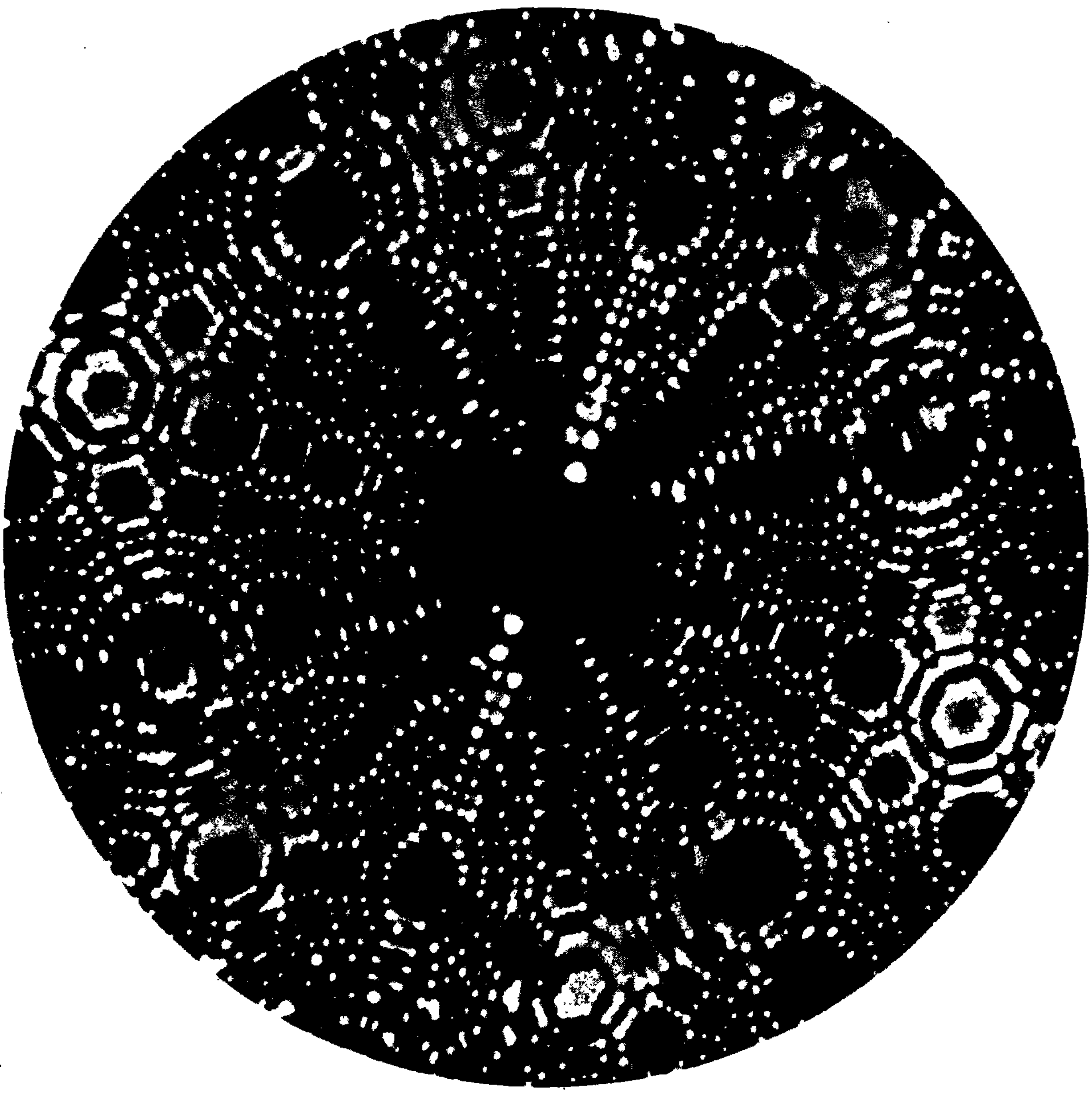
No. 61

Technology assessment: review and implications for developing countries

Science policy studies and documents



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Atul Wad and Michael Radnor

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PREFACE

The Unesco series 'Science policy studies and documents' forms part of a programme initiated by the General Conference of Unesco at its eleventh session in 1960, which aims at making available factual information concerning the science and technology policies of various Member States of the Organization as well as technical studies of interest to policy-makers and managers.

The country studies are carried out by the government authorities responsible for policy-making in the field of science and technology in the Member States concerned.

The selection of the countries in which studies on the national science and technology policy are undertaken is made in accordance with the following criteria: the originality of the methods used in the planning and execution of such policy, the extent of the practical experience acquired, and the level of economic and social development attained. The geographical coverage of the studies published in the series is also taken into account.

The technical studies cover planning of science and technology policy, organization and administration of scientific and technological research, and other questions relating to science and technology policy.

The series also includes reports and other related documentation of Unesco international meetings on science and technology policy, in particular regional ministerial conferences which the Organization convenes regularly in the different parts of the world.

The present Study on Technology assessment has been prepared under contract with Unesco by Dr Atul Wad (India) and Michael Radnor (USA) from the Center for the Inter-disciplinary Study of Science and Technology, Northwestern University, Evanston, III, USA. It is the first in-depth study to be published in this series on the problems connected with the choice and evaluation of operational technologies, as perceived from the angle of governmental science and technology policy. It is designed to serve primarily policy-makers in developing countries in their first attempts to cope with "technology assessment" at the national level, be it inside the government administration or in parliaments.

The Study draws heavily on the United States' experience in "Technology assessment" which dates back to 1967, when the US Congress called for a new form of policy analysis capable of dealing with the various pervasive - and often negative - effects of technological innovations which have a high diffusion potential in the productive sectors of the national economy.

The authors are responsible for the choice and presentation of the facts contained in this book and for the opinions expressed therein, which are not necessarily those of Unesco and do not commit the Organization.

CONTENTS

I. INTRODUCTION

1. Outline and objectives

This publication attempts to present an overview of the current state of Technology Assessment (TA) and Risk Analysis (RA), with a specific emphasis on issues relevant to the application of these fields in developing countries. Though most research and practice in TA and RA have been in the industrialized countries and particularly in the United States, there is growing interest in the utility of these approaches to technology policy-making and analysis in the Third World.

Though there have been some activities in TA and RA in developing countries, these have been somewhat tentative and limited. On the other hand, the key role that science and technology are recognized as playing in the development process makes it imperative that developing countries master techniques that are designed to enhance and improve the contributions of technology to society and to minimize the negative consequences of technological developments.

The document starts with a brief description of the historical background of TA and its main current trends and directions. This is followed by a discussion of methodological aspects of TA. The section following describes and compares the main techniques that have been used in or developed for various stages of the TA process. This is followed by a discussion of some of the major problems or concerns that are associated with the field of TA and which have serious implications for the future of TA. Section VI discusses institutional considerations in TA and its relationship to the policy process, followed in the next section by a description of the international context of TA. Section VIII addresses the key issues that arise with respect to TA in developing countries, with particular emphasis on how TA may need to be modified in order to be more useful and relevant. Section IX presents a review of risk analysis and its implications for developing countries, followed by a concluding summary section.

The text is accompanied by a selected bibliography on TA and RA which is not meant to be exhaustive but rather reasonably representative of the work that has been done in the field.

The overall objective of this publication is to contribute to the development and improvement of capabilities for technology assessment and risk analysis in developing countries. As such, the general perspective towards the field of TA is critical and evaluative. The field as it exists now is extremely diffuse and characterized by a number of perspectives and problems - many of which are directly relatable to the non-paradigmatic status of the field. There is also a great deal of rhetoric that goes along with the field, as well as some internal contradictions. In considering the utility of TA and RA in developing countries, it becomes important to distinguish these features of the field and to take into account the context specific features of developing countries in the formulation of TA concepts, criteria, methodologies and practices. Just as the transfer of technology from developed to developing countries raises questions about the appropriateness of that technology to the different context in which it is to be used and the need for modification and adaptation, the use of knowledge such as TA from one context to another raises similar questions about contextual differences in the social, economic, political and institutional environments between countries and their implications for the application of that knowledge. In particular, attention has to be paid to those factors that influence the policy decision environments in different countries.

While this document is described as a review of technology assessment and risk analysis, the emphasis is mainly on the former, since this is at present an area of greater expressed concern in developing countries and also because many of the issues that arise in the context of TA pertain to RA as well.

2. Definitions

The term Technology Assessment was coined in 1967 and is generally attributed to Congressman Emilio Q. Daddario, who first called for a new form of policy research to help policy makers deal with the various pervasive effects of technology on society.

There have been numerous definitions of TA since then which are generally in considerable agreement with each other. One of the more classic definitions was offered by Joseph Coates:

> Technology assessment is the name for a class of policy studies which attempt to look at the widest possible scope of impacts in society of the introduction of a new technology or the extension of an established technology in new and different ways.
>
> (Coates 1976a; p. 139.)

According to Armstrong and Harman (1977), most definitions of TA are based on two assumptions:

(i) that the implementation of new or expansion of an old technology is (or should be) a conscious societal choice; and

(ii) that it is not generally technology of itself which is inherently harmful but its management, and that management should be conducted for the long-range interest of society.

These assumptions reflect the growing concern with the societal implications of technological developments and the need to monitor and control these developments.

In reviewing various definitions of TA, Armstrong and Harman (1977) identify five elements that appear to be central to most such definitions:

(i) that it is possible and desirable to manage technology objectively toward goals that contribute to societal benefit;

(ii) that the prime objective of TA is to inform policy decisions by providing information on the potential advantages and disadvantages to various societal groups of likely technological developments and alternatives;

(iii) that TA is inherently and necessarily a multidisciplinary field;

iv) that TA entails projecting into the future and addressing the uncertainties associated with such projections; and

(v) that the term "technology" includes both "hard" and "soft" technologies.

Risk Analysis or Assessment is closely related to technology assessment but focuses more on notions of probability and uncertainty and the potential risks associated with technological developments. According to Otway and Pahner (1976) risk analysis consists of two elements:

(i) risk estimation, which involves the identification of indirect and direct consequences of a decision and the estimation of the probabilities and magnitudes of these effects; and

(ii) risk evaluation, which involves anticipating the societal response to risk, or more specifically, determining the value of the risks to those social groups that are affected.

A third element of risk analysis that has been suggested is:

(iii) risk identification, which involves the reduction of descriptive uncertainty (Kates 1976; Rowe 1977) whereby the parameters of a particular risk are specified. The more specific the description of the risk, the lesser is the uncertainty about its character.

The two fields of TA and RA are often associated closely with each other, though it could be argued that TA is a more encompassing field than RA, and is somewhat older.

3. Relationships to other policy sciences

It is useful at the outset to understand the disciplinary context of technology assessment and risk analysis. The past two to three decades have seen a tremendous surge in what are referred to as the policy sciences, reflecting a growing concern with the need for systematic, rational analysis as an input into the policy process. Systems analysis constitutes a core element of this trend and is manifested in more specific forms in a variety of applications areas - environment, space, aeronautics, etc.

There are two aspects of TA as a policy science that bear consideration. The first has to do with its complementarity to other fields concerned with the assessment of impacts, most notably Environmental Impact Assessment (EIA). In fact, in the literature, there is some ambiguity in terminology with technology assessment (TA), environmental impact assessment (EIA), social impact assessment (SIA), etc., often overlapping substantially with each other. The point, however, is that TA represents a part of a broader concern with the assessment of societal impacts approached from a multi-disciplinary, integrated and systematic perspective. The recent interest in Integrated Impact Assessment (IIA) (Rossini and Porter 1983) and the establishment of the International Society of Impact Assessment testify to this trend. Within the policy sciences, therefore, TA as a field could be argued to be evolving and simultaneously converging with other similar fields into a more broadly defined and integrated approach to the study of societal impacts.

Secondly, TA has an intimate relationship with other policy sciences, particularly technology forecasting, cost-benefit analysis, futures research, etc. In other words, as currently practised, it is intertwined ideologically and methodologically with the family of policy sciences.

> ... technology assessment is an extension of the operational research/systems analysis/futures research family of thinking (Kenward 1972), and ... technology assessment is viewed as a systematic planning and forecasting process .... It may be considered as a natural follow-up to systems engineering (Strasser 1972).
>
> (Both cited in Wynne 1975.)

It is important to recognize and understand the implications of these aspects of TA, particularly when examining the possible application and relevance of TA in developing countries. The disciplinary constellation within which TA lies - policy sciences/ impact analysis - helps to establish the limits within which this field, in its present form, can be applied in developing countries and also helps to demarcate the directions in which it should evolve in order to be of greater relevance to the development process. These issues will be taken up at greater length later in this document.

II. HISTORICAL BACKGROUND AND PERSPECTIVES

1. Origins and evolution of TA

TA and RA have emerged into prominence relatively recently. In terms of their evolution as disciplines or fields of inquiry, Nehnevasjsa and Menkes (1981) identify three (and perhaps four) stages in the growth of TA and RA. The first phase, which according to Nehnevasjsa and Menkes, was influenced by the classic National Academy of Sciences (1969) report, "Technology: processes of assessment and choice," represented the effort to extend cost-benefit analysis to include other factors which went beyond considerations solely of economic feasibility. Disappointing results with this approach, particularly in terms of the inability to provide a more comprehensive picture of the complexity of technologically induced changes, created the conditions for stage 2 in the evolution of TA. This stage was characterized by:

> attempts to study systematically the consequences of choices and trade-offs between: (1) short-range and long-range impacts, (2) first-order and higher-order effects, and (3) direct benefits and costs and negative externalities, with heavy emphasis on the comprehensive identification and analysis of the full range of social, economic and environmental effects of technological inducements.
>
> (Nehnevajsa and Menkes 1981, p. 248.)

However, the goal of full-comprehensiveness that stage 2 called for ran into the problem of feasibility and practicality and led to stage 3, which reflected the pragmatic approach of "disjointed incrementalism" propounded by Charles Lindblom. Here the emphasis is on contingency analysis, pragmatic bounding of the assessments and the generation of policy options that are subject to external constraints and are internally consistent with respect to them. As Nehnevasjsa and Menkes note, this stage reflected some of the epistemological limitations of technology assessment - i.e. the practical limits to perfect rationality and perfect information that are associated with instrumental forms of knowledge which deal with social processes such as decision making. The concomitant attention then given to personality and organizational factors and behavioural variables delineates the fourth stage of TA, where although the contingency approach is retained, it is dominated by the personality and organizational perspective.

Nehnevajsa and Menkes further draw a comparison between the evolution of TA and that of risk analysis and suggest that risk analysis, based on the criteria used to define it, the types of studies that are being supported by agencies such as the National Science Foundation and the specific objectives it is meant to meet, appears to be in transition from stage 1 to stage 2 along the lines described earlier for TA.

TA is clearly most firmly institutionalized in the United States as compared to other countries.* The institutional history of TA in the U.S. is therefore useful to understand for what it reveals about the process of institutionalization and legitimation of a field

* France has recently adopted a bill creating the "Office parlementaire d'évaluation des choix scientifiques et technologiques" (Loi 83-609 du 8 juillet 1983) published in "Journal officiel" of 9 July 1983, p. 2125.

of policy science. As described by Fred Wood of the OTA:

> Phase 1 (1963-1967) was the birth of the TA concept in Congress, starting with the formation of the Subcommittee on Science, Research and Development of the House Science and Astronautics Committee in 1963 and ending with the introduction of H.R. 6698, the first technology assessment bill, on March 7, 1967. During phase 2, (1968-1972), a consensus on OTA developed in Congress through a long series of studies, hearings and bills, leading to the enactment of H.R. 10243 and signing of P.L. 92-484 (Technology Assessment Act of 1972), on October 13, 1972. During phase 3 (1973-1979), an operational role for OTA was created under the direction of OTA's first two directors. This phase included initial efforts to organize OTA, establish program areas, set priorities and produce credible reports. In phase 4 (mid 1979-present), the emphasis has been on institutionalizing the OTA process in Congress and improving OTA's methodology and management.
>
> (Wood 1982, p. 211.)

In other industrialized countries, the institutional evolution of TA has been quite different, and even today the U.S. and France are the only countries with an office such as the OTA. What is critical to understand is that the institutionalization of TA was directly responsible for the growth of research in this field. The majority of TA research originates today in the U.S., and both the OTA and the NSF are major actors in these research efforts. Also important to note is that the growth of TA followed from a clearly articulated need, as expressed by Congressman Daddario in 1967, which pointed to a field of inquiry which in turn was epistemologically (or some would say ideologically) congruent with prevailing trends in other related fields and which potentially could address felt societal concerns at the time. As such, it acquired an uniquely U.S. character as a field and it is this aspect of TA that is vital to understand, along with the historical context of its evolution, when addressing the relevance of TA to developing countries. The types of problems that are addressed, the types of impacts that are assessed, the criteria for evaluation, the methods used and the analytical techniques that constitute TA need to be seen in this historical light before they can be applied in altogether different situations. This is not to criticize TA but rather to point to its historical context specificity and to the need to transcend the limitations to the transferability of the practice of TA that derive from this specificity.

