TECHNOLOGY ASSESSMENT

Alan L. **Porter'**

The meaning of technology assessment (TA) is changing in important ways. TA is an essential tool of the 1990s to enable sustainable development and facilitate management of technology. Yet, it is a tool in need of serious repolishing. This paper tracks the evolution of TA; juxtaposes TA with other forms of impact assessment; briefly considers doing and using TA; and poses four serious issues for the future of TA.

TA: AN EVOLVING DEFINITION

It should not shock us that two general, widely used, and ambiguous terms—'technology' and 'assessment'—when combined, do not yield a singular meaning. Nonetheless, we can track and even, perhaps, make sense of the usage of 'technology assessment' (TA). The initiation of TA in the late 1960s in the USA engendered lively discussion along two distinct streams (reviewed in Porter et al. 1980). The more direct sought to devise an effective policy analysis mechanism to help the U.S. Congress better cope with executive branch proposals. The other, philosophical in bent, concerned the broad roles of technology in society, seeking to help society better manage technology. Both streams struck fear in those committed to technology-based free enterprise, as expressed in charges that TA meant 'technology arrestment'.

The basic TA model in the scholarly community traces back to the National Science Foundation (NSF) program led by Joe Coates in the 1970s that

[1] Dr. Alan Porter is director of the Technology Policy and Assessment Center and professor of industrial and systems engineering and of public policy at Georgia Tech, Atlanta GA 30332 USA.

supported development of a body of knowledge about doing TA. An enduring TA definition reflects this perspective (Coates 1976):

> . . . the *systematic* study of the *effects on society*, that may occur when a technology is introduced, extended, or modified, with emphasis on the impacts that are *unintended, indirect, or delayed* [italics added].

Note the italicized terms. Systematic study entails an approach that is as orderly and comprehensive as possible. The effects on society are the impacts of the changed technology across all sectors. The unintended, indirect, or delayed impacts are those not traditionally considered in economic analyses. Figure 1 illustrates the notion of indirect impacts. Coates' companion retrospectives on the automobile and the refrigerator also end in sixth-order divorce. These semi-serious analyses show both the notion of 'effects of effects' and the complex nature of technology–society interactions. The latter imply that TA cannot describe the future with certainty; it can only aspire to reduce future uncertainties.

This model—call it the comprehensive TA model, the NSF model, or the western TA mock—has evolved into **a** variety of forms. For one, the scope of TAs varies greatly according to user needs and study resources, ranging From comprehensive, full-scale studies involving interdisciplinary teams for several person-years to quick-and-dirty (say, one person-month) micro assessments (Rossini et al. 1976).

Erik Baark (1991) distinguishes four schools of TA thought that aid in tracking TA evolution. These draw from different perspectives on the technological innovation and diffusion process:

Regulatory. Perceiving technological development as deterministic, expects the state to set limits on the use of a particular technology (e.g., food additives) or legislate requirements (e.g., safety precautions); TA is to help the state exert control, in a reactive sense, over actual or projected impacts.

Promotional. Again, the course of technological development is pretty much given, guided largely by market forces; but TA should help formulate suitable policies to promote technological innovation in the interest of national competitiveness or development.

Figure 1. **The effects of technology**

At times, technologies have unintended consequences that combine to have serious impacts undreamed of by the creators of the technology. The following example (adapted from Coates 1971) demonstrates how television may have helped to break down community life.

CONSEQUENCES OF TELEVISION

1st order:	People have a new source of entertainment and enlightenment in their homes
2nd order:	People stay home more, rather than going out to local clubs and bars where they would meet their fellows
3rd order:	Residents of a community do not meet so often and therefore do not know each other so well (also, people become less dependent on other people for entertainment)
4th order:	Strangers to each other, community members find it difficult to unite to deal with common problems; individuals find themselves increasingly isolated and alienated from their neighbors
5th order:	Isolated from their neighbors, members of a family depend more on each other for satisfaction of most of their psychological needs
6th order:	When spouses are unable to meet heavy psychological demands that each makes on the other, frustration occurs; this may lead to divorce

Constructive. Does not accept that the course of technological development is deterministic; rather, seeks to tune that development in response to social and political priorities; this suggests proactive state intervention (e.g., devising incentives to encourage alternative energy sources); seeking to 'constructively' redirect the process of technical change, uses **TA** to clarify interests among technology developers and users.[2]

[2] Arie **Rip** and colleagues initiated this social construction of technology perspective on TA **(cf.,** Smits and Leyton 1991; den Hond 1993).

