-out of study

As has been said, methods of analysis are applied in all types of TA. The following examples of such methods can be given:

- **Technological forecasting**.
  Technological forecasting aims at developing pictures of the future development of technology. Sometimes, particularly in ATA, these pictures are considered as predictions of future technologies. In CTA, forecasts are carried out too, but then they are generally considered more as probable futures (under 'business as usual' conditions) or technological options (as specific conditions change). The realization of these futures is considered to depend on actions of different parties involved. Technological forecasts, particularly if conceived in the strict predictive sense, have considerable limitations (Schnaars, 1989). Firstly, there is the problem of predicting technology itself. It appears to be especially difficult to predict whether a technology will actually take off. For example, Harold Dewhurst, the man that introduced the concept of product life cycles, used this concept to predict that glass fiber would replace synthetic fibers as a reinforcing material in tires (Dewhurst, 1970). However, glass fibers never caught on as tire cords (French, 1991). Secondly, societal

development is often hard to forecast. For instance the oil crisis (1973) was only expected by very few people. By the oil crisis, many forecasts could be used as fuel for heating. A third limitation is the unpredictable types of use of new technologies. There are many examples of technologies which became popular for another purpose than expected. For instance, the telephone was introduced for business purposes. After some time it became especially important in social communication.

- **Impact assessment**.
  Very elaborate impact assessment methods are scarce in the field of TA. Within this field, impact assessment has often had the character of impact identification, based on expert interviews, brain storms and common sense. The proper analysis of impacts has been left to experts in the specific fields. The evaluation of impacts again is often the task of the Technology Assessor (Porter et al., 1991, p. 289-302).
- **Scenario analysis.**
  Scenarios may be used to describe possible future states of society, including technological developments (for general description see Godet, 1987). Two types can be distinguished:
  - scenarios which concern an organization or specific problem, and in which the environment of the organization or problem is modified; These types of scenarios are especially used in corporate planning (Amara/Lipinski, 1983, Ralph McNulty, 1977)
  - scenarios which concern the society as a whole or larger parts of it. These types of scenario's are especially used for 'public' TA (Cf. Andersen et al., 1992)

  Scenarios often aim at stimulating discussions which may support or end in specific interventions. Oil company Shell has especially become well known for its successful use of scenarios (Beck, 1983, Wack, 1985)

Lay-out of interventions

Lay-outs of interventions are mainly used in CTA. The following examples can be mentioned:

- **Intervention in innovation networks**
  Analysis and adapting technology networks. The network of actors involved in some way or another is assumed to constitute the course of technological development, including its direction (Håkansson, 1989, Håkansson, 1987, Mulder, 1992, Shrum, 1985). Adaptations of the network can modify this course into socially desired directions. An example of an intervention is organizing interfaces between research departments and other actors, particularly those representing societal interests. Governments might evaluate the networks in which government sponsored R&D takes place, and manipulate them (Callon et al., 1992). R&D Companies might stimulate network formation for better corporate performance (Charan, 1991).
- **Connecting separated networks**.
  This is in fact a specific example of an intervention in innovation networks. The approach is developed in the study Environmental Design by Cooperation) of the Dutch Technology Assessment Institute (Rathenau Institute), conducted around 1990 (Den Hond et al., 1992). The study concerned recycling of cars. An analysis showed that two networks of actors could be distinguished in the life cycle of a car: the design and reprocessing context. In the design context the main heuristics (search direction in

accomplishing changes) were: diminishing weight of cars by new materials, increasing safety, styling and reduction of corrosion. In the reprocessing context the recycling of parts and materials and the reduction of non-reprocessable litter were the main objectives. These different heuristics were quite contrary: the use of new materials hindered effective recycling. Starting communication between the actors from the different contexts, and adapting the design process contributed to a solution.
The well-known PRISMA project of the same institute, aimed at reducing waste is another example network manipulation. It aimed at connecting separated networks (government agencies and companies or company departments) (Crul, 1994).