2. Historical perspectives

Whereas the prior discussion focused on the historical evolution of TA, particularly in the U.S., the historian Lynn White raises three crucial issues with regard to technology assessment from the perspective of an historian (White 1973). The first is that the entire approach to TA in the U.S. at that time tended to be ahistorical in terms of a lack of a sense of depth in time. White ascribes this to the disciplinary background of most TA practitioners - engineering, systems analysis - and also because the problems set before TA practitioners for solution are future-oriented and "discourage probing the genesis of things" (White 1973, p.3). However, according to White, TA could become more sophisticated and richer as a field were it to draw upon the experiences with technology in the past and to bring an historical analysis perspective to contemporary problems. Though Nehnevajsa and Menkes (1981) do suggest that the incorporation of historical experiences would probably characterize the next stage of TA, or the enrichment of the present stage, they have in mind as history the period since the establishment of TA as it is understood in the modern sense, i.e., since 1969, and the historical experience that this new stage of TA would draw upon would be the knowledge gained through TA practice and research in the past two and a half decades.

White has a much longer historical horizon in mind. For developing countries, this point is important because many of the problems of development have long historical roots which must be explored in the assessment of contemporary technological problems. Furthermore, it also points to the need to look into the technological heritage of a country and not to limit the analysis or choices to modern technologies. The recent emphasis on the relevance of traditional technologies in developing countries (e.g. Swaminathan, Von Weizsacker and Lemma 1983) bears witness to this view.

The second point raised by White is that TA must be based on a careful discussion of the "imponderables" in a situation and not be restricted to only those elements that are measurable. He argues that a failure to recognize these intangibles can lead to dangerously misleading conclusions, supporting his arguments with several case studies of technological developments in the past in a variety of societies. In this regard, he notes the importance of recognizing cultural factors. A technology that is assessed as positive in one culture can quite easily be rejected in another.

A third point that comes out of White's discussion is that it may be unrealistic to view TA as an entirely new field. Every society in some way assesses technology, very likely in an implicit fashion. The distinguishing feature of modern-day TA is that it is an explicit attempt to deal with the assessment and selection of technologies. However, this does not require the rejection of past approaches to the assessment of technology, even if they are non-articulated and implicit. Instead it points to a need to study these approaches and explore how they could perhaps be incorporated into and integrated with more modern approaches. Once again, this is particularly salient in developing countries where there is often a tension between the modernizing effects of technological progress and the sociocultural fabric of the society. Cultural anthropology could contribute substantially in this regard, as exemplified by the work of Mary Douglas on cultural perceptions of risk.

3. Recent trends and directions in TA

Technology assessment has gone through several phases and is still continually evolving. It has to some extent provided positive inputs into the policy process, especially in the U.S., and has attained a certain level of "maturity." Nevertheless, there are many problems and shortcomings in the field and these, combined with the lack as of yet of a paradigm for TA, imply that the field will continue to evolve and change. Some of the trends in TA that have been highlighted in the literature are:

(i) A move towards integrated assessment and relatedly, towards a greater interdisciplinary approach, the latter having both theoretical and methodological implications (Rossini and Porter 1983).

(ii) A trend towards internationalization of the field in the sense of it being applied in different national contexts as well as at the international level (Wood 1982).

(iii) A more cumulative approach to TA, as the body of literature, empirical, theoretical and methodological, and the pool of experience, increases (Martino et al. 1978).

(iv) Increasing institutionalization of TA and the infrastructure for TA, in the form of university departments, societies, journals, meetings and networks of communication (Martino et al. 1978).

(v) The development of more substantive and rigorous "core" knowledge within the field and the subsequent evolution of the field into a well established discipline in its own right (Martino et al. 1978).

While it is not definite that all these trends will materialize in the future, they do indicate where researchers and policy makers view the field as headed. As far as the implications for developing countries are concerned, it is significant to note that both the OTA and the NSF have become more international in their outlook and that the problem of technology assessment in developing countries is receiving increasing attention from researchers in the field. However, whether this means that there will be adequate attention given to such issues as contextual differences and the imperatives of development in the application of TA to developing countries, or whether it will be mainly a simple extrapolation of the field into the international domain, remains to be seen.

III. METHODOLOGIES FOR TECHNOLOGY ASSESSMENT

The methodological aspect of TA has been much discussed in the literature, reflecting a general concern within the field about procedural, methodological and analytical issues in technology assessment. A wide variety of methodological approaches have been adopted in actual assessment reports and these studies have also varied in terms of their emphases on different sets of factors and different bounding approaches.

To a large extent, the problems of methodology are inherent in the nature of TA, given its broad scope and interdisciplinarity and the complexity of the issues involved. However, part of the problem has also been due to some vagueness and inconsistency in the use of the term "methodology". It is frequently used to refer to the various stages in the assessment process, but it is also sometimes used to refer to the analytical techniques that are used in TA or to the manner in which the TA is organized and managed.

Taken in a broad sense, TA methodology should include all these aspects but with their different roles clearly delineated. It should also include the process whereby a study is defined and bounded. Hence, a TA methodology should cover:

1. the major stages in the assessment process, including study bounding and definition.

2. the organization and management of TA.

3. the analytical techniques used in TA.

We shall examine the first two in this section and discuss specific analytic techniques in the next.

1. Major stages in the assessment process

There have been several proposed structures for technology assessment listing what are considered the key stages in the TA process. The most well known are those proposed by Jones (1971), Coates (1976), Armstrong and Harman (1977) and Porter, Rossini and Carpenter (1980). These are presented together in Figure 1. The Porter et al. (1980) framework tends to be the most comprehensive in the sense of incorporating the main elements of the earlier studies, but there is in any event considerable congruence between the different frameworks.

The frameworks described are not intended to be rigid prescriptions for the conduct of a TA, but rather to indicate the various foci and elements in an assessment process. Depending on the particular circumstances of the study, some stages may require more attention than others.

Following the Porter, Rossini and Carpenter (1980) framework, the various stages of an assessment are described below:

(i) Problem definition

Although all the frameworks include this as an important component, it is in many ways a prior activity to the actual assessment, since it sets the stage for subsequent TA

FIGURE 1: STAGES IN TECHNOLOGY ASSESSMENT

Porter et al. (1980)	Jones (1971)	J. Coates (1976b)	Armstrong and Harman (1977)
Problem definition	Define assessment task	Examine problem statements Identify parties interest	Bounding the assessment domain
Technology description	Describe relevant technologies	Specify systems alternatives Identify macro-system alternatives	Data acquisition
Technology forecast			Technology projection
Social description	Develop state-of-society assumptions	Identify exogenous variables or events	Whole societal futures Societal values
Social forecast			
Impact identification	Identify impact areas	Identify possible impacts	Impact criteria selection
Impact analysis	Make preliminary impact analysis	Evaluate impacts	Predicting and assessing impacts
Impact evaluation			Impact comparisons and presentations
Policy analysis	Identify possible action options Complete impact analysis	Identify decision apparatus Identify action options for decision apparatus	Policy analysis
Communication of results		Conclusions (and possibly recommendations)	Validation, and public participation

Source: Porter, Rossini & Carpenter (1980).

activities. This component involves the proper specifications of the problem to be studied and the establishment of limiting parameters on the study (bounding). There is widespread agreement in the field for the necessity to limit explicitly the scope of an assessment since there is a strong likelihood of the study becoming increasingly complex and cumbersome.

This stage also involves examining critically the need for the assessment in the first place and focusing the assessment on a specific and useful subject. Questions about the need for the output of the TA, the significance of the problem, the basic assumptions in the study and particularly about the parties at interest (the "stakeholders") need to be raised during this phase.

The bounding activity is primarily intended to allow the work to proceed systematically and within the given resource constraints. Six areas or parameters that can be used to bound studies have been suggested by Berg (1975):

(a) Time horizons

(b) Spatial/geographical scope

(c) Institutional scope

(d) Technology and range of applications

(e) Impact areas/sectors

(f) Policy options.

In addition, the assessors must also decide on limits with regard to the sources of inputs for the study and determine who will be the users of the final output.

Bounding is not a one-shot event, but a continuous process of fine-tuning as the study progresses with the flexibility to react to new developments as they occur.

Armstrong and Harman (1977) argue that it is conceptually useful to recognize bounding constraints as arising from three major driving forces:

(a) the TA sponsors

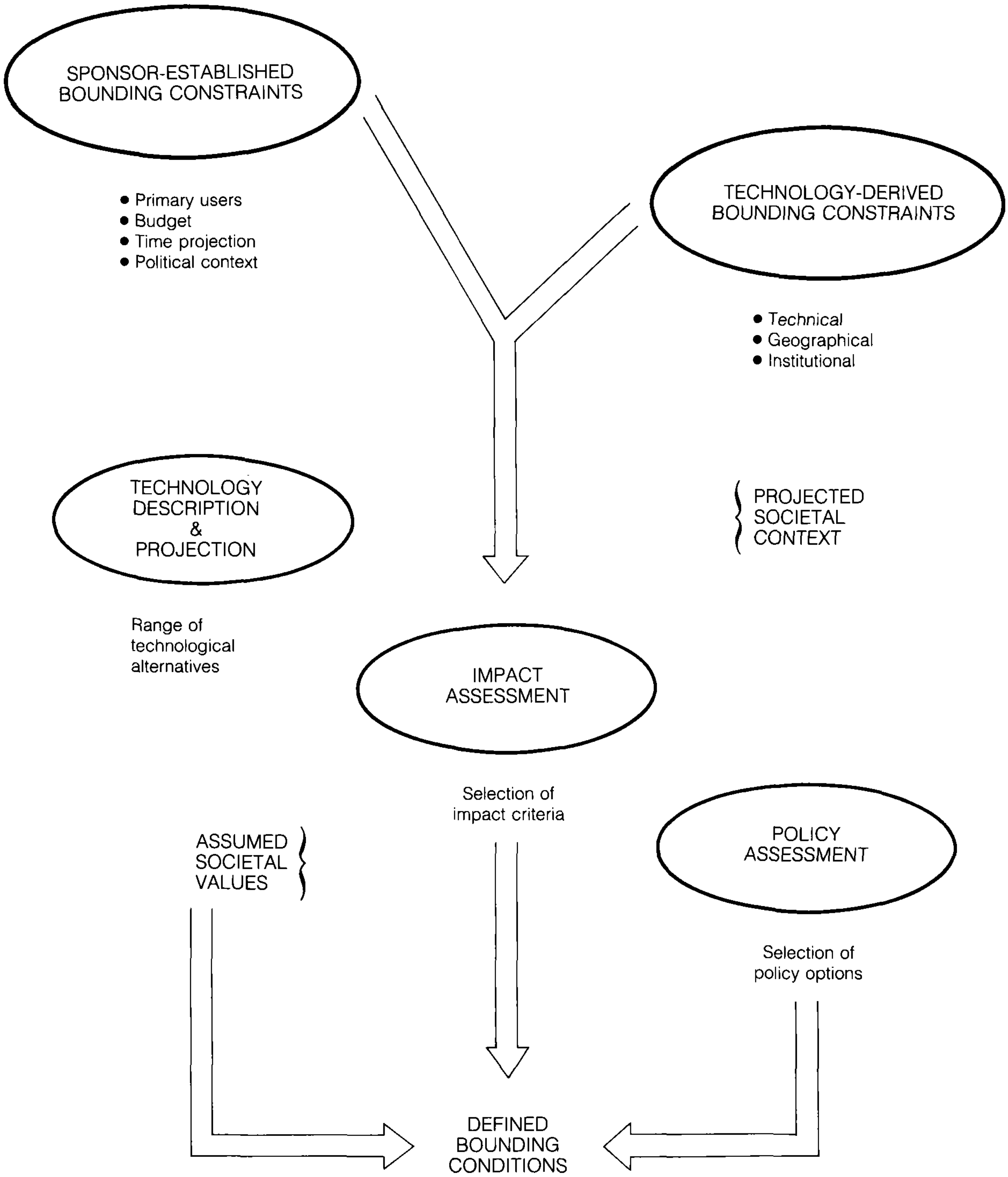
(b) the technology, its development and projected span

(c) the choice of projected societal value structures.

> The sponsor typically identifies the major thrust and intended users of the assessment (which in turn reflects how the need for the assessment emerged to complement or supplement other ongoing efforts) and, of course, provides budgetary and political limits to which the effort must conform. The assessment team has a responsibility to insure the bounding constraints admit logical and feasible projections of the subject technology, a responsibility which could require an extension or relaxation of sponsor-suggested constraints. The sponsor and assessment team share responsibility to project a range of future societal contexts to include those judged feasible and consistent with the projected technology and which, of course, must be adjusted to conform to budgetary constraints and needed assessment priorities.
>
> (Armstrong & Harman 1977, p. 28)

Figure 2 shows how the various elements in the bounding process are interrelated.

FIGURE 2: CRITICAL ELEMENTS IN THE PROCESS OF BOUNDING A TECHNOLOGY ASSESSMENT



Source: Armstrong & Harmon (1977).

One of the approaches used in bounding is what Porter et al. call a "microassessment", which is a quick and rough attempt at the overall assessment, given easily available data and accomplished in a fairly short time period.

(ii) Technology description

Early prescriptions for TA, such as Coates (1976) and Jones (1971), gave considerable importance to technology description. Once the problem definition and bounding tasks are over this constitutes the first major functional element of TA. It is also often the assessment task for which the most data exist. The major objective of this stage is to develop a comprehensive description of the technology that is to be assessed and project its development into the future. Armstrong and Harman (1977) identify three main elements to this task: (a) bounding, (b) data acquisition, and (c) technology forecasting. On the other hand, Porter et al. (1980) describe technology description and forecasting as distinct but inter-related stages and treat bounding in the first stage. In both cases, nevertheless, data acquisition is the major component of technology description.

The data in mind here are those that relate specifically to the technology per se and not to its potential impacts. Broad data about the general features of the technology need to be combined with more detailed information on those dimensions most crucial to the assessment. In this sense, a useful starting point is to describe the technology along the dimensions suggested in Figure 3, which is drawn from Porter et al. (1980).

(iii) Technology forecasting

Projecting into the future and formulating several mutually exclusive technological alternatives is essential for a comparative impact and policy analysis to be made. The projections are not intended to reflect which choices are most likely, but to present the range of feasible choices, so as to permit impact evaluations and determine secondary and higher order impacts for a range of alternatives.

A number of techniques are available for technological forecasting which are discussed in the next section. Prior to selecting and using these techniques, however, there are five concerns that have been identified as important to recognize (Armstrong and Harman 1977):

(a) Deciding the relative emphasis to put on projecting past trends as compared with defining desirable future objectives toward which to develop a technology.

(b) Determining limits for high- and low-level technological alternatives.

(c) Choosing the time intervals by which alternatives are "grown" from the present to the projected future time period.

(d) Choosing how to describe technological alternatives.

(e) Inclusion of models or simulations to aid technological alternative generation.

FIGURE 3: EFFECT OF FOUR ASSESSMENT DIMENSIONS ON TECHNOLOGY DESCRIPTION AND FORECASTING

Assessment dimension	Characteristics
Technology-oriented	Projection of a single technology along alternative paths
vs. Problem-oriented	Comparison of characteristics of several different technologies; projection of several technologies
Physical technology	Technical feasibility limits alternative choices; policy not heavily involved
vs. Social technology	Political feasibility limits alternative choices; alternatives often closely related to policy options
Existing technology	Feasible alternatives limited by polarization of interest groups; innovative alternatives difficult to introduce
vs. Emerging technology	Possibilities of innovative alternatives; relatively long time frames necessary and hence high uncertainty in forecasts common
Major intervention	Technological alternatives interact strongly with social projections; policy thrusts likely to be inherent in alternatives
vs. Minor intervention	Technological alternatives relatively independent of social projections

Source: Armstrong and Harman (1977: pp. 102-12).

Following this, a variety of approaches can be used to gather further and richer data - checklists, as suggested, for example, in the Jones (1971), study, personal interviews with experts in the field, literature searches, conferences and workshops and mailed questionnaires/surveys. In this regard, a review of a number of TA studies by Armstrong and Harman (1976) found that personal interviews with knowledgeable persons was the most common source of such data.

(iv) Social description

Since the core purpose of TA is to examine the effects of technology on society, it is appropriate and necessary to describe the society within which that technology exists. Particular attention needs to be given to those elements which will most likely be affected by the technology, or vice versa, affect the technology.