> ***Experimental/Participative.*** This extension of the constructive approach requires active intervention; a wide spectrum of parties at interest participate in testing technological alternatives and/or performing social experiments to improve the design of the innovation.

This framework helps plot the evolution of TA. Studies by the **U.S.** Office of Technology Assessment (OTA) represent a largely regulatory stance (cf., figure 2 topics), with occasional forays into the promotional (e.g., 'technology opportunities for economic conversion'). 'Development TA' (Baark I991) favors promotional over regulatory issues. Recent European efforts explore the constructive orientation.

Baark's framework emphasizes public sector TA. Private sector TA is done by the firm, or industry association, to identify threats and opportunities for the sake of promoting development. Impacts are typically considered from a more limited, parochial point of view. TA may also entail public–private collaboration. For instance, the British Centre for the Exploitation of Science and Technology (CEST) assesses technological opportunities.

Continuing to stretch the promotional school model, one can fruitfully think in terms of a combination of technology foresight activities—*technology monitoring, forecasting, and assessment*. According to the UN/OTA workshop report (1991 : 4):

> Technology assessment ultimately comprises a *systems approach to the management of* ***technology*** reaching beyond technology and industrial aspects into society and environmental domains. Initially, it deals with assessment of effects, consequences, and risks of a technology, hut also is a forecasting function looking into the projection of opportunities and skill development as **an** input to strategic planning. In this respect, it also has **a** component both for monitoring and for scrutinizing information gathering. Ultimately, TA is a policy and consensus building process as well [italics added].

The 1993 UN expert group meeting further embeds TA with technology monitoring and forecasting (Porter and Weisbecker 1993; Weisbecker and Porter 1993). Monitoring consolidates available knowledge on a particular technology and its context (technological and social). Technology forecasting anticipates future developments. TA is integrated with monitoring and forecasting, rounding out a systems approach. 'TA' emphases vary enormously depending on the needs of the study users. For example, in many developing countries, such studies may emphasize monitoring (keying on what is available from developed countries and the impacts experienced there) more than forecasting or future-oriented impact assessment. In sum, TA has evolved into a set of foresight analyses adapted to particular users.

I must add that the systems view is stretched unnaturally far to accommodate all usages of ‘technology assessment’. Many, if not most, users of the term refer to *technical evaluations* that bear little resemblance to the TA types just catalogued (see figure 2). Of course, with stretching, the systems view could encompass these forms. Evaluation of alternative technologies may entail forecasting, as in the design of a future combat aircraft. Or in the case of an important TA form, medical (or health) technology assessment seeks to help decision makers deal with the development, acquisition, and utilization of health-care technologies (Menon 1993). While somewhat narrowly cast toward technical equipment evaluation, medical TA can entail predictive methods and weigh clinical and economic impacts (e.g., as in the assessment of computed tomography’s appropriate applications) (Wells et al. 1991).

TA AND EIA: DEVELOPING ON SEPARATE TRACKS

Both TA and environmental impact assessment (EIA) were legislated into existence in the United States to improve the social management of technology. We need not belabor the history of the U.S. National Environmental Policy Act of 1969 (cf., Caldwell 1970), nor the development of viable mechanisms to implement its required environmental impact statements (EISs). Neither need we reiterate the sequence of studies and deliberations, led by Congressman Daddario, resulting in creation of OTA in 1972 (cf. Porter et al. 1980), nor its trying evolution into a well-respected staff arm of the U.S. Congress.[3]

[3] Vig (1992) considers OTA’s institutional development and the evolution of parliamentary TA institutions in Europe.

Figure 2. 'Technology assessment' according to the databases

I searched four electronic databases for 'technology assessment' in December 1993. ACAD (Expanded Academic Index) primarily tracks social science journals, containing some 1.3 million items beginning in 1988. BUSI (Business Index) emphasizes management and industry sources, containing some 1.6 million items beginning in 1988. ENGI (Engineering Index) contains some 1.5 million items commencing in 1985. NTIS (National Technical Information Service) keys on US government research reports, with 1.7 million items from 1964.