- **Demand articulation**.
  The term 'demand articulation' is used in different ways in the field of Technology Assessment. When Smits and Leyten (1991) speak of 'demand articulation, they seem to indicate to adaptations in the socio-institutional system, necessary for the development and adoption of a new technology. More recently, the same term is used to indicate processes to make manifest certain latent societal demands for new technology. One way to do that is to offer a technology that meets this demand. Latent demands often seem to exist for more environmentally friendly products and services. People do not ask for a 'sustainable transportation service'. They ask for a car and, if asked, they are probably in favour of environmental protection. The importance of the articulation of demand for technology development is, that demand directs the innovation process and thus the technological development. The appearance of a certain product or service on the market quite often stimulates the demand (walkman, call-a-car, greenfreeze). So a possible strategy for demand articulation is starting up an iterative process between producers, consumers, and knowledge institutions, in which the demand is iteratively better articulated. In order to set up such a process a careful stakeholder analysis has to be carried out in order to find out what the goals and interests of the involved stakeholders are.

- **Consumer CTA**
  In this method developers of a new technology, consumers and other relevant actors are brought together in several stages of the development process to discuss future applications and consumer aspects. Images of future use of a technology are developed and adapted during the process (Fonk, 1994). An example of practical cCTA is the STD project "sustainable washing" (Vergragt/Jansen, 1993). In this project producers, consumers, experts on washing, washing machines, and textiles have been brought together to discuss images of future washing. These images were further refined and public reaction was tested in a large survey. The results of this analysis will perhaps lead to further social experiments with 'collective washing' (Vergragt et al., 1995).
- **Participatory Technology Assessment**.
  The aim of Participatory TA is to include interested actors in an innovation process, mostly by discussion meetings or workshops (Cf. Engel, 1995). An example of such an approach is the so-called 'Infra-lab' of Rijkswaterstaat (the Netherlands's National Public Works Administration) in developing adaptations to the road infrastructure. Car drivers, neighbours of the project to be accomplished, the local police and environmental organizations were invited to discuss the problems and possible solutions. Sometimes other solutions are chosen than expected or new, creative solutions come up (Vergragt/De Rooy, 1995). A large example of Participatory TA has been carried out in Germany on genetically engineered herbicide resistant crop

plants. In this example specific research projects were defined in the course of the discussions. In the end the environmental movement stepped out, which made the project fail largely.

- **Citizens' initiatives**

  Citizens' initiatives concern activities of citizens groups or entrepreneurs to develop new technologies. Examples in the field of sustainable technologies are:
  - citizens developing windmills
  - the German department of Greenpeace developing the Greenfreeze refrigerator (based on propane and butane instead of CFCs and HCFCs).
  - the Belgian firm Ecover developing environment friendly detergents.

  In a recent project the problem was studied under what conditions new technologies developed in such experiments get a wider diffusion (Verheul/Vergragt, 1995). Stimulating or facilitating citizens initiatives and their diffusion might be an interesting method to achieve technological changes.

- **Strategic niche management**

  The concept of 'strategic niche management is used for organizing a protected space for a new product or technology (Rip, 1989). The aim is to organize learning processes, which may stimulate the further improvement and adoption of the technology. The theoretical background of this method is the finding that technologies get their meaning during their actual adoption and application. Moreover in that phase scale effects and learning processes take place which result in performance improvements or price reductions. An example of strategic niche management are experiments with electric cars in the US and the Netherlands (Cf. Schot et al, 1994).

Tools for analysis

- **Trend extrapolation.**

  A well known and generally used model as a foundation of these forecasts is the 'product life cycle'. This model supposes that products had a 'life', i.e. they were created, grew, flourished, and eventually became obsolete and were replaced by new products. The model can be used to forecast the diffusion of a product (Cf. Porter et al., 1991). Sometimes purely technical aspects of a technology are forecasted, like the well known example of Moore's Law, predicting the development of the number of components on integrated circuits.

  A limitation is that trend extrapolation can only be performed when a new technology is already some time on its way. The longer the technology already exists, the better the forecast generally will be. If a technology is still in its infancy, analogy reasoning could be applied (relating the diffusion of a new technology to the known diffusion pattern of an already mature technology). However, analogy reasoning is highly speculative (van Doorn/van Vught, 1978).

- **Structured Interaction**.