There are three levels at which the description of society can be expressed. The first describes the basic assumptions about the state and stability of the society, assumptions that can be expected not to have to be changed in the foreseeable future, for example, that there will be no major war, or no major societal shift in ideology or values.

The second level of societal description deals with the macro indicators of that society - the economy, population, industrial and agricultural structures, education, etc. Jones (1971) describes six such categories for societal description: values and goals, demography, environment, social factors, economics and institutional structures. Underlying this level are more specific descriptions of particular aspects of the society that are important for that particular assessment. These may include more geographically specific data, or data about particular social groups or economic strata.

In addition to these factors, Martino (1978) also suggests the need to describe the ideological and symbolic elements of a society, particularly those elements that have implications for technology, for example, a concern over decentralization, as embodied by the proponents of appropriate technology.

The state of the art of societal description is very low, partly due to a lack of good conceptual frameworks about the interaction between society and technology and also partly because little attention has been given in the past to this aspect of technology assessment. In the context of developing countries, a proper description of the state of society is essential for two reasons: the socioeconomic characteristics of these countries are quite different from the developed countries and must be recognized as such, and secondly, developing countries differ among themselves in terms of their social, cultural and economic characteristics. In this regard, there are efforts underway in UN agencies and universities to develop context specific indicators of development and specifically of those aspects of society which are most relevant in terms of technology.

(v) Societal forecasting

Technology assessment depends very centrally on having some sense of the future state of society, since the nature and extent of the potential impacts will be a function of the specific characteristics of that society at that time. There has been considerable research on this subject, generally falling under the category of "futures" research. Armstrong and Harman (1977), identify four basic principles that underly this body of research:

(a) The tendency of social systems to exhibit continuity, especially in terms of their social and culture fabrics, even during periods of disruption, such as wars and revolutions.

(b) Social systems tend to exhibit self-consistency and have strong cohesive forces that make it difficult for tensions to persist and grow for extended periods without some resolution.

(c) Social systems are comprised by "stakeholder" groups which can lead to tensions and conflicts and thereby be a source of change.

(d) There are cause-effect relationships within a society which allow logical conclusions to be drawn from the occurrence of certain events. For example, a rise in prices will tend to decrease consumption of a good.

While these are basic concepts about societal behaviour, they do have their limitations, particularly in the case of developing countries. There is a high frequency of societal disruption in many such countries, which brings into question the assumption of continuity. Similarly, there are serious internal contradictions within many developing countries, for example between the modernizing elite and the rural poor, or in the marketplace in terms of pricing and distribution, which makes the value of using self-consistency as a basis for societal projection somewhat dubious. The predictability of cause-effect relationships is also subject to questioning in these societies. The failure of national planning efforts in many countries can be attributed to a mistaken assumption about the reliability of such cause-effect relations and indeed much of the more critical work on development theory has been precisely aimed at addressing the limitations of such an instrumental perspective on socioeconomic development.

While the need for good societal forecasting is recognized, in practice there are very few useful models. Two approaches that do tend to be used are cross-impact analysis and scenario construction, but both have limited applicability. By and large, the typical situation is that the societal future remains an invisible implicit backdrop against which the TA is cast (Armstrong and Harman 1977, p. 79).

(vi) <u>Impact identification</u>

After the tasks of problem definition, bounding and technology and society description and forecasting, the next major functional activities in a TA have to do with the impacts of the technology. These consist of impact identification, analysis and evaluation. While described here sequentially, Porter et al. point out that they should proceed together iteratively since there is considerable interaction between the various activities.

Impact identification largely consists of systematically producing knowledge about the technology and society in question in order to assess the range of consequences that will result from particular technological development patterns. Two types of approaches can be used: reductionist or holistic (Porter et al. 1980). In the reductionist approach, the totality of impacts are broken down into smaller groupings according to preselected criteria. Commonly used criteria are (Armstrong and Harman 1977):

(a) <u>Scientific discipline</u>: Impact areas are broken up into disciplinary groups which coincide with the disciplinary areas represented in the technology assessment team. For example, the range of impacts to be analysed for a TA could be categorized as: environmental, sociological, legal, economic, technical, political, institutional, psychological and cultural. Variants of this approach can focus on a smaller subset, or give more emphasis to some of the disciplines, depending on the exigencies of the situation.

(b) Arrangement by stakeholder groups: In this approach, the focus is on the parties which will be affected by the technology. This approach has been favoured in TAs where public input and review are considered important. The major problem in this approach is to identify and clearly define the various potentially impacted groups. Several techniques have been suggested for this purpose: use of newspapers, legal records, property titles, memberships in specific associations, historical reviews of certain events and interviews or surveys.

(c) Arrangement by functional dimensions of the technology: The overall technology can be divided into sub-elements and the impacts associated with each of these could be treated as a separate category.

(d) Arrangement by logical categories: An *a priori* logical analysis of the possible impacts that can be associated with the technology can be used to categorize the impacts for a TA. There are various techniques available for this purpose, including morphological analysis, checklists and relevance trees.

Holistic strategies are those which allow the field of impacts to emerge in the course of the study, without the use of prestructured categories. While potentially more flexible and comprehensive, the major problem with holistic techniques is that they can result in a lack of focus in the TA.

An important consideration in the impact identification process is the choice between scanning techniques which use a direct, intuitive, single-stage approach, and tracing techniques, which use an indirect, sequential and multistage approach (Chen and Zissis 1975). Scanning involves a search process to ensure that major and significant impacts will not be excluded from the assessment. There is considerable reliance on the researchers' imagination and intuition. In tracing techniques, a chain of events or impacts are identified in logical or chronological sequence, with each step being made explicit. Tracing techniques include impact trees and theoretical modelling (Chen and Zissis 1975).

A final consideration in the impact identification stage is the question of the human resources that are used. The choices here include single individuals *versus* teams or groups for inputs about the impacts to be studied, use of internal personnel *versus* using outside resource persons, and the use of representatives from potentially impacted parties versus "non-interested" or third parties.

These various issues and their implications for the selection of techniques are summarized by Porter et al. (see Figure 4). The choice of a particular technique or set of techniques needs to be based on an appraisal of the appropriateness to the particular problem at hand as well as the time and resource constraints for the study.

FIGURE 4: CHARACTERISTICS OF SELECTED IMPACT IDENTIFICATION TECHNIQUES

METHOD	Tracing/scanning method	Time requirements	Resource requirements	Use of external resource people	Degree of input quantification	Degree of output quantification	Chapter where discussed
Modelling	T	H	H	*	H	H	9
Surveys	S	*	*	Required	L	*	6
Delphi	S	M-H	*	Required	L	L	6
Literature research	S/T	*	L	L	L	*	
Historical analogies	T	L	L	L	L	L	7
Scenarios	T	L	L	M	L	L	7
Matrix approaches	S	M	M	*	L	L	8,9
Checklists	S	L	L	L-M	L	L	8
Morphological analysis	S/T	M	M	*	*	*	8
Relevance trees	T	*	M	M	L	L	8,14
Brainstorming	S	L	L	M	L	L	1

Legend: S, scanning method; T, tracing method; L, low; M, medium; H, high; *, variable - depending on scope or intent of application, or expertise and composition of team.

Source: Porter et al. (1980).

Porter et al. (1980) also list four criteria for judging the importance of the impacts that have been identified so that the impact field can be narrowed down:

(a) Centrality of the impact in terms of its significance to the stakeholders, policy-makers and sponsors associated with the TA.

(b) Resource requirements for the study of the impact in sufficient depth for meaningful policy analysis.

(c) Cognitive limitations associated with an impact based on the data that are available, the coherence of the relevant conceptual frameworks and the uncertainties that might be associated with the analysis.

(d) Political factors, in the sense of the political content of the impact and of the relative political importance of an impact over other impacts.

(vii) Impact analysis

Once the impacts have been identified and narrowed down for study, impact analysis can be undertaken. This involves the assessment of each of the impacts in terms of their significance, probability, timing, costs, affected parties, and an evaluation of the second and higher order impacts that may result. In many ways, impact analysis is the main body of a TA and involves a wide variety of activities and techniques. In the past, there has been a tendency to emphasize the use of formal models in the impact analysis process but, as Armstrong and Harman (1977) note, sophisticated quantitative techniques are not necessarily the best means of analysis.

Impact analysis includes the analysis of the overall impacts of a technology as well as more specific analyses, such as of the environmental, economic, institutional, technological and psychological impacts.

Armstrong and Harman (1977), describe three general approaches to impact analysis:

(a) Scientific disciplines: This refers to the use of specialists in the field to conduct the analysis and, frequently, the techniques used will reflect the established tools of the respective field. For example, economic impacts are estimated by cost-benefit analysis, environmental analysis could use air and water diffusion models and psychological impact analysis may use attitude measures.

(b) Interdisciplinary and futuristic: This covers a large range of techniques developed in various fields - futures research, systems analysis, etc. Some of the more common techniques here are: expert opinion, analogy, modelling, trend analysis and cross-impact analysis and scenarios.

(c) Social impacts: In this approach, the focus is on the broad set of social impacts identified with respect to the technology. Various techniques can be used here: quantitative measures, morphological analysis, expert opinion and polling.

Impact analysis is so centrally a part of TA that much of the research and debate in the field centres around it. There is considerable emphasis on the use of modelling for analysis - even though this has its limitations. These models can be categorized in several ways, of which the scheme suggested by Ayres (1966, cited in Porter et al. 1980), is particularly useful:

(a) Analytic model. The patterns of events can be predicted and explained in terms of more fundamental "laws" with wide applicability (e.g. Maxwell's electro-magnetic theory, Einstein's special and general theories of relativity).

(b) Empirical-phenomenological model. The pattern is adequately predicted by a mathematical formulation with empirically fitted parameters (e.g. Landau's two-fluid quantum model of superfluids).

(c) Quasi-model (more than (d) and less than (b)). Qualitative operational predictions can be tested (e.g. Darwin's theory of survival of the fittest).

(d) Metaphor or analogy. The outlines of coherent patterns are perceived (e.g. the mechanical analogy of an electrical circuit).

(e) Conjecture. Probable positive correlation between some pairs of observations (e.g. weather and sun spots).

The selection of models to use in analysis requires careful deliberation over the context specific characteristics of the TA. The scheme suggested by Howard (1968) to define the problem space for impact analysis is useful in viewing the role of models in this task. Figure 5 shows this scheme, which has three dimensions: degree of uncertainty, complexity and time (static/dynamic). While TAs have in the past tended to lie in the corner - high complexity, uncertainty and dynamic, it could be argued that this is very much inherent in the nature of technology assessment.

There are several advantages to using models: they enable a systematic analysis to be carried with implicit assumptions being made explicit, they offer direction to subjective judgments, they can be replicated and validated and they provide some basis for comparability across TAs. On the other hand, they can be time-consuming and overly complex, often quantitative analyses are not appropriate or even legitimate given available data and it is often difficult to communicate the results of the analysis to persons not familiar with the model, which in turn can affect the credibility of the findings.

(viii) Impact evaluation

The last stage before policy analysis is the evaluation of impacts. This entails the signing of values to specific impacts and involves two elements: criteria and measures (Porter et al. 1980). The criteria are based on the values held by the evaluators or the social groups they represent. The extent to which these criteria are met is determined by measures. For example, the degree of accomplishment of the criteria of income generation could be measured by the incremental change in average income within a group or region.

To some extent, evaluation is implicit in prior stages of the TA process, particularly in the impact identification and assessment stages. In impact evaluation, the underlying assumptions are made explicit and are themselves judged for their effects on the evaluation. Impact evaluation is also concerned with the comparison of impacts and their presentation in a systematic manner.

Several techniques are available for evaluation:* dimensionless scaling, decision analysis and policy capture. The latter technique consists in constructing a mathematical model to parallel the actual decision process; a number of scenarios are prepared in which the factors, assumed important to the judgment, are weighted and varied systematically. It is during impact evaluation that the various pieces of an assessment are pulled together and efforts are made to compare impacts, and the output of the evaluation process becomes the input for policy analysis.

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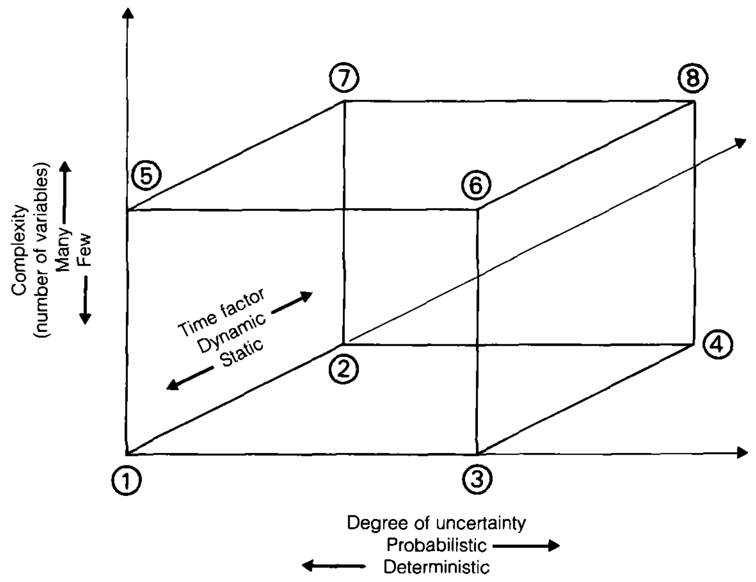
* See Porter, Rossini et al. (1980) for a general review and policy capture; Roper and Dekker (1978) for dimensionless scaling; Sage (1977) for decision analysis; Hamond and Adelman (1976) for policy capture.

FIGURE 5: THE PROBLEM SPACE



Source: Howard (1968).

A primary concern in evaluation is to enhance the objectivity of the assessment, and the extent to which this is achieved depends in part on the approach to the evaluation. Porter et al. (1980) list three different approaches to evaluation:

(a) carried out by the assessment team alone, in which case the underlying values, biases and experiences of the team members need to be systematically elucidated,

(b) stakeholder representations, via team role-playing, conferences, feedback, interviews with stakeholders, or direct participation,

(c) advocacy impact assessment, where the stakeholder groups assess the development from their own perspectives.

(ix) Policy analysis

The ultimate goal of TA is to provide useful inputs to the policy process. In turn, the objective of policy analysis is to present policy makers with a comparative analysis of the full set of feasible options that are available to achieve some desirable goal with respect to the technology. Armstrong and Harman (1977) identify two levels of this analysis process: the first level is concerned with specific policy options for implementing each feasible alternative, and the second level is concerned with identifying and assessing the general uncertainties, obstacles, concerns and conflicts that might be associated with the technology under consideration.

The first level policy analysis consists of four steps:

(a) Formulation of feasible policy options through which to implement each technological alternative.

(b) Comparative analysis of the options by making use of the impact assessment for each alternative and including additional impacts which might be caused by the implementation of that particular policy option.

(c) Synthesis of the best or optimal option or combination of options for each technological alternative.

(d) Presentation of a summary comparison of the optimal alternatives so as to present a set of feasible alternative paths through which a technology can be developed.

Policy analysis is an iterative process which is conducted throughout the course of the TA, as the initial data begin to be analysed. By the end of the assessment, a comprehensive policy analysis should be able to provide the decision maker with a fairly substantial, realistic and objective description of the various available alternatives, their implications and their feasibilities.

(x) Communication of results

The communication of the results of a TA to the various concerned parties remains one of the most serious and challenging tasks in TA. There are a large number of problems in this process, but effective communication of results is essential to the success, indeed to the very legitimacy of the assessment. The objective of communication is to present the substance of the TA in an easily comprehensible fashion. Martino (1978) summarizes some of the main issues facing the TA field with respect to communication.

(a) Communicating policy-relevant results: TA is ultimately a policy tool and it is therefore imperative that the results are communicated effectively to policy-makers. Specifically, the policy-maker needs to know what are the advantages and disadvantages of the different paths or options for a particular situation; what the consequences of each option will be, including the higher order consequences, and what might be some of the obstacles to successful implementation of different options. It is also important for the policy-maker to understand the system that pertains to the technology under study. Also to be communicated to the policy-maker is information about new options which might have been created during the course of an assessment. Furthermore, it is necessary to inform the policy-maker about the discounting implicit in certain choices and trade-offs between present and future benefits and costs. This type of information is critical in making choices about the timing of certain decisions and policy actions.

(b) Project-related communication: During the course of the TA, certain features of the process need to be communicated to the team members. This includes information about the bounding parameters of the study, so that individuals do not exceed the set bounds. This information also needs to be communicated to the sponsor of the TA. Project-related information that originates from the public or stakeholders also needs to be communicated to the team members and the sponsor.