'Technology (adjacent to) assessment' occurred 369 times in ENGI. In a small sample of those, almost half referred to narrowly defined technical evaluation, another third denoted medical TA, and a very small percentage pertained to either technology forecasting or impact assessment. Amazingly, the term appeared 11,500 times in NTIS. Disappointingly, in a small sample, these overwhelmingly concerned technical evaluation, largely in the military and nuclear technology arenas. Perhaps 15% evidence impact assessment.

'Technology assessment' appeared 286 times in ACAD. I inspected a small sample of these abstracts, finding that over 90% referred to an OTA report *or* activity.

'Technology assessment' appeared 426 times in BUSI, showing the most diversity in usage. To explore usage further and to see if there were notable changes over time, I consolidated the 164 articles dated 1988–1989 as one 'early' bunch, and the 81 articles dated 1992–1993 as a 'recent' bunch (incomplete 1993 coverage contributes to the reduced number). This yields the following tabulations of index terms in those articles:

> **1988–89:** 392 keywords, led by 'Office of Technology Assessment' (131); frequent mentions (4 or more, most likely reflecting foci of OTA studies) of hazardous waste, industrial research, environmental policy, biotechnology, superconductivity, medicaltechnology, digital audio tape, magnetic recorders, hospitals, balance of trade, genetic engineering, refuse, and manufacturing industry
>
> **1992–93:** 151 keywords, led by OTA *(37);* frequent (3 or more) mentions of pharmaceuticals, defence, environmental policy, automobiles, developing countries, and air quality.

In sum, 'our' meaning of TA differs from 'their' meanings. In some literatures, TA means technical evaluation. Our meaning is primarily represented in the literature by **OTA** references.

Beginning in the early 1970s, the NSF TA program funded some two dozen comprehensive TAs and related studies (Rossini et al. 1978). These nurtured an academic and professional TA community. That community formed a professional association, the International Society for Technology Assessment (ISTA), which flourished in the mid-1970s, expiring abruptly due to financial difficulties. In the late 1970s, Charlie Wolf, Fred Rossini, and I moved to establish a successor professional association. I phoned Walter Hahn, founding president of ISTA, for his advice—the key element of which was not to use the term 'technology assessment'. Walter felt that TA failed to draw in those professionals engaged in EIA, etc. Hence was born the International Association for Impact Assessment (IAIA).

IAIA has consistently sought to bring together those practicing TA, EIA, social impact assessment (SIA), and (less successfully) those doing risk assessment. These forms of impact assessment (IA) share many essential features, thus warranting close scholarly and professional interchange among their practitioners (Porter et al. 1980). Most importantly, all purport to *address the future, in terms of the potential effects, of technological changes, for the purpose of informing policy making.* Distinctions among the forms of **IA** often blur.

TA keys on an input consideration—'technology'. Yet on the one hand, most IA concerns the potential effects of technological developments, and, on the other, some 'TA' focuses on problems (e.g., alternative energy choices) or policies (e.g., implications of telecommunications standards).[4] Risk assessment keys on a particular form of concerns, implying performance of TA to get at those risks. Risk assessment in practice tends to be narrower in focus than does TA and more quantitative (e.g., nuclear plant fault tree analyses, epidemiological cancer profiles).

TA generally contrasts with EIA in *not being driven by explicit governmental EIS requirements, and not being localized to a particular site development.* Also, EIA policy considerations are typically more circumscribed; participatory procedures are more developed and routinized; the impact horizon is shorter; and data sources are more likely to be primary (direct data

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[4] 'Integrated impact assessment' addresses a class of technologies, sometimes for a geographic area (e.g., **U.S.** Environmental Protection Agency sponsored TA of western U.S. energy, focusing on the policy issues involved).

collection as opposed to relying upon literature). Furthermore, those who perform TA (e.g., OTA staff) are rather distinct from the larger contingent who perform EIA (e.g., professional consultants). The distance is even greater between EIA practitioners and those who perform more promotional forms of TA, involving monitoring and forecasting, private sector foresight studies, etc. TA and other forms of IA thus overlap considerably. We might all have been spared considerable confusion had technology assessment been named instead 'Technology Impact Assessment'![5]

Returning to institutionalization matters, IAIA has advanced IA by providing meeting grounds, written media, and networking (Porter 1989). In the 1980s, IAIA became thoroughly international through a series of successful meetings outside North America—in Australia, the Caribbean, China, and Europe.