  Getting the opinions of experts or relevant actors is often very important. However, it is often important structure interactions with actors, and their mutual interactions. Brainstorming has been a very popular method to generate new ideas. Whether this method really produces new ideas is rather questionable. Robert Jungk (1981) promoted a variant of brainstorming, i.e. future workshops, which were intended as being less expert oriented and more democratic.

  Nowadays various techniques are available to support the basic idea of brainstorming:

for example a group decision room is a computer supported brainstorming technique. Participants react to anonymous comments of other participants about a specific problem. In the end the comments may be ranked according to relevance.

- **Delphi.** The Delphi method can be seen as an example of structured interaction. The method is generally used to forecast future technological developments. It tries to create consensus between experts on future developments. The method includes interviewing of, and anonymously exchanging answers between experts. In this way an attempt is made to make an estimate of future developments without any interference of the social relations that exist between these experts. Based on the results of a Delphi, scenarios of future situations may be developed. Delphis may also be used for less strictly forecasting purposes, for instance to explore options for future developments, the materialization of which still depend on specific actions of actors involved (Helmer/Gordon, 1964, Linstone/Ruroff, 1975).
  A limitation of the application of this method is that interviewing experts by a Delphi or otherwise generally produces biased results. On the short time (5-10 years) experts (who often also have an interest in promising fast technological development in their field) tend to be too optimistic about technological possibilities. On the longer term (20-50 years) however, they tend to be too pessimistic (Schnaars, 1989).
- **Cross-impact analyses**, are sometimes used as a variation of Delphi. The basic adaption is caused by the fact that the chance that an event might actually occur, is conditional to other events. In cross-impact analyses, expert fill out matrices on the chances that an event will occur, given that an other event will (not) occur. These matrices can be manipulated mathematically in order to calculate the likeliness of series of events (Gordon/Hayward, 1968). Kane simulation is an even more refined form of cross impact analyses. It is based on the assumption that cause-effect relations take time. The delay can be brought into the matrix by which a dynamic prediction of the occurrence of certain events can be developed (Kane, 1972).
- **Social simulations**. In a social simulation, the real world is simulated by living people. Generally, only organizational structures are given, and the players of the simulation start their own 'world'. The social patterns that develop could be seen as the outcome of the experiment, and these patterns could be related to the given organizational structures (Van der Meer 1986, Boskma, 1986). The number of technologies that are suitable to study in such an experiment is limited.
- **Checklists**
  Checklist are a practical tool in order not to forget specific aspects in a TA study. There is an enormous amount of checklist, like for example that on good OTA reports (Gray, 1982).
- **Socio-technical maps**
  Socio-technical maps might be seen as types of checklists by which various aspects of socio-technical development are captured. For example, one kind of map focuses on
  - the hierarchy of variation and selection involved in technological development,
  - the roots of innovations,
  - the actors involved,
  - expectations of actors,
  - effects of innovations
  - critical episodes in trajectories
  - developing episodes

Intervention tools

- The **Consensus conference** is mostly used in Participatory TA. Lay people are brought together in a workshop setting taking some days, to discuss a new innovation. They are entitled to call upon experts. In the end the lay people have to come to a conclusion (if possible consensus) on the subject at stake. The outcome, and the conference itself are used to stimulate public debate on the specific subject. The method is mainly appropriate for innovations which involve ethical issues, for instance in genetic engineering or issues of birth control (Agersnap, 1992, Sclove, 1994).
- **Structured Interaction**
  Structured interaction might also explicitly be used to bring a specific group of actors in contact with each other. This applies, among others, to scenario-workshops. In these cases, the main aim of the method is not to produce a forecast or a statement, but to establish relations, change the mind-set of participants, etc (Cf. Andersen et al., 1992, Beck, 1983).

Criteria for choice

The question is: what are the criteria for the choice of type of TA, project outlay and tools for the solution of a specific problem? This is yet an open question, since we already noted that many of these methods are developed in practice, and few people reflect on their choice. Therefore we have to rely on current TA practices to develop criteria. From our own experience we would suggest the following ones:

- **Phase in the development**
  We can distinguish a number of phases in the development of technology: idea generation, development/design, market introduction, growth, maturing, decline. The choice of type of TA and method depends on the phase of the technology (whether it is part of the problem or part of the solution). For instance, Constructive TA generally refers to technologies that are in their early phases. An exception is formed by the so-called (above-mentioned) citizens' initiatives, in which often 'forgotten' technologies, are revived. Strategic niche management is applied in the prototype phase of technologies. Another example is the delphi, which is mostly applied for technologies in the phase of early development/design.