(c) Mechanics of communication: There has been considerable concern over the lack of communication of the results of a TA to the relevant audiences, and part of the reason is that this is a difficult activity. Some of the recommended techniques to enhance the quality of such communication include use of quantitative, though simple, indicators and measures to describe impacts, the organization of the findings in formats or categories that reflect the divisions within the audience for the TA (e.g. by stakeholder group, impacts area, etc.), and the use of schematic or tabular presentations wherever possible.

Martino (1978), also describes some of the major barriers that have hampered effective communication in recent TAs.

(a) Sensitivity of issues: Many TAs deal with sensitive issues and should the findings be potentially controversial, their communication could present a problem.

(b) Probabilistic analysis: Many users of assessments tend to be unfamiliar with the probabilistic techniques used in TA and risk analysis. Emphasizing more deterministic approaches may serve to overcome this barrier.

(c) Assumable risk: A communication barrier may arise between the technology assessment team and assessment user from the fact that the user may be making a choice on behalf of a constituency and he may be unwilling to assume a risk on the behalf of this constituency, even if he personally is willing to assume the risk.

2. Organization and management of technology assessment

Given the nature of technology assessment, its breadth, the complexity of the problems it is designed to address and the interdisciplinarity of the field, organizing and managing an assessment is an extremely difficult activity. As such, management and organizational problems in TA are to a large extent dealt with as part of the TA field, and a number of recommendations have been made for the effective management and organization of a TA.

Several issues have been identified as particularly important in the management and organization of a TA. Porter et al. (1980) categorize them into those relating to the structural features of the TA and those pertaining to process characteristics. Structural features include:

(a) Boundary conditions: The character of the subject matter of the TA affects the conduct of the study. Highly technical topics may present more problems than subjects that are relatively simple technically. Budgetary resources for the study are also important since they will determine the extent to which trade-offs have to be made, the equipment that can be used, the time duration of the study and the number of personnel. The organizational context of the study, whether it is designed for interdisciplinary or interdepartmental work and interaction, the extent of formalization of procedures, the organizational hierarchy and the relationship between the TA unit and other organizations all can affect the conduct of an assessment.

(b) Project team characteristics: The leadership style of the team manager has an important influence on team effectiveness, with democratic and participatory styles being associated with more successful assessments. The size of the core research team influences such factors as the patterns of communication in the team, team cohesiveness, division of labour and overall team capability. Differences in the experiences, disciplinary specializations and research approaches will also influence patterns of communication, selection of techniques, motivation and team stability.

Process features that are important in a TA include:

(a) Project scheduling: This includes bounding the study, scheduling the main activities and milestones and establishing criteria for schedule reviews. Gantt charts, PERT and CPM, milestone charts and network techniques are useful in this context.

(b) Communication patterns among the project team: To some extent these can be influenced by designing the team in a particular manner. Smooth communication is essential to a TA, especially when it involves several different disciplines and analytical dimensions. Certain types of structures are conducive to particular types of communications, and are best suited for certain types of tasks. Selecting the proper structure requires analysing the types of activities that the TA entails, the desired types of communications and changing requirements over the duration of the TA.

(c) Integration: TA requires that the various activities - forecasting, analysis, description, etc. - be fully integrated despite the inherent tendency towards fragmentation because of the complexity of TA. Different approaches to enhancing integration have been proposed: common group learning, where the team as a whole undergoes a learning experience, the use of models to integrate diverse information, delegation of specialized tasks, negotiation among experts, and integration by the team leader.

In general, the management and organization of a TA have to be undertaken on an *ad hoc* basis. Certain general prescriptions have been made, but the ultimate success of a TA will depend on how well the study is designed given the specific contextual situation. The key problem, in most cases, appears to be that of integrating an interdisciplinary team (Chubin et al. 1979).

IV. ANALYTICAL TECHNIQUES

A substantial range of techniques has been developed or adapted from other fields for use in the various stages of assessment. They range from extremely sophisticated quantitative approaches to subjective and qualitative procedures. Each technique is relevant for one or a few tasks in technology assessment, and improvements in existing techniques or the development of new techniques are continually underway. To describe the details of each technique is beyond the scope of this review. Instead, the most important current techniques will be mentioned and their relative merits and demerits described. Since the selection of analytical techniques is an important, if not crucial, component of TA, criteria for the choice of techniques will also be discussed.

1. Major analytical techniques

Dobrov (1978) correctly notes that there is no known list of TA techniques that can be said to be complete. Similarly, there is no one universally good method for all TA applications. Figure 6, drawn from Coates (1976a) lists many of the major techniques for TA and indicates the specific application areas for which each is relevant. Figure 7 is a more recent listing of techniques and their applications drawn from Porter et al. (1980). It also has the advantage of providing key references for each technique.

FIGURE 6: ELEMENTS IN A COMPREHENSIVE TECHNOLOGY ASSESSMENT

	Steps in an assessment of technological systems											
	1	2	3	4	5	6	7	8	9	10	11	12
Study techniques	Structuring the problem	The systems alternatives	Possible impacts	Evaluating impacts	Identifying decision-makers	Identifying possible action options for decision-makers	Parties at interest	Macro systems alternatives	Exogenous variables state of society	Conclusions and recommendations	Participation of parties at interest	Presentation of results
Historical surveys	*	*	*		*	*	*	*	*	*		
Input/Output	*			*			*					*
Compilation of prior work	*	*	*	*	*	*	*	*	*	*		*
Cost-benefit	*			*			*					*
Systems analysis	*	*	*	*		*		*				
Risk-benefit	*			*			*					*
Systems engineering	*	*	*	*				*				
Simulation	*	*	*	*			*		*		*	*
Experts panels, workshops	*	*	*	*	*	*	*	*	*		*	*
Modelling	*	*	*	*			*		*		*	*
Hearings	*	*	*		*	*	*	*	*	*	*	*
Interpretive structural modelling	*				*		*			*	*	*
Field on-site investigation	*		*	*	*		*				*	
Signed digraph	*		*	*	*	*						*
Trend extrapolation and analysis			*	*					*			
Physical models			*	*								*
Delphi	*	*	*	*	*	*	*	*	*		*	
Scenarios/games	*	*	*	*	*	*	*	*	*	*	*	*
Cross impact	*	*	*	*		*			*		*	
Moot courts			*	*	*	*	*			*	*	*
Check lists	*	*	*		*	*	*					*
Telecommunication participation			*	*	*	*	*		*	*	*	*
Morphological analysis	*	*						*				
Syncons			*	*	*	*	*	*	*	*	*	*
Historical analogy	*		*	*	*	*	*		*	*		
Survey techniques				*			*		*	*	*	*
Decision/relevance tree	*	*	*	*	*	*						*
Ballots				*			*		*	*	*	*
Fault tree	*		*	*								*
Decision theory				*		*				*		*
Scaling				*					*	*		*
Brainstorming	*	*	*		*	*	*	*	*	*	*	
Graphics				*							*	*
Judgment theory				*		*				*		
Dynamic modelling	*	*	*	*					*	*		*
KSIM	*	*	*	*				*	*	*	*	*

Source: Coates (1976a).

FIGURE 7: ASSESSMENT TECHNIQUES

Technique description	Characteristics	Uses	References
Brainstorming/a group or individuals generate ideas with no criticism allowed	Group or individual Scanning Global inquiry Unstructured	Problem definition Generating lists of potential impacts, affected parties, policy sectors, etc. Performing micro-assessments	Ayres, 1969 Sage, 1977
Interpretive structural modelling/Directed graph representation of a particular relationship among all pairs of elements in a set to aid in structuring a complex issue area	Group or individual Scanning/tracing A-priori inquiry	Developing preliminary models of issue areas Impact evaluation	Malone, 1975a, 1975b Sage, 1977 Watson, 1978
Trend extrapolation/A family of techniques to project time-series data using specified rules	Individual Tracing Empirical inquiry	Technology forecasting, both parameter changes and rates of substitution	Hencley & Yates, 1974 Mitchell et al., 1975 Ayres, 1969 Bright, 1978
Opinion measurement/A variety of techniques (including survey, panels, and Delphi) to accumulate inputs from a number of persons, often experts in an area of interest	Group Scanning/tracing Empirical inquiry	Technology forecasting and description Social forecasting and description Impact identification Impact analysis, especially social	Linstone & Turoff, 1975 - on Delphi Warwick & Lininger, 1975 - on survey
Scenarios/Composite descriptions of possible future states incorporating a number of characteristics	Individual or group Scanning Synthetic inquiry Largely qualitative	Social forecasting Technology forecasting Impact analysis Policy analysis Communication of results	Hencley & Yates, 1974 Bright, 1978 Mitchell et al., 1975
Checklists/Lists of factors to consider in a particular area of inquiry	Individual Scanning Synthetic inquiry	Impact identification Policy-sector identification	Leopold et al., 1971 Warner & Preston, 1974
Relevance Trees/Network displays that sequentially identify chains of cause-effect (or other) relationships	Individual Tracing A-priori inquiry	Impact identification and analysis	Hencley & Yates, 1974 Bright, 1978

Cross-effect matrices/ Two-dimensional matrix representation to indicate interactions between two sets of elements	Individual Scanning Synthetic inquiry	Impact identification and analysis Analysing the consequences of policy options	Bright, 1978 Kruzic, 1974 - on KSIM Linstone & Turoff, 1975 Sage, 1977
Simulation models/ Simplified representation of a real system used to explain dynamic relationships of the system	Individual Tracing A-priori inquiry Formal and quantitative	Technology forecasting Impact analysis	J. Coates, 1976a Wakeland, 1976 - compares KSIM, QSIM, & Dynamo Sage, 1977
Sensitivity analysis/ A general means to ascertain the sensitivity of system (model) parameters by making changes in important variables and observing their effects	Individual Tracing Synthetic inquiry Quantitative	Impact analysis Policy analysis	Leininger et al., 1975
Probabilistic techniques/Stochastic properties are emphasized in understanding and predicting system behaviours	Individual Tracing Empirical inquiry Often requires opinions of subjective probabilities	Technology forecasting Impact analysis Impact evaluation	Gordon & Stover, 1976 Gohagen, 1975
Cost-benefit analysis/ A set of techniques employed to determine the assets and liabilities accrued over the lifetime of a development	Individual Scanning/Tracing Synthetic inquiry In broadest case, mixes quantitative & qualitative factors	Economic impact analysis Environmental impact analysis	Sassone & Schaffer, 1978
Export base models/ Estimates regional changes through a multiplier applied to the development in question	Individual Tracing Synthetic inquiry Quantitative	Economic impact analysis	Tiebout, 1962 Isard, 1960 Richardson, 1969 Sage, 1977 - on input-output analysis
Decision analysis/ Formal aid to compare alternatives by weighing the probabilities of occurrences and the magnitudes of their impacts	Individual Tracing Synthetic inquiry	Impact evaluation Policy analysis	Bross, 1965 Howard et al., 1972, an example Sage, 1977

Policy capture/A technique for uncovering the decision rules by which individuals operate	Group Tracing Empirical inquiry	Impact evaluation Policy analysis	Hammond & Adelman, 1976

Source: Porter et al. (1980).

Figure 7 also denotes the characteristics of each technique in terms of (a) whether it involves an individual or group; (b) whether it is a scanning or tracing technique; (c) the scope of the technique; (d) whether it is qualitative/quantitative; and (e) the mode of inquiry, and gives a brief description of each technique.

Even though there is such a large variety of available techniques, most have been relatively ignored by TA practitioners. Some of the reasons given are that they are too formal, or not suited to the problem at hand. Many of the techniques also have not been properly validated. However, Balachandra (1980) evaluated the perceived usefulness of some of the more commonly used techniques and the results of his research are shown in Figure 8. Of those techniques that were assessed, brainstorming, expert opinion and trend extrapolation were perceived to be the most useful, which indicates a preference for qualitative and somewhat less formal approaches among practitioners.

FIGURE 8: FREQUENCY OF USE AND PERCEIVED USEFULNESS OF DIFFERENT TF TECHNIQUES

No.	TF technique	Not used 1	Less useful 2	Moderately useful 3	Useful 4	Very useful 5	Not Used	Weighted usefulness measure
1.	Brainstorming	6.8*	15.5	26.2	11.7	13.6	26.2	2.24
2.	Expert opinion	-	3.9	18.4	31.1	26.2	20.4	3.18
3.	Scenarios	4.9	8.7	18.4	17.5	3.9	46.6	1.62
4.	Delphi	10.7	9.7	14.6	9.7	2.9	52.4	1.17
5.	Trend extrapolation	1.9	8.7	24.3	27.2	4.9	33.0	2.24
6.	Signal monitoring	5.8	7.8	15.5	14.6	6.8	49.5	1.55
7.	Morphological analysis	14.6	11.7	5.6	2.9	-	65.0	0.52
8.	Relevance trees	13.6	10.7	10.7	5.8	1.0	58.3	0.82
9.	Cross-impact analysis	9.7	9.7	9.7	8.7	2.9	59.2	0.98
10.	Simulation	6.8	8.7	11.7	15.5	2.9	54.4	1.29

* Percentage of total respondents.

Source: Balachandra (1980).

While the final selection of techniques for a specific TA must be based on the assessor's judgement, Porter et al. suggest ten guidelines or criteria which would prove useful in this selection (Figure 9).

There have been some attempts to go beyond these known techniques and to develop more integrated and systematic approaches to TA. Linstone et al. (1981) for example, describe the "multiple perspective" approach which is not a technique per se but a particular way of approaching the TA problem which involves using organizational/societal, personal/individual and technical perspectives simultaneously. Merkhofer (1982) suggests a decision analysis based process for technology assessment which attempts to extend the conventional knowledge base by combining methods of TA with principles of decision analysis.

FIGURE 9: METHODOLOGICAL CONCERNS IN SELECTION OF TECHNIQUES

Inferential power	Distinguishes effects of the technology in question from effects due to other causes or to interacting causes; suitable for the assessment design to yield causal understanding.
Assumptions	Explicit as to assumptions and criteria employed; robust, not overly sensitive to analytical assumptions that do not fit the real situation.
Resources required	Type of data required (necessary precision, accuracy, and level of quantification) is available; sampling principles and practicalities consistent with the TA/EIA assignment; costs of data retrieval and computational procedures are tolerable; special skills available; available time to perform the analysis.
Objectivity	Emphasis on objective measures.
Reproducibility	Insensitive to analysts' biases; reliable in character.
Uncertainty	Indicates degree of confidence, likelihood of indicated results.
Specificity	Identifies specific indicators to be measured; provides for the measurement of impact magnitude; distinguishes effects on different geographical or social groups (distributional effects).
Comprehensiveness	Generalizable across the range of technologies, different scales, and impact types under consideration; suitable for the entire time frame of interest.
Comparisons	Suitable for comparing all the alternatives of interest; provides a means for reasonable aggregation of impacts of different types to allow desirable comparison.
Communicability	Suitable for involvement of lay persons in analysis or interpretation; provides a format for communicating results, highlighting key issues.

Source: Porter et al. (1980).

V. KEY ISSUES AND PROBLEMS IN TECHNOLOGY ASSESSMENT

Though technology assessment has gathered considerable momentum in the past decade and a half, the field is still characterized by many problems and has been criticized on theoretical, methodological and ideological grounds from a variety of perspectives, both from within and outside the TA community. This section describes the main issues and problems in TA at the present and what they may imply for the future of the field.

1. Technical perspectives in TA

One of the most serious problems in TA work has been the difficulty associated with the inclusion of non-quantifiable data. TA methodology has placed a disproportionate emphasis on formal, quantitative analytic techniques and there has always been an implicit sense that quantitative data are preferable and "more scientific" than qualitative information. Yet, many of the problems that TA seeks to explore and resolve are not completely understood and hence amenable to structure, nor are the variables of concern always quantifiable. There is a need, as White (1974) suggests, to examine the "imponderables" in the analysis of the impacts of technological developments.

To some extent, the preference for quantitative data and analysis is due to the relative lack of adequate tools and concepts for dealing with "softer" data. Partly, the desire to produce coherent and clear-cut assessments leads to a pressure to present conclusions in numerical form. One reason is that the background of many TA researchers and practitioners is in science and engineering or systems analysis, all of which lean heavily towards quantification.

Hoos (1979) argues further that the prevailing "systems analysis" paradigm underlying TA itself forces TA into a structured and thus distorting framework that precludes consideration of social and cultural dimensions. Indeed it is argued that nobody really knows how to conduct a "social impact analysis." This in turn then relates to the existing view that technology assessment is in fact a technical task that "is rooted in the acquisition, processing and interpreting of data" (Hoos 1979, p. 192). TA in this light can be seen as representing the bureaucratization of social science in the sense that "with the institutionalization of the systems approach has come a subtle shift from problem or substance focus to methodology or technique focus, with the modelling process no longer dependent on the unique entity being modeled" (Hoos 1979, p. 193).