Through meetings and resultant publications (cf., UN 1991 and 1993), the UN Branch for Science and Technology for Development has significantly advanced TA. The branch earlier had established the Advance Technology Alert System (ATAS) and now bears responsibility for TA in the UN system. They focus on development of TA capabilities in developing countries. The branch has also spurred a new 'association of associations' to promote TA—the International Association of Technology Assessment and Forecasting Institutions.'

DOING TA

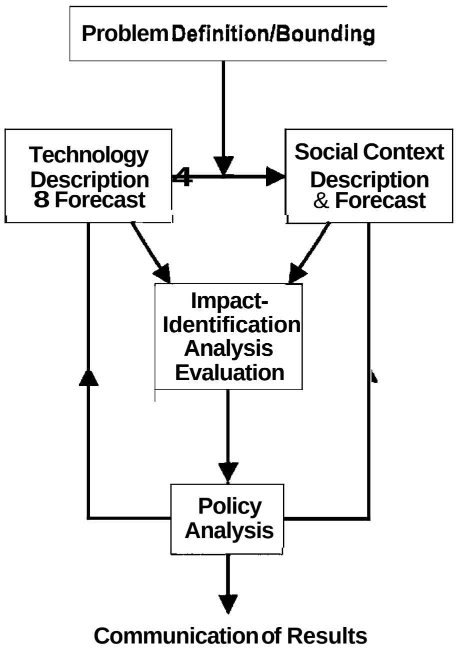
Figure *3* gives our 10 steps for TA (Porter et al. 1980). Briefly, the assessors first bound the study to focus on the main concerns of their intended users. The next four steps describe the technology and its context, then anticipate how these are likely to evolve over the time horizon of interest. Technology description and forecasting emphasize the functional capabilities of the changing technology and its direct applications. Societal context description and forecasting seek to ascertain the key influences upon

[5] This title was chosen by David Minns in organizing a session at the Canadian Chemical Engineering Conference, Ottawa, October 1993.

[6] For information on IATAFI, contact Gary Williams, Environmental Assessment and Information Sciences Division, Argonne National Lab, 370 L'Enfant Promenade SW, Suite 702, Washington DC 20024 USA.

the technology's development. Note how readily these steps fit the 'systems approach' and the inclusion of monitoring and forecasting with TA. The next three steps [impact identification, analysis, and evaluation] are the soul of TA. These progress through asking 'what might result?' to 'how much is likely?' to 'so what?'. In principle, these steps consider all potential impacts[7] and how they affect all parties at interest. Extending the notion of ***all*** impacts through a cascade of indirect impacts (figure 1) conveys the challenge of IA. Impact analyses are followed by policy analyses to elucidate current decision options and their prospective consequences. Lastly, communication to all interested parties is essential.'

Figure 3. **Problem definition/bounding**



[7] I like the generic checklist of the acronym, 'THISPECIES'—Technology, Health, Institutional, Social, Political, Economic, Cultural, Individual, Environmental, and Security (Porter et al. 1991).

[8] And should begin at the *problem definition* step. The steps should be iterated fully or partially, as warranted, not treated linearly.

Each of the 10 steps receives more or less emphasis depending on the orientation of the **TA** (technology development versus impact appraisal), the interests of the target audience,[9] data availability, and the study resources available. **To** accomplish the steps, assessors draw upon a variety of qualitative and quantitative methods. **A** survey of practitioners (Lemons and Porter 1992) shows considerable overlap in the methods used in **TA, SIA,** and **EIA** in both developed and developing settings. The table in figure **4** tabulates the more prominent **TA** methods. Expert opinion and monitoring are most widely used. Note that most **TA** relies on multiple methods.

Figure 4. **TA methods used (%)**

	Developed countries	**Developing countries**
Expert opinion	72	87
Nonexpert opinion	25	36
Monitoring	64	70
Trend extrapolation	48	84
Scenarios	41	65
Modeling (qualitative)	34	15
Modeling (quantitative)	18	10
Checklists	16	26
Matrices	13	17

NOTE: 'Use' is the mean percentage of studies reported to use each method, averaged for three time periods: 1980–84, 1985–96, and planned for 1990–94. For developed countries, 14 respondents described 157 studies averaging 3.3 methods/study; for developing countries, 5 respondents described 28 studies, averaging 4.2 methods/study.

[9] For instance, OTA's Congressional users prefer to receive comparisons of policy options, not explicit recommendations.