- **Degree of polarization**
  Some approaches are inappropriate when opinions in society are highly polarized. An example is backcasting, which approach assumes a high level of consensus on desirable (or even inevitable) futures. On the other hand, participatory TA presupposes the existence of contradictions, since it aims at diminishing these.

- **Origins of the problem**
  TA studies and activities always focus on problems related to technologies. The problem may be *technology driven*, in the sense that a new technology creates or tends to create a social problem. The field of information technology provides a lot of examples. The problem may also have *societal origins*, for instance in case of the

environmental movement. In this case, technology can be part of the problem, but it may also potentially be part of the solution. Impact assessment is mainly appropriate for technology driven problems, whereas backcasting is primarily applied for problems with a societal background.
The way of application of specific tools is also different. In case of a technology driven problem, technology experts in a workshop have mono-disciplinary or have related backgrounds, whereas in case of a problem with social origins many different disciplines may be represented, since different types of technologies may be part of the solution. Forecasting (for instance by means of a delphi) generally refers to one technology in the first case, and to many in the other one.

- **Type of technology**
  The type of technology involved is an important parameter: independent artefacts vs. technology that includes a physical infrastructure. For instance, citizens' initiatives are difficult to organize for a highly systemic technologies like the transport system, particularly if a new infrastructure would be required.

- **Position on the R&D agenda**
  A Delphi can only be organized if the technology involved is on the R&D agenda, since researchers got to have opinions about it. Citizens' initiatives can be organized if the technology is not on the R&D agenda (and may even be useful to get it on the agenda).

- **Time dimension**
  Many methods have a middle or long time dimension, particularly the delphi and backcasting. Certain applications of participatory TA have a short time horizon (such as the Dutch InfraLab experiment, in which the National Public Works Administration discusses changes in the road infrastructure with many interested parties).

- **Aim of TA: study or intervention**
  Finally, an important determinant of the choice of method is the aim of the TA project: study or intervention. If there is an explicit aim, for instance diminishing polarization, generating new alternative solutions for a problem or determining impacts of these solutions, this will be very influential on both the type of TA that is performed and the choice of method. Here it has to be noted that not always specific aims are clear from the beginning. The beforementioned reflective studies may serve to specify such aims.

In figure 3 the project lay-outs mentioned above are classified according to the first two of these criteria, phase in the development of technology and degree of polarization (based on our own judgement).

	Degree of polarization

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Phase in development	Low	High
Idea	Delphi	Delphi
Design	Impact Assessment Consumer CTA Strategic Niche Management	Demand articulation Consumer CTA Participatory TA
Market introduction	Impact Assessment Trend extrapolation	
Maturity	Network manipulation	Citizens Initiatives Scenarios Participatory TA

Figure 3. Classification of methods according to phase of the technology and degree of polarization.

As a practical example of the choice of appropriate methods and the application of the above mentioned criteria we will discuss two cases: the sustainability discussions concerning PVC and the base metals industry respectively.

Case 1: Poly vinylchloride (PVC)

After polyethylene, PVC is the most produced and used plastic material. It is used in thousands of products, ranging from everyday life products as credit cards and toys, to professional building and construction materials, and highly specialized applications like for example medical equipment. However, notwithstanding its popularity, already from its early commercial production in the thirties, PVC repeatedly has been the subject of criticism because of health and environmental aspects. Influenced by the environmental movement, recent years have known fierce debates between protagonists and antagonists of PVC; the PVC and chlorine industry is striking back hard on everyone who dares to accuse PVC. In spite of several endeavours to start up a more constructive debate between the antagonists, they seem not to be able to come on speaking terms. Problematic is that the discussion is characterized by many uncertainties concerning the precise nature and extent of possible impacts, technological (im)possibilities for improvement, the current and future performance and availability of alternative materials, etc. In fact, up till now it is impossible to give objective and rational answers to the question whether we should continue and improve PVC-production and consumption, or (partly) phase it out and switch to alternative materials, for the sake of the so desired sustainable development.