In a practical sense, this implies that TA research is becoming increasingly divorced from the reality of TA practice and the reality which TA is ostensibly designed to study. This, in fact, is confirmed by a study by Rossini et al. (1978) which found that TA practitioners rarely use the techniques developed for TA and in fact have a disdain for them, preferring to rely on their own judgments and intuition in the selection of approaches and in the design of the TA.

A particularly distressing aspect of this trend is the tendency to try to quantify even those variables that are not quantifiable through elaborate procedures of coding, ranking and the like. In particular, Hoos points to the case of cost-benefit analysis, which encourages the assignment of numbers rather arbitrarily to factors that are little understood.

These two aspects of TA, the tendency towards quantification and the overemphasis on methodology have important implications for the use of TA in developing countries. Firstly, even if quantitative analysis per se were acceptable, there is a serious shortage of most types of data in developing countries because information collection and processing capacities are either weak or underdeveloped. Secondly, the categories of data that would be required for a TA may not map onto the categories whereby data are organized in these countries. Thirdly, TA in developing countries must be undertaken with a sensitivity to the exigencies of the contexts of these countries, and the methodology should ideally derive from the situation and problems at hand. The straightforward application of the increasingly context "independent" techniques of TA may not be the most suitable and desirable option. If the techniques of TA receive scant attention from practitioners within the very society from which TA evolved as a body of knowledge, it is very questionable whether they would have much relevance in other, quite different, societies.

2. Political and ideological dimensions of TA

Closely related to the above issues is the question of the ideological and political dimensions of TA. Critiques at this level largely derive from the critical perspectives on modern industrial society of such writers as Marcuse, Habermas, Dickson and Ellul. TA is seen as reflecting the interests of certain classes of society and favouring certain types of social structures in both capitalist and socialist societies. The instrumental rationality underlying TA in particular, and systems analysis in general, is associated with what Dickson (1974), refers to as the "ideology of industrialization," which views social progress as a technical problem that can be accomplished through increased industrialization and rationalization of society. The notion of an "information society" tending towards "perfect rationality" is attacked on the grounds that information itself is not neutral but reflects the interests of certain social groups. The concern in TA over objectivity and validity is seen as an attempt at "scientism," an attempt to give a scientific character to what is eminently a political process.

In one of the more scathing critiques of TA from such a perspective, Wynne (1975) argues that TA is a process that supports and serves to legitimate the concept of consensus politics wherein political issues and conflicts between different interest groups are resolved by "objective" analyses based on scientific percepts. Wynne levels his critique at the concept of science itself in modern society, particularly the policy and social sciences:

> In particular, it (TA) is based crucially upon a fallacious account of knowledge in society, and of scientific technical knowledge in politics. This fallacy is, I argue, encouraged because of the widely expressed view that technology, science and social language are objective and neutral, reflecting no cultural-contextual conditions or values. This lends itself to the highly misleading idea that more knowledge of a situation, more widely disseminated, will lead naturally to the adoption by all concerned, of a consensual view of what the problems are, how they should be attacked, etc., i.e. a single "definition of the situation" will be universally established, by natural law. Cementing this fallacy is the view that rationality is purely a function of technical sophistication rather than a framework of thought and action subordinate to prior, though often implicit, commitments with respect to the purpose and significance of these enterprises.
>
> (Wynne 1975, p. 112)

Hence, the implicit ideological premises in TA as well as the relationship between TA and the political process are seen as far from the rationality and objectivity that is claimed, or desired.

With regard to developing countries, this view is not too different from some of the more critical perspectives on such problems as the choice of techniques. In fact, technology assessment can be seen as a more generalized formulation of the "choice of technology" problem in developing countries. Dickson (1974) and others argue that the choice of technology in developing countries is scarcely a process that follows the lines of economic logic but is more accurately understood in terms of the political interests of various social groups and the imperatives for the reproduction and legitimation of existing social structures and relationships.

If this concept is taken as valid, then it is imperative that these "non-technical" factors - political interests, legitimation interests, etc. - be integrally considered in the TA exercise in developing countries, thus making what is implicit and misleading in the process explicit and understood.

3. Boundary conditions and core assumptions

At a more operational level than earlier issues is the problem of bounding assessments and the inherent limitation of many of the core assumptions in the assessment process. While there have been various suggestions of criteria to guide the bounding of a TA (Lee and Bereano 1981; Porter et al. 1980), it still remains one of the most pervasive methodological and intellectual problems in the field. There is an inherent contradiction between the comprehensiveness of the theoretical literature and the practical limitations of time, resources and knowledge.

In a survey of several NSF-supported TAs, Armstrong and Harman (1977) found that over half the assessments had been seriously hampered by the initial delay in problem bounding and definition. Martino (1978) further identified an unwillingness to bound rather than an inability to do so, and suggested that a major cause for this unwillingness to bound was a reluctance on the part of the researchers to begin their analysis before they had completed the data acquisition.

Ascher (1979) raises a related problem in the practice of TA, that of the limitations that derive from the core assumptions in assessment. Noting that increasingly sophisticated methodology has not been accompanied by greater accuracy, Ascher argues that such methodologies cannot save forecasts and assessments based on faulty core assumptions. For example, mistaken assumptions about declining U.S. birth rates in the 1930s and 1940s led to drastically wrong population forecasts. He identifies three causes for the persistence of faulty assumptions: (a) the overspecialization of TA and TF practitioners, and the simultaneous need to make forecasts in areas beyond their expertise. Unless resources are available to mount fresh studies in other areas, the assessor must rely on older available studies, which may be out of date; (b) the high cost of assessments and forecasts, which forces the analyst to rely on whatever data are available, even if it is obsolete; and (c) the uncertainty about new data - whether it actually represents a new pattern. Short-term deviations from long-term trends may be mistakenly interpreted to indicate a change in a pattern, and hence result in the adoption of faulty assumptions.

Both the bounding and the core assumption problems have important implications for developing countries. Resources are generally in shorter supply in the Third World for activities such as TA, making the need for bounding more imperative. Yet the parameters for assessment are less clearly defined and understood within developing countries and this only compounds the existing difficulty in setting bounds. As far as core assumptions are concerned, there is a substantial lag in the availability of data, partly due to the poor information gathering capacities in these countries, and sometimes because of the enormous size of the populations, as in China and India. In such cases, census data, for example is often obsolete even before it is compiled and released. Techniques need to be developed to anticipate such lags and compensate for them in the information gathering activity.

4. Interdisciplinary issues

The conduct of technology assessment is an interdisciplinary exercise involving specialists from various fields and addressing a range of variables both technical and non-technical. It therefore encounters the problems that are typically associated with interdisciplinarity. The problem is at least in part an epistemological one of having to deal with the different "world views" of different disciplines, but it is also a practical problem in terms of the interactions between team members in an assessment. Martino (1978) describes several problems associated with interdisciplinarity in TA:

(a) Assumptions and standards: Every discipline has its own standards and core assumptions, its own concept of what is science and its own approach to research, and these vary widely, creating considerable problems as far as agreeing on a common approach, or integrating various approaches, is concerned.

(b) Willingness to speculate: Some disciplines are more oriented towards laboratory experiments and empirical research whereas in others there is more space for conceptual and speculative research. Criticisms can emanate from either perspective. For example, charges of empiricism, or contrarily, a charge of esotericism or abstraction. While these are disciplinary differences, they are often rooted in deep-set psychological attitudes on the part of the researcher and are sometimes inseparable from the conduct of research in that discipline.

(c) Attitudes toward data: Some disciplines tend to place a heavy emphasis on data, and there are different views as to what constitutes "good" or reliable data, how much data are enough, and what are legitimate forms of data collection. One of the common conflicts is in the attitude towards quantitative versus qualitative data. The orientation towards quantification associated with TA can create problems for those researchers who place greater emphasis on qualitative data.

(d) Scientific "pecking order": There is an implicit hierarchy among disciplines, even if the representatives of all disciplines do not agree to this hierarchy. It is manifested in terms of the differences in the extent of funding received by different disciplines, differences in salaries among researchers in various disciplines, the social prestige and status associated with a field, etc. This too is a problem with deep-set psychological roots and is inherent in the structure of contemporary science and its relationship to society. It is also a context-specific property, with the hierarchy varying across countries and cultures depending on the priorities of that society.

The problem of interdisciplinarity is, over and above the level of interactions among researchers from different disciplines, a problem of integration of disciplines into a truly interdisciplinary conceptual framework accompanied by appropriate methodologies. Such a framework has to be more than a simple combination of different disciplines which still maintains the traditional disciplinary boundaries. It needs to synthesise and integrate contributions from different disciplines into conceptual categories that are more suited to a holistic interpretation of the subject of study.

5. Validity and validation of TA

As Martino (1978) notes, there is considerable debate about what constitutes validation in TA, reflecting a similar debated in the larger sphere of the social sciences. The key question here is how one goes about ensuring that the results of a TA are indeed accurate, reliable and objective. This involves examining the internal and external validities of the measures used in the assessment, examining their completeness and constantly improving upon them as more experience is gained. There have been measures developed for validity testing in the social sciences which can be applied in the case of TA. However, it is still debatable as to whether these validations might not be serving to further obscure what some believe to be the implicit value-laden and interest-specific nature of TA theory and methodology. The problem of validation must therefore examine critically the fundamental criteria in an assessment in terms of the political and value components, and it is at this level that the problem of validation becomes controversial, and can be expected to be perhaps even more controversial in a developing country.

6. Epistemological issues in TA

The tremendous self-consciousness of the TA community is in part a result of substantial epistemological confusion in the field. A philosophical and epistemological inquiry is essential, particularly, as Gray (1981) notes, when addressing questions about international technology assessments. Menkes (1979) explores this aspect of TA in some depth by asking fundamental questions about why we wish to carry out TA, what ultimately is its function, and how it relates to prevailing theories of social and political change.

Examining TA from a philosophical or epistemological standpoint does run the danger of degenerating into a discussion about what is technology or what is truth, but to some extent these questions are not unimportant nor irrelevant to the TA process. The former leads at least to an appreciation of the difference between social and physical technologies and the need for different approaches to assessment for each set, a need that is now widely recognized in the TA community. The latter raises the question of different perceptions of reality and objectivity across social strata, cultures and stages in history. Similarly, the question of why TAs are undertaken leads to an appreciation of the distinction between problem-driven and technology-driven assessments. All these have important implications for developing countries; they influence the extent to which current TA theory and practice can be applied in other countries, they highlight the need to explore alternative conceptions of objectivity and rationality to serve as the basis for alternative formulations of TA for developing countries, and they raise questions about the realistic expectations that one can have for TA and hence of the particular role it can play in social change and development.

Finally, and perhaps most important, it forces a confrontation with the dilemma of social choice - the "moon-ghetto" metaphor. In the Third World these choices are often extreme, with one side of the equation in any development choice frequently having to do with the lives and existence of people. Given these choices, and the scarcity of resources to surmount them in the foreseeable future, the role of TA has to be carefully thought out in developing countries, and its limits understood.

Two distinctions made in the literature (Armstrong and Harman 1977; Martino et al. 1978) have to do with the scale and historical dimension of technology and how they affect the particular approach that is adopted in TA at a philosophical and methodological level. The first is between major and minor technologies, with the former understood as those which will require drastic changes in the social, cultural and institutional fabric of society and the latter, those which have relatively less turbulent effects. The former necessitates an examination of the nature of social change and the interaction between technology and society at a macro level. Questions have to be asked not only about specific impacts of the technology, but of the desirability of the concomitant changes. The second distinction is between existing and emerging technologies - a particularly salient issue at this time in view of the tremendous advances in microelectronics, biotechnology and other frontier technologies. Can these technologies be treated in the same manner as more conventional and better understood existing technologies? What techniques can be applied? Is it at all possible to even partially assess their impacts when the core body of knowledge is itself changing so rapidly?

Both these distinctions may require the development and use of substantially new models and frameworks. In the case of microelectronics, for example, it has been suggested that the field herald the advent of a new technological revolution, equal in significance to the invention of the steam engine and electricity. The work of Kondratieff, Kuznets and Freeman on long waves in technology is relevant in this regard and may offer useful perspectives for the assessment of these technologies.

Both distinctions are also important for developing countries, the former because the question of the direction of social change is central to development, and the latter because of the potentially major impacts, both negative and positive, the new technologies are likely to have on the Third World.

7. Public participation

Because TA is meant to be a method to ensure that the interests of various social groupings are reflected and addressed in the development of technology, much attention has been given to public participation in the TA process (Porter et al. 1980; Martino 1978). While there have been efforts to incorporate such public inputs into all stages of the TA process, typically, these have been limited to initiating contacts with representatives of concerned public interest and stakeholder groups, and to seeking expert advice. Armstrong and Harman (1977) note that useful public input is difficult to obtain, partly because the inherent "futuristic nature of TA involves situations for which experience in the present offers little or no analogy" (p. 124).

While a large number of approaches and techniques have been suggested to solicit public participation - interviews, representation, use of media, questionnaires, participatory assessment, conferences, role playing, etc. - the reality of the matter is that to accomplish such a goal satisfactorily is often expensive, time-consuming and requires a considerable commitment on the part of the assessors. In developing countries, one has also to face the problem of low educational levels and illiteracy. Many of the proposed approaches presume a certain level of education and awareness on the part of the public. However, it could also be argued that the level of awareness does exist in developing countries but that the means of assessing and articulating public opinion need to be developed.

VI. INSTITUTIONAL CONSIDERATIONS IN TECHNOLOGY ASSESSMENT

At present, the United States and France are the only countries in the world which have formally institutionalized the TA function - in the form of the "U.S. Congressional Office for Technology Assessment" and the "Office parlementaire des choix scientifiques et technologiques" respectively. While many other countries do have technology assessment activities, they have not achieved the level of operationality of the U.S. There are also problems related to the role of TA in the private sector and the evaluation of TA which are discussed below.

1. Institutionalization of TA

The key issue in institutionalization is that if TA is to be truly effective, it must be properly integrated into the decision process, and the key problem lies in designing structures or processes that ensure or enhance such an integration.

The establishment of the OTA followed a fairly lengthy process of discussion, research, legislation and controversy. In the course of its life, the OTA has developed a somewhat systematic procedure for carrying out TAs. This process was the subject of study of a Task Force on Technology Assessment Methodology and Management set up by the OTA Director in 1979. The activity was part of a larger concern with the instituion-alization of the OTA process in Congress and with improving the OTA's methodology and management, a concern that Wood (1982) describes as characterizing the fourth phase of TA activities in the U.S. (Phase I was the birth of the TA concept, and the first TA bill, Phase II involved consensus building and the enactment of the Technology Assessment Act. During Phase III an operational role was created for the OTA.)

The Task Force identified a series of steps through which most OTA assessments proceed, based on an analysis of past TAs done by the OTA. These steps are listed in Figure 10 (drawn from Wood 1982). It should be noted that most OTA studies are carried out at the request of one or more committees of the Congress and that the OTA is seen as purely providing inputs into the policy and decision process. Gray (1982) notes:

> At the time of the floor debate in the House of Representatives over the Technology Assessment Act, for example, Rep. Charles A. Mosher argued that "both the new Office of Technology Assessment and the board that shall oversee its operations, are being created to perform only staff work for the Congress, not to make decisions, not to make national policy. I repeat, with emphasis, the OTA will not be a decision making body, nor a policy making body. It is absolutely fundamental to our entire concept, and it is the very essence of this bill, that the OTA shall not in any way usurp any of the intrinsic powers or functions of the Congress itself, nor of any of the Congressional committees (Congressional Record, February 8, 1972, p. 868).
>
> (Cited in Gray 1982).

It has been argued that this "neutral" role for the OTA is made possible by the political structure in the U.S. and that the parliamentary system may not be the most suitable for such an agency (Coates and Fabian 1982). However, there may be alternative types of arrangements that would be more feasible in different countries though there has been little work done on this subject.

FIGURE 10: STEPS THROUGH WHICH MOST OTA ASSESSMENTS PROCEED

1. Consultation with committee members and staffs
2. Proposal preparation and internal review
3. TAB review and approval of proposal
4. Staffing
5. Planning
6. Selecting and convening an advisory panel
7. Ensuring public participation*
8. Data collection and analysis
9. Contracting
10. Report writing
11. Review and revision
12. OTA Director and TAB approval of report
13. Publishing
14. Follow-up
15. Close-out

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* Public participation occurs at several steps in the assessment process.

Source: Wood (1982)

In the U.S., TA activities are mainly carried out by the research community (Bozeman and Rossini 1979), though the OTA represents a serious continuing effort by a public agency to do assessment intramurally. Other agencies, such as the National Aeronautics and Space Administration, the Environmental Protection Agency, and the Department of Energy also sponsor or undertake TA's. The National Science Foundation is the principal source of funding for assessment and the principal distinction between the OTA and the NSF is that the former is charged with carrying out assessments for Congress whereas the NSF is responsible to the Executive Branch.