This paper frames TA as a single study of a single technological opportunity. Instead, one may establish an ongoing TA process. That implies capabilities to (1) monitor emerging technologies to determine when TA is warranted, (2) arrange for such TAs to be done, and **(3)** update information and revise projections as new information becomes available and concerns arise. In that TA is often needed 'immediately', an institutionalized TA process, with effective memory, can better respond to the occasional windows of opportunity to resolve policy issues.

USING TA

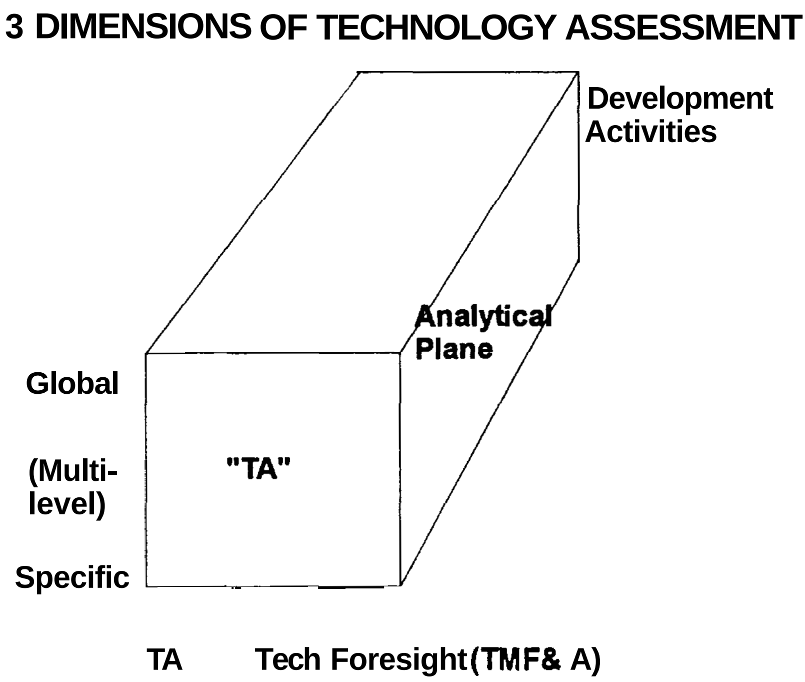
TA should inform decision making. Such information, however, can extend over a wide spectrum. At one end lies the early warning, *intelligence* function, alerting parties to be 'at interest' concerning an emerging technology. At the other, lies the *decision-aiding* function. This function can be served by framing policy options, helping to weigh the merits of such options, and/or providing ammunition for stakeholders to support their existing positions. 'Constructive TA' goes further in striving to improve the options under consideration.

The most intriguing application arena for TA is the developing country—the thrust of the UN TA initiative. Developing countries, after several years of hesitation that TA was being foisted upon them as a device to stall their development, have warmed to the challenge of adapting western TA approaches to their contexts. This adaptation favors a promotional 'systems approach', inclusive of monitoring and forecasting as well as IA. In particular, an indigenous TA capability should aid in technology acquisition decisions. Issues include whether to import a particular advanced technology, versus a possibly more 'appropriate' technology; whether to buy components or entire systems; as well as whether to accept the environmental and social impacts attendant on introduction of the technology and siting of facilities.

Clark (1990) suggests that development TA must deal with three broad concerns: (1) policies to promote the relevant science and technology base, (2) those concerned with economic applicability—that is, assessing where resources should be targeted to optimize development; and **(3)** those concerned with the institutional changes needed for effective adoption (e.g., regulations, venture capital availability).

Discussions at the UN expert group meeting (1993) also affirm that TA in developing countries is inextricably wedded to development concerns. Figure 5 sketches three **TA** dimensions. *Level* stretches from the specific (technology, site) to the global; *tech foresight* stretches from **TA** (as regulatory TA) to a systems approach (monitoring, forecasting, and assessment). The third dimension ranges from TA as analysis (the focus throughout this article) to TA as development activity (institutionalization, promotion, etc.).