The question is which TA methods could contribute to the solution of the problem. If we look at the criteria mentioned before, the situation can be described as *highly polarized*, with increasingly 'quantitative' debates (parties fire each other with ever new facts and figures). The discussions concern *specific technologies*, which are generally *mature*, and of a *non-systemic* nature (alternatives can exist side by side, it is not about a true 'battle of the

systems'). In figure 3 the PVC problem would have to be situated at the right and at the top (polarized/mature). Furthermore rather *long term* decision and development processes are involved, whereas the *scale of the problem* differs to the various parties mentioned (PVC producers will be more affected by a 'negative' outcome of the decision process than PVC processors, which on their turn will be more effected than end-consumers). The problem resides rather high on the *political and societal agenda*. As PVC industry makes it appear, the search for alternative materials or production businesses is not on their *R&D agenda* (although it is, of course, on the agenda of the alternative materials producers). However, the other (and their favoured) future direction is; the improvement of PVC and its production and processing occupies an important part of their R&D activities.

The most appropriate TA approach for this problem would entail a *combination of analysis and process oriented activities*, the result of the first serving as a basis and input for the second. *TA analysis* might focus on developing *future scenario's*, to gain insight in the various sustainable future options. Scenarios could be used to obtain more clarity on the differences and similarities between the development paths leading to these different futures. This could yield insights in which technologies and innovation options are useful in different futures, and hence are worth developing despite possible remaining uncertainties on which future is the most desirable ('robust' technology options).

However, more importantly, because the PVC-debate apparently is based in differences in norms and values of the different parties involved, the TA analysis have to be followed by constructive debates and decision processes between these parties. Because up until now every effort in this direction has failed, the *process oriented TA* should primarily focus on starting up and facilitating (constructive) interaction, and on building mutual understanding between the parties. Only then constructive debates and decision processes will become a possibility. Hence, the most appropriate general project lay out seems to be *participatory technology assessment*. So far the most appropriate methods are in accordance with figure 3. Moreover, when a certain level of mutual understanding is reached, a *consensus conference* might be organized to facilitate the actual decision making process and the formulation of strategies.

Other intervention oriented project lay outs that might be useful instead of or complementary to the participatory TA, are *demand articulation* and *strategic niche management*. On first sight demand for changes is clearly present, but in practice, PVC-product suppliers often state that as long as the consumer wishes to buy PVC, they will continue to supply it. In fact, this demand articulation is exactly what Greenpeace tried to work on in their PVC-free Municipalities campaign. Strategic niche management could take the form of giving extra attention to already existing alternative materials (e.g. gathering data, developing improvement options), to bring these alternative options on a more equal knowledge and competition level with PVC.

Case 2: Base metals production

Industrial production processes, like the production of base metals, are rather inert. Ideas for cleaner production processes do exist (although not always fully mature yet), but in practice they are scarcely implemented. The adoption of these processes is unlikely, because the existing processes are deeply entrenched systems, both technologically and socially, which makes it very difficult to redirect these processes quickly and effectively towards more sustainable alternatives, even when the need to do so is generally acknowledged. Therefore, new approaches of management of technology in its social context are required in order to

further develop and implement cleaner industrial production processes. The central question to be answered, then, becomes: what are the barriers to technological innovation in base metals production and which strategies can be used to (re)direct these innovations towards cleaner production processes?

Applying the two **criteria** for the choice of project lay-out mentioned in figure 3, the base metals problem has to be classified in the same way as the PVC problem, which means that we deal with a **mature** technology with **highly polarized** perceptions. The applied production processes in the base metal industry are rather old. They are used world-wide and they all have reached maturity. At the moment only some (energy) efficiency improvements take place. The problem can be regarded as highly polarized, since the base metals production industry itself is very conservative and doesn't consider the appearing environmental problems as very important. Furthermore, the base metal industry is a very large, capital-intensive industry, which is not willing to change very easily. Environmental groups, governments and individuals, however, do emphasize the environmental problems, related with base metals production. This means that the various parties involved have different problem perceptions.