Bozeman and Rossini (1979) note that technology assessments "have largely had their beginnings and ends in a bureaucratic milieu, while their actual performance has been in the external research community" (p.25). Their analysis of the institutional and structural dimensions of TA in the light of three models of decision making: (a) the rational actor model, which presumes complete information and perfect (or near perfect) rationality in decision making and assumes unitary decision making; (b) the organizational process model, which assumes multiple actors; and (c) the bureaucratic-politics model, which views decisions as the result of political compromises and negotiations between different interest groups or individuals - is potentially useful for examining institutional issues concerning TA in developing countries. They argue that a combination of these three models offers a realistic perspective on the TA process. The rational actor model is dominant in the R&D environment, where new technologies are developed, though there are also significant elements of the other two models, particularly since the R&D function has itself become institutionalized. The other two models are more appropriate to government agencies and public sponsors of TA. Neither the political and administrative structures nor the R&D systems of developing countries are similar to the U.S., but what can be derived from the Bozeman and Rossini (1979) analysis is the need to examine separately these three components of the TA system in a country and subsequently develop an analysis of the specific patterns of decision making in the context of TA.

2. Public and private sector issues

Technology assessment has been largely an activity carried out in the public sector. However, there have been attempts to adopt it in the private sector. As Maloney (1982) notes, TA in the private sector entails somewhat different goals and criteria than in the public sector, though many companies are becoming increasingly concerned about the social impacts of their new products and processes - partly due to the elaborate legislation that has developed in this regard and partly because of public opinion. Figure 11 lists the main differences between public and private sector TAs.

FIGURE 11: COMPARISON OF PRIVATE AND PUBLIC SECTOR TECHNOLOGY ASSESSMENT

Industrial	Governmental
OBJECTIVES	
Profit maximization	No interest in profit
Conflict identification and positioning	Conflict identification and resolution(s)
Market diversification based on perceived consumer need	Market creation based on perceived social welfare need ("... the common good ...")
Identification of consumer need	Balancing "public" needs
Corporate direction setting/decision making	Formulate public policy options
STRUCTURE	
Flexible process	Highly structured series of steps
Ad hoc, mission-oriented task force	Formally organized group
Mostly internal effort, some use of external resources	Mostly external effort, some use of internal resources
Private, oral report	Public written, published report
TIMEFRAMES	
Short- to mid-term view	Generally long-term view
Study takes 1 year to complete	Study takes 1 year to complete
OTHER PERCEPTIONS	
Complete thinking	Holistic thinking
Accountable to stockholders	Multiple accountabilities
Survival of firm	More rational government
Competitive environment	No competition

Source: Maloney (1982)

The need for TA in the private sector arises particularly in those situations where a firm is considering diversification or new products for new markets, and there have been techniques developed for this purpose, often drawing from the public sector experience (Maloney 1982). However, there have also been some mild criticisms of private sector TA. For example, Coates and Fabian (1982) argue that the term "technology assessment" should be reserved to describe a form of policy analysis designed to assist public sector decision making and resource allocation and that to use it to describe corporate decision-oriented planning studies is misleading and casts into negative perspective some useful and progressive developments in corporate planning. Coates and Fabian's critique is based on the view that private sector TA is counterproductive to the private sector itself, and that even good planning techniques may encounter internal resistance as a result. One could also argue that if TA is indeed an activity concerned with societal well-being, it should not be encouraged in the private sector because of the potential possibility of it being used to legitimate technologies which might still have adverse effects from a broader perspective. On the other hand, it is also likely that TA may be a useful method for improving the social responsibility of private sector firms. The question ultimately appears to be whether (a) TA should be carried out in the private sector; and (b) whether it should be undertaken in the same fashion as in the public sector. Both are relatively unresolved but are important issues in developing countries.

3. Evaluation of assessments

Much has been written on the question of evaluation of TA (Connolly et al. 1979; Koppel 1979; Porter and Rossini 1977; Mayo 1982; Gray 1982). The main issue has to do with the type of evaluation design that is best suited for TA. Porter and Rossini apply the logic of experimental and quasi-experimental design to the evaluation of technology assessment and forecasting. This is an approach that is reasonably well developed and applied in the evaluation research literature. However, Koppel (1979) argues that this approach concentrates on evaluating possible distortions in the internal validity of a TA when in fact external validity - i.e. generalizibility to other situations and parameters is the major issue. Furthermore, he argues,

> Experimental design is intraparadigmatic. It cannot screen alternative models, but rather can only provide a basis for excluding alternative hypotheses within a model. This means that even the proposed focus on internal validity cannot be realized unless a high degree of consensus on the maintained hypotheses of all TAs can be justifiably assumed. (p. 148.)

In another stream of concern over TA evaluation, Gray discusses the need for criteria of "completeness" of TA reports, specifically in the case of the OTA, in terms of the types of activities and goals that should be undertaken or met to ensure that the TA is reasonably complete in scope and process. Drawing on a theory of the logical relation between congressional technology assessment and congressional decision-making, and from the nine dimensions of assessment report quality suggested by Rossini et al. (1976) and shown in Figure 12, he derives a "checklist"* to evaluate the "completeness" of OTA assessments, which considers such factors as whether all congressional options have been explored, whether the scenarios considered were mutually exclusive, whether stakeholder opinions were solicited, etc.

* See Gray L. (1982) pp. 316-17

FIGURE 12: DIMENSIONS OF REPORT QUALITY

A. Validity

1. Cause-effect understanding
2. Balance
3. Methodological soundness

B. Utility

4. Pertinence
5. Timeliness
6. Credibility
7. Communicability
8. Economy of assessment

C. State of the art

9. Advancing assessment methodology

Source: Rossini et al. (1976)

While the Gray approach is pragmatic and context-specific in its approach, the Porter/ Rossini and Koppel approaches are more concerned with the general problem of TA evaluation. Hence the debate at that level implicitly reflects many of the larger debates about what TA should be and whether it is really a viable social science. In the context of a developing country, the latter issue would seem to be more crucial in the long term, but the functional checklist approach may be more practical in the short term to enhance the reliability and consistency of TAs.

VII. INTERNATIONAL PERSPECTIVES ON TECHNOLOGY ASSESSMENT

Since the creation of the field there has been considerable international interest in TA, although most of the activities are still concentrated in the U.S. At least three major international conferences have been held on the subject (Chen 1979), and there have been various TA activities in the United Nations and other international agencies. The OECD in particular has exhibited considerable interest and has published four books on the subject (Hetman 1973; OECD 1975, 1978, 1982) and has also attempted to promote international cooperation in TA (Chen 1979). Other organizations include the International Society for Technology Assessment and the International Institute for Applied Systems Analysis (IIASA). The approach to TA has differed from country to country, and each has had its own measure of success or failure. Of particular interest are the experiences of some of the OECD countries (other than the U.S.) and the centrally planned economies.

1. Europe

There have been a number of attempts in various European countries to develop a TA function to serve the national legislature, but only one - France - has met with much success. In the Federal Republic of Germany, two proposals to set up a national office of technology assessment have been made. The first, in 1973, was proposed by the opposition party, the Christian Democrats, but was defeated in the Bundestag in 1975. A second attempt was made in 1977, but this also failed. Coates and Fabian (1982) explain these failures as resulting from the particular features of the parliamentary system, in which the legislature does not have the control over planning and policy that exists in the U.S. Congress. Cabinet members are chosen from the parliamentary majority and the role of information as an instrument of power is more clearly emphasized in the parliamentary system. As a result, a legislative TA office which would include involvement of the opposition party is likely to face considerable resistance from the ruling majority party.

Coates and Fabian also surveyed other European countries and found similar experiences. In the Netherlands there were two abortive attempts to introduce a legislative office in the Dutch parliament. Similar efforts have also failed in Sweden. By and large, therefore, TA activities in Europe have been outside the legislature, either in universities or in government ministries. For example, in the Federal Republic of Germany, the Ministry of Research and Technology has sponsored several TAs and the Ministry of Inner Affairs is becoming increasingly concerned with TA. In the Netherlands, the Commission for Development of Policy Analysis and the Council for Science Policy have been active, with further activities being undertaken in various government offices. The Swedish National Board for Technology Development and the Secretariat for Future Studies have conducted or sponsored TAs in Sweden, and in the United Kingdom the Programme Analysis Unit and the National Research and Development Corporation are key agencies in TA. Canada has three governmental bodies that are tapped by the cabinet for technology assessment inputs - the National Research Council, the Ministry of Science and Technology and the Science Council (Coates and Fabian 1982).

At the regional level, the OECD has tried to enhance cooperation by sponsoring TAs in three areas - new urban transportation systems, humanized working conditions and telecommunications technologies, but only the first study has continued (Chen 1979).

2. Japan

There have not been any attempts to introduce a legislative TA unit in Japan but there have been three attempts to introduce an Environmental Assessment Act to the Diet, all of which have failed because of opposition from the ruling majority party, the Liberal Democratic Party (Coates and Fabian 1982). However, there are TA activities in Japan, and the traditionally close relationship between government and industry has set the pattern for such work. Over half the TAs conducted in Japan have been conducted by industry. At the request of the Ministry of International Trade and Industry (MITI), the Japanese Industrial Technology Council established a Technology Assessment Panel which recommended that TAs should be done by those involved in the development of technology and that the government should both carry out TA and encourage it in the private sector (Chen 1979).

The Japanese Agency of Industrial Science and Technology has also been a major actor in the dissemination of the TA concept and in actual assessment. The concept of TA is itself slightly different in Japan. Hoashi (1982) defines it as:

(a) establishment of an ideology of technology which is understood to contribute to enhancement of human welfare;

(b) analysis and evaluation of technology affecting the natural environment of society;

(c) control and management of technology that is developed, based on (a) and (b).

(p.2)

Furthermore, the national agencies that carry out R&D are required to make the TA results public in principle before carrying out the actual experiments, as are private sector firms that do government-sponsored R&D. This approach has been particularly effective in promoting the actual application of TA in R&D planning (Chen 1979).

3. Centrally planned economies

The approach to TA in the Soviet Union and other centrally planned economies is conditioned by their political ideology. Science and technology goals are subordinate to broader national goals and TA is seen within the overall planning framework as a tool for the social management of technology. TA itself is seen as part of what Dobrov (1978) refers to as the Systems Assessment of New Technologies (SANT), a concept that encompasses technology assessment, forecasting, evaluation of variants for technology policy, evaluation of R&D, and science and technology potential indicators.

The concerns underlying TA in the CPE countries (which include all the CMEA countries) are somewhat different than in the OECD nations. Chen identifies a concern over the possible detrimental effects of imported technologies and a concern over the traditional laissez-faire tendency in science and basic research as two points of divergence. TA is seen as a tool to identify possible side effects of imported technology and as a means to make science more manageable.

The approach to TA also involves more of an attempt to anchor itself in theoretical principles of organization, objective measures of performance, rational planning techniques and cybernetics. As such, it reflects more of a concern with being comprehensive and rational in technology planning. This view is reflected in the comments of various high-ranking scientists and officials that such studies are concerned with the general laws of development of science and technology and would become the theoretical basis for science and technology policy (Chen 1979).

4. Developing countries

Though it is generally agreed that technology assessment is of crucial importance to the developing countries, there are few concrete activities in this field. Predictably, the most activity has been in those countries with a fairly strong R&D and industrial base, such as India. The United Nations sponsored a seminar on "Technology Assessment for Development" in Bangalore in 1978 (UN 1979) where many of the experiences and perspectives with respect to development and TA were brought together. More recently, the advent of new technologies such as microelectronics and biotechnology have spurred interest in this field, as reflected in the plans for a monitoring system for frontier technologies to be implemented by the United Nations Centre for the Study of Science and Technology for Development (UNCSTD).

The few efforts in TA in developing countries reflect the overriding concerns of these economies - agriculture (Lim Fat 1979), health (Sallam 1979), energy (Larson 1978), industrial development (Sharma 1978), etc. A United Nations Environmental Program (UNEP) seminar on "Environmental Aspects of Technology Assessment," held in Geneva in 1982, brought together the experiences of developing countries in environmental assessment, which has become an increasingly important issue (see, for example, the papers from that seminar: Rohatgi 1982, Ribeiro 1982, Hussein 1982, Ventura 1982, and Sharif 1982). There have also been various efforts to examine the impacts of imported technologies on the development process - as reflected in the literature on technology transfer, choice of technology, appropriate technology and multinational investment which have relevance in this context. At a broader level, there has been considerable concern with understanding the relationship between technology assessment and science and technology policy in general, with the development process as a whole. This in turn relates to the questions and issues that arise in the use of technology assessment in developing countries, which is discussed in the following section.

VIII. TECHNOLOGY ASSESSMENT IN DEVELOPING COUNTRIES: KEY ISSUES

It is only natural that technology assessment be viewed with considerable interest in the context of development. Science and technology are increasingly being seen as crucial components of development and growth, and many of the problems of underdevelopment have been attributed to weak indigenous science and technology capacities, inappropriate technological choices, poor technological development policies and dependency-producing transfers of technology. All these problems underscore the need for a capability to assess technology in the context of the development strategy of a country.

The two central themes that emerged in support of technology assessment from the United Nations Department of Economic and Social Affairs seminar on technology assessment for development (UN 1978) were that TA could serve to (a) generate expanded choices, and (b) expand decision variables for decision makers at all levels of the development process. In other words, it is seen as improving the knowledge base and degrees of freedom with respect to the application of technology for development purposes. It is also seen as a means of choosing appropriate forms of technology in accordance with the three key elements of the concept of eco-development proposed by UNEP - self-reliance, basic needs, and environmental soundness.

The other benefits identified by the UN seminar are: (a) the enhancement of national and regional negotiating capacities, (b) the promotion of public participation in the technological development process, (c) enhanced accountability in the planning process and (d) the possibility of multiplying resources available to policy makers and planners, both intra-nationally and internationally.

However, it is also important to recognize the limitations of TA in development - it is not a panacea for the problems of the poor nations and there are several problematic issues that arise in the application of TA to development.

1. Difference in goals and objectives

TA has evolved in a particular form in response to the exigencies of industrialization in the advanced countries. The concerns which led to the growth of TA have generally dealt with the potential deleterious effects of technology and the need to control and monitor technology from a societal point of view. While these concerns also hold true in the developing countries, there is additionally the overriding concern with harnessing the potential of technology to accelerate the development process and to deal with some of the characteristic problems of developing countries - unemployment, socioeconomic inequity, poverty, etc. Furthermore, the desire for indigenous capacity development is dominant in most Third World nations, and this concern with breaking out of the structure of dependence is quite specific to the developing world. These types of concerns are associated with goals for TA that are not altogether congruent with TA goals in developed nations; rather they are inextricably linked with the strategies for development chosen by these countries and by the structure of the international political and economic system within which the developing countries occupy an historically unique position. Sagasti (1980) identifies three broad objectives in this regard: (a) the expansion and reorientation of the science and technology system, (b) the selective and systematic recovery of the traditional technological base, and (c) the transformation of the productive system.

Similarly, Hoashi (1978) describes the goals of TA in development as: (a) improvement in the quality of life, (b) expansion of the economy, (c) establishment of basic conditions for economic development and (d) promotion of creativity. While both sets of goals are somewhat general and would need to be elaborated and detailed further in order to be meaningful at a sectoral or project level, they do indicate the types of concerns associated with TA in the development process.

2. Criteria for TA in development

Related to the question of goals for TA are the types of criteria that ought to be used in the assessment of technologies in a developing country environment. While there will obviously be some overlap with the criteria used in advanced industrialized nations, it is useful to note the points of departure in terms of content and emphasis. Chatel (1979) lists a number of such criteria:

(i) employment generation
(ii) capital saving
(iii) energy conservation and efficiency
(iv) environmental soundness
(v) socioculturally and economically appropriate design
- compatibility with local tastes and cultures
- designed to address context specific needs and constraints
- compatible with local purchasing power
- utilization of local raw materials

(vi) involvement and participation of women
(vii) consistency with other activities in a systems sense.

Though these criteria approximate very closely the features used to describe "appropriate" technology, this similarity only emphasizes the close relationship between processes of technology assessment and technology choice in developing countries and highlights the need to bring to bear the considerable work that has been done on choice of technology on the design of technology assessments.

3. Issues in the adaptation of TA for development

Apart from the broad issues concerning goals and criteria, there are some specific features of developing countries that bear on the transferability of technology assessment concepts and practices to developing countries and which relate to what Medford (1978) refers to as the "assessment gap."

(i) Data availability: Most developing countries do not have well developed information systems and the data that are available are often of poor quality and out of date. Techniques need to be developed to deal with these data related inadequacies since they detract from the accuracy, timeliness and comprehensiveness of an assessment.