***Figure* 5. Three dimensions of technology assessment**



EMERGING ISSUES IN TA

I spotlight four issues deserving serious consideration:

1. Stretching TA to incorporate life cycle analysis prompted by concerns for sustainable development
2. Devising TA mechanisms for transnational issues
3. Adapting TA to new thrusts in the management of technology and technology policy
4. Developing frameworks and support for knowledge generation and dissemination about the TA process

TA enhances sustainability considerations by directing attention to technological options (through monitoring and forecasting) and broadening consideration of potential impacts beyond the natural environment. We need to inform the sustainable development community about TA and **IA** so that these are included in their frame of reference (e.g., ‘Design for Environment’ guidelines being crafted with U.S. Environmental Protection Agency support).

Conversely, sustainability criteria enrich TA. Sustainable development objectives crystallize concern about the long-term viability of given technologies. They provide a readily grasped benchmark (Can the environment support this activity indefinitely?) to help assess proposed technologies. Most important, sustainability criteria challenge TA to address the full technological life cycle. Upstream, this means that we need to consider (ideally, categorize and measure) the resources required for the technological development (e.g., raw materials, habitat affected). Downstream, it means we need to address (ideally, categorize and measure) the residuals. We need to reach beyond the technology (as product, process, or service) itself to assess attendant waste disposal or utilization, and re- opportunities (reuse, reclamation, remanufacturing, recycling).

Transnational issues arise as certain impacts (such as global warming) transcend national boundaries. The severity of such potential effects cries out for TA, but the difficulties are daunting (Porter 1987). Who holds responsibility to **do** transnational assessments? Who will provide the resources? Where are the policymakers to act on the findings? The UN is tackling some transnational concerns. In particular, the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 focused attention on global change and sustainability issues. The Montreal Accords on limiting chlorofluorocarbons to protect the ozone layer offer encouragement that nations can mobilize rapidly to address a difficult transnational impact.

TAs or integrated IAs are needed to confront a growing list of transnational issues attendant to: human biology (population control, AIDS, increased life spans), information age (network management, global village, changing work patterns), and the globalization of the economy (while relying upon national controls).

'Management of Technology' (MOT) is growing explosively in academia. MOT is prompted by concerns about enhancing competitiveness, seen as highly dependent on technology. Usually based in business schools, MOT engages engineering in providing the skills needed to manage technologically based enterprise. The list of such skills includes analysis of technological innovation processes; technology monitoring, forecasting, and assessment; and risk assessment. These foresight analyses are vital to succeed in "managing the present from the future" (Porter et al. 1991). That is, we need to develop sound (not certain) projections of alternative futures and use these to inform the decisions we are making today. TA needs to be operationalized as an MOT tool to address specific technologies. But, in addition, we might do well to revisit the 'big picture' philosophical TA discourses of the 1960s; TA could also help society rethink what its larger objectives are, with an eye toward the tradeoffs among impacts (Harman 1992).

Technology policy opens up another critical venue for a systems approach to TA. The legitimation of proactive governmental technology management suggests a strong role for promotional, constructive, or experimental/ participative TA. How is this to be institutionalized?

Lastly, we need to develop the TA (and IA) knowledge base. The nurturing role played by NSF in the 1970s has not been taken up by another institution.[10] As a result, there is no research base on how best to perform TA/IA. How valid and useful are TA/IAs? What makes some better than others? What methods work best—where, when, and why? Given the vital

[10] Only the risk assessment area continues to receive any NSF support.

national interests in the policies that TA can inform, there would be tremendous payoff from modest, but well-led, support for such studies.

As a consequence of the lack of a research base, there is no teaching base for TA. To the best of my knowledge, the last TA textbook was published in 1980 (Porter et al.). There are no clearcut intellectual homes for this interdisciplinary activity in the university. Yet someone needs to ascertain ways to model technology life cycles with regard to impact assessment, to advance creative participatory mechanisms for TA, and so on. Initiatives to promote the collation and dissemination of knowledge on TA/IA are desperately needed. There is an outrageous mismatch between the importance of the activity and the inattention to training people to do it well.

In conclusion, TA needs attention. Through the 1980s, the practice of TA was visible mainly in the fine work of OTA. Thanks to formation of TA offices by a number of countries (Vig 1992) and efforts by international bodies, especially the UN, TA is coming back into scholarly and professional prominence.[11] That is rightful in that TA deals with the really big issues—the implications of emerging technologies on entire societies and environments. We need to devote resources to improving the TA process and effectively integrating it into MOT and sustainable development efforts.

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[11] Unfortunately, the UN Branch for Science and Technology for Development was disbanded in 1994. It is *not* clear which, if any, UN agencies will assume responsibility for TA.

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