Other problem dimensions are the following: The production of base metals can be seen as an *independent technology / artefact* in the whole chain from mine to metal product. However, when the production of base metals is regarded as a necessary element of making the metal product, then there exists some *systemic* nature. The environmental problems with base metals production are mainly *societally driven*, because the environmental movement and governments have focused attention on the problem. Nevertheless, this base metals production problem is not (yet) high on the *political/societal agenda* as a whole, except for some specific, regional, urgent (environmental) problems with energy subsidies, health, waste, groundwater pollution, and SO_2 and fluoride emissions. Within the base metals production industry, cleaner base metal production processes are even scarcely on the *R&D agenda*, especially not when it concerns long-term, radical changes in production processes. Industry regards itself as a very good follower of new, often incremental, technological developments. *The time dimension* is also a problem, since the transition towards cleaner base metal production needs a long term perspective, whereas most base metal industries only think in short- en middle-long terms.

Part of the methods that are mentioned at the right and at the top of figure 3, where this base metals problem has to be situated, can usefully be applied to this problem: *Scenario analysis* could be applied to the environmental problems in base metals production, because such analysis puts the problems into future perspective, and gives insight into the various cleaner technological options. The *Delphi* method could give insight into the technological alternatives and their feasibility, by consulting metallurgical and environmental experts. The resulting information and insights can form the input for interventions in the current situation, for instance intervention in innovation networks. *Participatory TA* would be a useful intervention lay out; The differences of opinion could, then, be diminished by means of discussions, and by workshops with several specific actors, involved in base metals process developments (like mining engineers, suppliers, contractors, producers, customers, consumers, governments, university and institutional research groups, environmental movements, individuals). A *consensus conference* could also be organized to start a public debate about the undesirable environmental effects of the existing base metals production and about the possibilities to implement cleaner production processes. However, it will be difficult to get all actors at the same level involved in the decision making about process innovations. *Citizens' initiatives*, also found at the right and at the top of figure 3, are not useful in this case, since the scale of the base metals production processes far exceeds the

possibilities of citizens' groups. Moreover, base metals production can hardly be influenced by consumer actions, because the base metals production stands far from the ultimate consumer of metals and focuses mainly on processes within the chain from mine to product, in stead of focussing on the end products, the metals.

Apart from the methods mentioned above, also *strategic niche management* could usefully be applied to further develop relatively small cleaner production processes. These developments will mostly not take place in the existing base metals industry, because this industry is fixed in the traditional technology paths, but will take place for example in small and medium sized firms or universities, or (government paid) independent research institutes. These alternatives have chances to be further commercialized in the future, by proving that the alternative technology is technologically and economically viable, and by building up new actor-networks around the alternative technology to get the technology more entrenched in society.

Conclusion and discussion

In this paper we have classified methods of Technology Assessment, including both traditional and modern approaches of TA. We made a distinction between approaches, project layouts and tools, and we gave a first indication of the criteria for choice between project layouts. The paper may serve as an introduction for new entrants to the field of Technology Assessment, and as a reference for more experienced practitioners.

It is clear that this paper forms only a first step into developing, what may be termed, a methodology for Technology Assessment. Such a methodology does already exist for traditional forms of TA (for instance represented in the handbook of Porter et al, 1991). The point here is in include modern approaches, such as CTA, and to integrate them with traditional TA methods.

Further study is required to attain this purpose. The application of different modern TA methods needs to be evaluated more systematically to determine in which situations the application of the methods has been successful, and in which not. For the execution of such a project at least two problems have to be solved. Firstly, criteria of success have to be formulated. When do we consider a consensus conference or a citizens' initiative a success? It is clear that the long term effects would be most indicative, but these effects are hard to measure. Secondly empirical material will have to be collected. This is very hard, since hardly any of these methods have been applied explicitly very often. It means that cases of studies and interventions have to be collected that are not explicitly presented as applications of TA by the authors or initiators, but the method of which show a strong resemblance with specific TA methods. In spite of these and other difficulties such a research project would certainly contribute greatly to the growth to maturity of TA as a discipline.

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