(ii) Sources of technology: Most developing countries obtain much of their technology from overseas, or are in some way technologically dependent on external sources of finance, assistance and information. This constrains the technology choices available to the decision-maker. TA therefore needs to be conducted with this dependence in mind and with a view to reducing the adverse effects of such external dependence.

(iii) Shortage of expertise: Medford (1978) points out that to a large extent the "assessment gap" is due to the small numbers of analysts and the general shortage of skills relevant to the assessment process. This has two types of consequences: (a) the shortage of such skills implies that the needed level of assessments cannot be undertaken, and (b) given such shortages, analysts who are not necessarily competent in TA carry out the work, which can result in inaccurate or poorly conceived studies.

(iv) Variations among countries: TA must be designed to suit the contextual conditions of the country in which it is to be applied. While there are general similarities between developing countries, there are also considerable variations. In the Caribbean, for example, most nations are small, island economies and require approaches suited to these conditions. In particular, Ventura (1978) notes, environmental concerns are paramount given the environmental fragility of most Caribbean countries. Similarly, Hussein (1978) discusses the characteristic features of the Arab countries and what these imply for the application of TA. Of particular importance is the need for information and assessment of the large civil construction, petroleum, power, transport and industrial and agricultural projects that Arab countries have contracted with large international firms. In countries such as China and India, the large population and the size of the country need to be considered in technology assessment and planning. Different imperatives would emerge for small land-locked nations such as Rwanda, and the possibilities of regional technology cooperation through the pooling of resources may be more salient. For the export-oriented economies of Southeast Asia some recent technological developments would be particularly important - for example, the growth of microelectronics and the implications of increased automation in the West for their cheap-labour driven economies. Countries that depend on the export of a few commodities would be specifically concerned with those technological developments that could potentially affect the world market for these commodities - for example, advances in fibre optics have important implications for traditional copper exporting nations such as Chile, Zambia and Zaire.

The variations between nations is considerable and what is urgently needed is a systematic categorization of countries according to features specific to their contexts and critical to their unique development trajectories.

Additionally there are political and structural factors - opposition from various groups, weaknesses in the structures of policy implementation, discontinuities in national policies - and cultural and ideological factors that must be considered. While it may be impossible to resolve all these issues in the near future, TA efforts in developing countries must be based on a recognition of these potential barriers. Furthermore, there is a need for the development of techniques for TA specifically suited to developing countries. Some efforts have been made in this regard, for example, the analytic hierarchy approach suggested by Ramnanujam and Saaty (1981), and there have also been various attempts to adapt conventional techniques to a developing country context, such as Bowonder's (1979) multiple network analysis of the Green Revolution in India, and Rohatgi and Rohatgi's (1979) analysis of the value of Delphi as a tool for technology choices in India, but there is still a need for more refined and relevant techniques.

IX. RISK ANALYSIS

As Nehnevajsa and Menkes (1981) point out, risk analysis is closely related to technology assessment but historically has lagged behind it. They expect that it will evolve through the same process as did TA. The primary difference between TA and risk analysis (RA) is not very significant and operates mainly at the level of technique and in terms of what kinds of problems are considered important. In the former case, RA tends to be more relevant on developments in probability theory, and in concepts such as risk and uncertainty, and is therefore more mathematically oriented. In terms of problem focus, RA is more concerned with those technological developments that are potentially hazardous, whereas TA, especially in a developing country context, ostensibly is more concerned with the systematic application of technology in a constructive fashion. Both disciplines have their fuzzy edges, and both are still grappling with the intangibilities of producing results that are meaningful in a policy sense. This document has focused mainly on technology assessment and this last section is solely meant to present a capsule summary of the pertinent features of RA and to bring it into perspective in the larger context of the role of science and technology in the development process.

Risk analysis has been defined variously, but the definitions tend to converge towards that offered by Rowe (1977) and quoted in the first section of this paper. It is nevertheless important also to understand what are deemed to be the social motivations for the development of this field:

> The need to help society cope with technological hazards has given rise to the development of a new intellectual endeavour: risk analysis. The scope and complexity of risk analysis requires a high degree of cooperative effort on the part of specialists from many fields. Analyzing technical, social, and value issues requires the efforts of physicists, biologists, geneticists, physicians, chemists, engineers, political scientists, sociologists, decision analysts, management scientists, economists, psychologists, ethicists, and policy analysts.
>
> (Covello and Menkes 1982, p. 1)

While that description of risk analysis is characteristic of the tenuous eclecticism of fields that are young and attempting to gain a position in the constellation of policy sciences, it does reveal the panoply of concerns that come together under the label of risk analysis. It also reflects the underlying insecurity of the field - the technical focus is much clearer than the substantive. Risk analysis is ostensibly intended to address the problem of potential technological hazard. Yet, the concept of hazard is rooted in a somewhat limited concept of societal concerns. Admittedly, pollution, dangers to physical safety, environmental degradation, etc., are of serious concern to all societies, but risk analysis appears to treat these as the prevailing concerns of society rather than attempt to address the question of appropriate paths of socioeconomic development, and the fundamental question of what types of effects are to be considered in the analysis of risk. For example, does the risk of alienation in the labour force merit the same consideration as the risk of water pollution? At this point risk analysis runs into the same problem as technology assessment: it is difficult to separate the ideological content of the field from its purportedly scientific content.

In recent years, there has been considerable interest in risk analysis and various efforts have been made to systematize the field and suggest analytical techniques (for example, Rowe 1977; Crouch and Wilson 1982; Hohenemser and Kasperson 1982). However, there are still many unresolved or contentious issues in the field, which have been aptly summarized by Covello and Menkes (1982):

> (a) the determination of acceptable levels of risk for society; (b) the adequacy of the data upon which risk estimates are calculated; (c) the strategies that can be developed for coping with situations where the risk is essentially unknown; (d) how implicit estimates of risk are used in the decision-making process; (e) the institutional constraints associated with decision-making involving risk and uncertainty; (f) the factors that influence individual and social perceptions of risk; and (g) how value, equity, distributive and intergenerational considerations are balanced in the decision-making process and what means can be used to balance the costs, risks, benefits to different groups in society.
>
> (p.2)

Risk analysis techniques can be broadly categorized into formal and informal methods (Rowe 1977). Informal risk evaluation depends to a large extent on expert advice and comes into play when an individual or group feels unable to make a voluntary risk decision. The extent of acceptance of the advice depends on the degree to which the expert is considered competent and reliable in his field. Informal risk evaluation can also occur through risk decision sharing, where instead of seeking advice, the decision is shared with others facing the same risk situation.

Formal risk analysis techniques involve four steps (Rowe 1977):

(a) establishment of a risk referent level which is viewed as acceptable on the basis of some criteria.

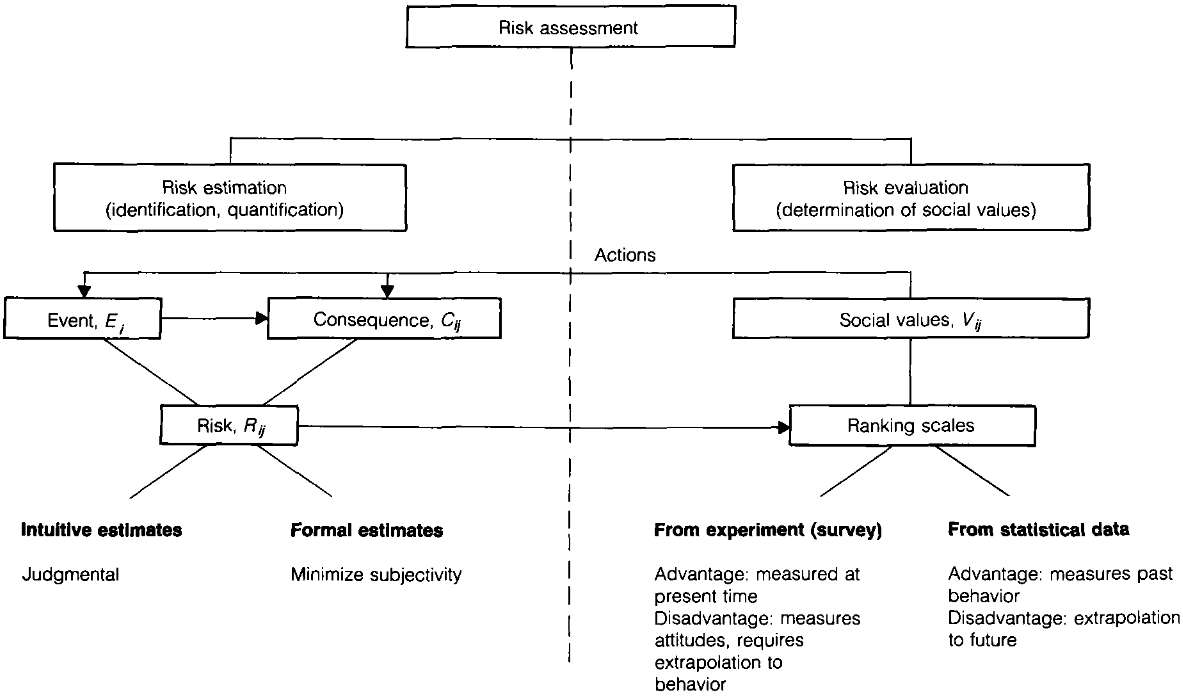
(b) determination of the level of risk associated with the new programme or technology.

(c) comparison of the risk with the referent level, within the limits of error.

(d) undertaking of risk aversive action. If the risk is acceptable, efforts to reduce the level as much as is possible can be undertaken. If the risk level is unacceptable, alternative programmes can be considered.

Othway and Pahner (1976) suggest a useful structural conceptualization of the risk analysis process based on the three constituent components of RA - risk assessment, risk estimation and risk evaluation (Figure 13). The concept of risk involves both the probability and uncertainty of an occurrence and the probability and uncertainty of a consequence if the event occurs. Risk evaluation and estimation can be calculated either by intuitive or formal methods. Risk evaluation involves assessing the value of the risks to the parties affected and this can be evaluated either by survey techniques or by the analysis of behavioural patterns.

FIGURE 13: GENERAL STRUCTURE OF RISK ASSESSMENT



Source: Otway and Pahner (1976).

When viewed in the context of development, there are several issues concerning the application risk analysis. Bowonder (1981) describes four categories of such issues and constraints:

(a) Technique-oriented issues: These relate to the anticipation of risks and their estimates and to their assessment and evaluation. Two major reasons suggested for technique-oriented errors in risk anticipation are polarization, where one set of risks is overemphasized with respect to others, and competition between different groups involved in the risk forecasting exercise. In the assessment and evaluation of risks, distortions can take several forms: the subjective measurement of probabilities is a complex and bias prone approach; human judgements of probabilities are subject to bias; ill-defined problems do not lend themselves to quantitative analytical methods; low probabilities tend to be overestimated and high probabilities underestimated, etc.

(b) Problem-oriented issues: Distortions can also occur in the task itself, due to incorrect considerations of data interactions, attempts at partial solutions, ill-defined problems, wrong assumptions, etc. This "task bias" - solving the wrong problem - is often a more common and fundamental mistake than errors in the techniques used.

(c) Result-oriented issues: Once the risk analysis is over, the dissemination and implementation of the results is critical to the overall value of the effort. However, oversimplification of results, bureaucratic problems, corruption, poor dissemination techniques, etc., can all contribute to distortions in the final stage of the analysis.

(d) System-related issues: An extremely serious barrier to risk analysis is the structure of the system within which it is carried out. The tendency for organizations and institutions to perpetuate themselves is a strong barrier to change and if a risk analysis results in a recommendation for basic structural changes, it is likely to encounter such opposition.

While risk analysis has obvious implications and value for developing countries, it is an extremely complex process and the lack of adequate expertise and experience in this field suggests the need to develop local capabilities in the various aspects of risk analysis. They also need to improve their informational bases. In particular, Bowonder (1981) suggests the need for "early warning systems encompassing all possible disciplines with wide international links and a national utilization and dissemination network" (p. 122), plus extensive educational and training efforts for policy makers and the public in the relevant subjects.

X. SUMMARY AND CONCLUSIONS

This publication has attempted to review the literature on technology assessment, and in a more limited sense, risk analysis, including their implications for developing countries. The fields are still growing and becoming more refined, but there is little question of the value of technology assessment and risk analysis to the development process. However, both fields require modification to be more suited to the specific environments of developing countries and to be able to address the over-arching concerns of these countries. These reorientations must be at the epistemological, theoretical and methodological levels and may require the generation of new theory about the interactions between technology and society and the dynamics of social change.

International agencies can play an extremely useful role in this process and can fruitfully supplement efforts at the national level. However, in both instances there is a need to move beyond simply holding conferences and workshops on the state of the art to an emphasis on critically examining the basic concepts and values implicit in these fields in light of current social, political and economic circumstances, such as the advent of the "frontier" technologies, and more efforts at the practical implementation of TA and RA in cooperation with institutes in developing countries. The three processes of critical analysis, theoretical and methodological advance and practical capability development must proceed together.

BIBLIOGRAPHY

Armstrong, Joe E. and Harman, Willis W. Strategies for Conducting Technology Assessments, Stanford University, Department of Engineering Economic Systems, Stanford, California, December 1977.

Arnstein, S.R. and Christakis, A.N. "Perspectives on Technology Assessment," Methodologies in Perspective, Jerusalem: Science and Technology Publishers, 1976.

Ascher, William. "Problems of Forecasting and Technology Assessment," Technological Forecasting and Social Change 13, 149-156, 1979.

Auerback, Lewis. "The Berger Report Sets an Important Precedent in Assessing Technology's Effects," Science Forum 10(4) 22-25, August 1977.

Ayres, Robert U. Technology Forecasting and Long-Range Planning. New York: McGraw-Hill, 1969.

- "Coalplex": An Integrated Energy/Resource System Concept. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 4 December 1982. United Nations Environment Programme, UNEP/WG.80/6, 3 November 1982.

Balachandra, R. "Perceived Usefulness of Technological Forecasting Techniques," Technological Forecasting and Social Change 16, 155-166, 1980.

Barus, Carl. "On Costs, Benefits and Malefits in Technology Assessment," IEEE Technology and Society Magazine, March 1982.

Berg, Mark N.; Brudeny, Jeffrey L.; Fuller, Theodore D.; Michael, Donald N. and Roth, Beverly K. Factors Affecting Utilization of Technology Assessment Studies in Policy-Making, University of Michigan Institute for Social Research, Ann Arbor, 1978.

Berg, M.R. "Methodology" in Arnstein, A. and Christakis, A. (eds.) Perspectives in Technology Assessment. Jerusalem, 1975.

Bogumil, R.J. "Limitations of Probabilistic Risk Assessment," IEEE Technology and Society Magazine, September 1982.

Boroush, Mark A.; Chen, Ken and Christakis, Alexander N., (eds.) Technology Assessment: Creative Futures (Perspectives From and Beyond the Second International Congress), New York: Elsevier North Holland, 1980.

Bowonder, B. "Appropriate Technology for Developing Countries: Some Issues," Technological Forecasting and Social Change 15, 55-67, 1979.

- "Impact Analysis of the Green Revolution in India," Technological Forecasting and Social Change 15, (4), December 1979.
- "Environmental Risk Assessment Issues in the Third World," Technological Forecasting and Social Change 19, 99-127, 1981.

Bowonder, B. and Rohatgi, P.K. "Technology Forecasting: Applicability, Relevance and Future Crisis Analysis in a Developing Country," Technology Forecasting and Social Change, Vol. 7, No. 3, 1975.

Bozeman, Barry and Rossini, Frederick A. "Technology Assessment and Political Decision-Making," Technological Forecasting and Social Change 15, 25-35, 1979.

Braun, Ernest and Collingridge, David. Assessment of Technical Decisions: Case Studies, London, Boston: Butterworths, 1979.

Bright, J.R. Practical Technology Forecasting: Concepts and Exercises, Austin TX: The Industrial Management Center, 1978.

Bright, James R. and Schoeman, Milton E.F. (Eds.). A Guide to Practical Technological Forecasting, Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1973.

Bross, I.D. Design for Decision, New York: The Free Press, 1965.

Brusilovsky, B. YA. "Partial and System Forecasts in Scientometrics," Technological Forecasting and Social Change 12, 193-200, 1978.

Burby, John F. "Science Report/Infact OTA Seeks to Alert Congress to Technological Impacts," National Journal Reports 6, 1428, 1974.

Carpenter, Richard A. "The Scope and Limits of Technology Assessment," Technology Assessment, Vol. 1, No. 1, pp. 41-46, 1973.

Casper, Barry M. "The Rhetoric and Reality of Congressional Technology Assessment," Bulletin of the Atomic Scientists 34, 20-31, February 1978.

Cetron, Marvin. Technological Forecasting A Practical Approach. Gordon and Breach, New York, 1971.

- Encounters with the Future: A Forecast of Life into the Twenty-first Century, New York, McGraw-Hill, 1982.

Cetron, M.J. and Bartoche, B. (eds). Technology Assessment in a Dynamic Environment; New York: Gordon & Breach, 1973.

Chalk, Rosemary. "Technology Assessment: An Interdisciplinary, Integrative Approach," Technology Assessment, Vol. 2, No. 4. London: Gordon and Breach Science Publishers Ltd., 1974.

Chatel, Bertrand H. "Technology Assessment and Developing Countries," Technological Forecasting and Social Change 13, 203-211, 1979.

Chen, Kan. "International Perspectives on Technology Assessment," Technological Forecasting and Social Change 13, 213-233, 1979.

Chen, Kan and Zissis, George J. "Philosophical and Methodological Approaches to Technology Assessment," Journal of the International Society for Technology Assessment. International Society for Technology Assessment, Washington, D.C., March 1975.

Chubin, Daryl E.; Rossini, Frederick A.; Porter, Alan L. and Mitroff, Ian I. "Experimental Technology Assessment: Explorations in Processes of Interdisciplinary Team Research," Technological Forecasting and Social Change 15, 87-94, 1979.

Coates, Joseph F. "The Role of Formal Models in Technology Assessment," Technological Forecasting and Social Change, Vol. 9, 139-190, 1976a.

- "Technology assessment - a tool kit," Chemical Technology, p. 372, June 1976b.

Coates, Vary T. Technology and Public Policy: The Process of Technology Assessment in the Federal Government, George Washington University Program of Policy Studies in Science and Technology, Washington, D.C., July 1972.

- A Handbook of Technology Assessment, U.S. Department of Energy, Washington, D.C., March 1978.

- Technology Assessment in Federal Agencies 1971-1976, George Washington University Program of Policy Studies in Science and Technology, Washington, D.C., March 1979.

Coates, Vary T. and Fabian, Thecla. "Technology Assessment in Europe and Japan," Technological Forecasting and Social Change 22, 343-361, 1982.

- "Technology Assessment in Industry: A Counterproductive Myth?," Technological Forecasting and Social Change 22, 331-341, 1982.

Commission of the European Community. "Forecasting and Assessment in Science and Technology: Report of the FAST Team." (2 Vols.) Brussels, 1982.

Committee on Science and Astronautics, U.S. House of Representatives. A Study of Technology Assessment, Report of the Committee on Public Engineering Policy, National Academy of Engineering. Washington, D.C., July 1969.

Connolly, Terry; Porter, Alan L. and Rossini, Frederick A. "On the Evaluation of Assessment and Assessments," Technological Forecasting and Social Change 15, 73-76, 1979.

Covello, Vincent and Abernathy, Mark. "Technological Risk: A Bibliography Public Administration Series: A Bibliography." Monticello, Illinois: Vance Bibliographies, June 1983.

Covello, Vincent and Menkes, Joshua. "Issues in Risk Analysis," in Christopher Hohenemser and Jeanne X. Kasperson (editors); Risk in the Technological Society, Boulder, Colorado: Westview Press, 1982.

Covello, Vincent T; Menkes, Joshua and Nehnevajsa, Jiri. "Risk Analysis, Philosophy, and the Social and Behavioral Sciences: Reflections on the Scope of Risk Analysis Research," Risk Analysis, Vol. 2, No. 2, 1982.

Crouch, Edmund A. and Wilson, Richard. Risk/Benefit Analysis, Cambridge, Mass.: Ballinger Publishing Company, 1982.

DeAngelo, Linda. "A Comparative Assessment of Four Methods to Establish Priorities for Technology Assessments," Technology Assessment, Vol. 2, No. 3. London: Gordon and Breach Science Publishers Ltd., 1974.

deLeon, Peter. "Technology and Public Policy: Whither Side of Janus?," Policy Sciences 11 (3), 235-240, 1980.

- "The Evaluation of Technology R&D: A Continuing Dilemma," Research Policy 11, 347-357, New York: North-Holland Publishing Company, 1982.

Dickey, John W.; Glancy, David M. and Jennelle, Ernest M. Technology Assessment: Its Application to the Solid Waste Management Programmes of Urban Governments, Lexington: Lexington Books, D.C. Heath and Company, 1973.

Dickson, David. Alternative Technology and the Politics of Technical Change. London: Fontana Press, 1974.

Dierkes, Meinolf and Staehle, K.W. Technological Assessment: An Improved Basis for Managerial and Government Planning, 2nd Revision. Columbus, Ohio, Batelle Institute, July 1973.

Dobrov, Gennady M. "Systems Assessment of New Technology for Decision-Making in Government and Industry. Part I: The Model," Technological Forecasting and Social Change 12, 73-87, 1978.

- "Environment and Technology Assessment in Centrally Planned Economies," Seminar on Environmental Aspects of Technology Assessment, UNEP, Geneva, 29 November - 3 December, 1982.

Dobrov, G.M., Randolph, R.H., and Rauch, W.D., eds. Systems Assessment of New Technology. International Perspectives. (CP-78-8). Laxenburg, Austria: IIASA, 1978.

Donovan, Paul F.; Gaspari, George D. and Rosenblum, Bruce. "A Management Overview Methodology for Technology Assessment," Technological Forecasting and Social Change 22, 223-236, 1982.

East-West Center. Technology Assessing. The Quest for Coherence. An International Research Needs and Planning Conference held at the East-West Center in Honolulu, Hawaii, from May 30 to June 10, 1977, unpublished papers, Technology and Development Institute, East West Center, Honolulu, 1977.

Finsterbusch, Kurt. "A Policy Analysis Methodology for Social Impacts," Journal of the International Society for Technology Assessment. ISTA - International Society for Technology Assessment, Washington, D.C., March 1975.

Fowles, Jim (ed.). Handbook of Futures Research, Westport, Connecticut: Greenwood Press, 1978.

Freeman, Christopher. "The Kondratieff Long Waves, Technical Change and Unemployment", Mimeo, Science Policy Research Unit, University of Sussex, January 1977.

Friend, Jacob and Molnar, Paul. "A General Model for Culture and Technology," Technology Forecasting and Social Change, Vol. 8, No. 2, 1975-188, 1975.

Gibbons, Michael. "Technology Assessment: Objectivity or Utopia," Prometheus, August 1976.

Gibbons and Voyer. "Technology Assessment: Bias-Free Analysis," New Scientist 58, 466, 1973.

Glushkov, V.M. "Continuous Forecasting Methods," Technological Forecasting and Social Change 12, 155-163, 1978.

Gohagan, J.K. "A Practical Bayesian Methodology for Program Planning and Evaluation, Las Vegas: ORSA/TIMS Meeting (17-19 November) 1975.

Goldsmith, M. "Technology Assessment," Science Policy, Vol. 1, No. 6, November/ December, 1972.

Gordon, T.J. and Stover, J. "Using Perceptions and Data About the Future to Improve the Simulation of Complex Systems," Technological Forecasting and Social Change 9, 191-211, 1976.

Goulet, Denis. The Uncertain Promise: Value Conflicts in Technology Transfer. New York: IDOC/North America, September 1977.

Gray, Lewis. A Decision Theoretic Model of Congressional Technology Assessment. Ann Arbor, MI.: University Microfilms International, 1981.

- "On 'Complete' OTA Reports," Technological Forecasting and Social Change 22, 299-319, 1982.

Hahn, W.A. "Foreword" to S.R. Arnstein and A.N. Christakis, Perspectives on Technology Assessment. Columbus, Ohio: Academy for Contemporary Problems, 1975.

- Technology Assessment: Some Alternative Perceptions and its Implementation Outside the United States, Testimony Before the Subcommittee on Science, Research, and Technology. House Committee on Science and Technology U.S. Congress, August 3, 1977.

Hammond, K.R. and Adelman, L. "Science, Values, and Human Judgment," Science 194, 389-396, October 22, 1976.

Hencley, S. and Yates, J.R. (eds.). Futures in Education: Methodologies, Berkeley: McCutchan, 1974.

Henderson, Hazel. "Philosophical Conflict: Re-examining the Goals of Knowledge; Technology Assessment," Public Administration Review, January-February 1975.

Hetman, F. Society and the Assessment of Technology. Paris: OECD, 1973a.

- "Steps in Technology Assessment," International Social Sciences Journal, 25, 257, 1973b.

Hoashi, Koji. "Capabilities of Technology Assessment for Development," from Report of the United Nations Seminar on Technology Assessment for Development, Bangalore, India, 30 October - 10 November, 1978. Department of International Economic and Social Affairs, New York, 1979.

- Environment, Technology Assessment and Industrial Planning: The Case Study of Japan. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 4 December 1982. United Nations Environment Programme, UNEP/WC.80/4, 3 November 1982.

Hohenemser, Christopher and Kasperson, Jeanne X. Risk in the Technological Society. Boulder, Colorado: Westview Press Inc., 1982.

Hoos, Ida R. "Societal Aspects of Technology Assessment," Technological Forecasting and Social Change 13, 191-202, 1979.

Howard, Ronald. Social Decision Analysis, Proceedings of the IEEE 63:3, March 1975.

Howard, R.A., Matheson, J.E. and North, D.W. "The Decision to Seed Hurricanes," Science 176, 1191-1202, June 16, 1972.

Hussein, Yousef Norsi. Environment, Technology Assessment and Technology Planning in Arab Countries. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 4 December 1982. United Nations Environment Programme, UNEP/WC.80/5, 3 November 1982.

Indian Institute of Technology. International Conference on Technology Assessment, papers and proceedings, IIT, Bombay. Available from R.H. Randolph (IRRI) B. Koppel (E-W Center), 1978.

Isard, W. Methods of Regional Analysis: An Introduction to Regional Science New York: Wiley, Chapter 6, 1960.

Jantsch, E. Technological Forecasting in Perspective. Paris: OECD, 1967.

Jones, Martin V. A Technology Assessment Methodology: Some Basic Propositions Mitre Corporation, McLean, Va. Distributed by: National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, Virginia 22151, June 1971.

Kane, Julius. "A Primer for a New Cross-Impact Language - KSIM," Technological Forecasting and Social Change, Vol. 4, No. 2, 1972.

Kasper, Raphael, A. (ed.). Technology Assessment: Understanding the Social Consequences of Technological Application, New York: Praeger, 1972.

Kasper, Raphael, G.; Logsdon, John M. and Mottur, Ellis R. Implementing Technology Assessments, Final Report of Technology Assessment Implementation Project. Program of Policy Studies in Science and Technology, the George Washington University, Washington, D.C. July 1974.

Kasperson, Roger E.; Hohenemser, Christopher and Kates, Robert W. Assessing and Controlling the Hazards of Technology. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 3 December 1982. United Nations Environment Programme, UNEP/WG.80/9, 11 November 1982.

Kates, Robert W. Risk Assessment of Environmental Hazard, SCOPE Report No. 8, International Council of Scientific Unions, Scientific Committee on Problems of the Environment, Paris, 1976.

Kelman, Steven. "Cost-Benefit Analysis: An Ethical Critique," Regulations, 33. January/February 1981.

Kenward, M. "Technology Assessment: New Tool or Old Toy?", New Scientist, p. 3, October 5, 1972.

Koppel, Bruce. "Technology Assessing: A View from Asia," Technos 62-70, Oct-Dec. 1976.

- "Evaluating Assessment: A Comment and a Perspective," Technological Forecasting and Social Change 14, 147-152, 1979.

Kranzberg, Melvin. "Historical Aspects of Technology Assessment," Readings in Technology Assessment. Washington, D.C.: George Washington University, pp. 1-21, August 1975.

Kruzic, P.G. Cross-Impact Simulation in Water Resources Planning Report 74-12 to U.S. Army Engineer Institute for Water Resources, Fort Belvoir, VA, Palo Alto, CA: SRI, 1974.

Lanford, H.W. Technological Forecasting Methodologies: A Synthesis. New York: American Management Association, 1972.

La Porte, Todd R. Technology as Social Organization: Toward Improved Technology Assessments University of California, Berkeley, September 1981.

Larson, Ronal N. "Technology Assessment in Developing Countries: The Solar Technologies," Technology Assessment for Development, UN, 1978.

Lawless, Edward W. Environment, Technology Assessment and Agriculture Development: The Case in Developed Countries. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 4 December 1982. United Nations Environment Programme, UNEP/WG.80/7, 4 November 1982.

Lee, Alfred, M. and Bereano, Philip L. "Developing Technology Assessment Methodology: Some Insights and Experiences," Technological Forecasting and Social Change 19, 15-31, 1981.

Leininger, G.; Jutila, S.; King, J.; Muraco, W. and Hansell, J. The Total Assessment Profile. University of Toledo (NTIS No. N75-31919/4), Toledo, OH, 1975.

Leistritz, F.L; Halstead, J.M.; Chase, R.A. and Murdock, S.H. "Socio-economic impact management: Programme Design and Implementation Considerations," Minerals and the Environment, Vol. 4, p. 141.

Leistritz, F. Larry and Murdock, Steven H. The Socioeconomic Impact of Resource Development: Methods for Assessment. Boulder, Colorado: Westview Press, 1981.

Leistritz, F. Larry; Murdock, Steve H. and Chase, Robert A. "Socioeconomic Impact Assessment Models: Review and Evaluation," Impact Assessment Bulletin, Vol. 1, No. 4.

Leopold, L.B.; Clarke, F.E.; Henshaw, B.B. and Balsley, J.R. A Procedure for Evaluating Environmental Impact. U.S. Geological Survey, Circ. 645, Washington, D.C., 1971.

Lim Fat, E.L.M. "Technology Assessment in Mauritian Agriculture," Technology Assessment in Development, UN, 1978.

Linstone, Harold A. et al. "The Multiple Perspective Concept: With Applications to Technology Assessment and Other Decision Areas," Technological Forecasting and Social Change 20, 275-325, 1981.

Linstone, Harold A.; Lendaris, George G; Rogers, Steven D.; Wakeland, Wayne and Williams, Mark. "The Use of Structural Modeling for Technology Assessment," Technological Forecasting and Social Change 14, 291-327, 1979.

Linstone, Harold A. and Simmonds, W.H. Clive (eds.). Futures Research: New Directions Reading, Massachusetts: Addison-Wesley, 1977.

Linstone, Harold A. and Turoff, Murray (eds.). The Delphi Method: Techniques and Applications. Reading, Massachusetts: Addison-Wesley Publishing Company, Advanced Book Program, 1975.

Malone, D.W. "An Introduction to the Application of Interpretive Structural Modeling," Portraits of Complexity, Battelle Monograph No. 9, Columbus, Ohio, 1975a.

- "An Overview of Interpretative Structural Modeling," Perspectives on Technology Assessment (S. Arnstein and A. Christakis, eds.). Jerusalem: Science and Technology Publishers, pp. 229-233, 1975b.

Maloney, Jr., James D. "How Companies Assess Technology," Technology Forecasting and Social Change 22, 321-329, 1982.

Martino, Joseph P. Technological Forecasting for Decisionmaking. New York: American Elsevier, 1975.

Martino, Joseph, P.; Lenz, Jr., Ralph C. and Chen, Kuei-Lin. Technology Assessment: An Appraisal of the State of the Art. National Science Foundation (UNDI-TR-78-81), September 1978.

Mayo, Louis H. Monitoring the Direction and Rate of Social Change Through the Anticipatory Assessment Function, George Washington University Program of Policy Studies in Science and Technology, Washington, D.C., July 1977.

- Systems Thinking and the Anticipatory Assessment of Proposed Public Actions, prepared for the Silver Anniversary Meeting. Society for General Systems Research, London, August 20-24, 1979.

- "The Concern Approach to Anticipatory Assessment: Rating Alternatives in Terms of Potential Difficulty of Norm Resolution and Maintenance," unpublished manuscript in the Program of Policy Studies in Science and Technology, The George Washington University, Washington, D.C., February 1982a.

- "Thoughts on the Adequacy of Performance of Technology Assessments," Technological Forecasting and Social Change 22, 267-298, 1982b.

Medford, Derek. Environmental Harassment or Technology Assessment? New York, Amsterdam and London: Elsevier, 1973a.

- Technology Assessment Under the Auspices of the United Nations, report prepared for the Office for Science and Technology of the United Nations Secretariat, 1973b.

Menkes, Joshua. "Epistemological Issues of Technology Assessment," Technological Forecasting and Social Change 15, 11-23, 1979.

Merkhofer, M.W. "A Process for Technology Assessment Based on Decision Analysis," Technological Forecasting and Social Change 22, 237-265, 1982.

Mitchell, A.; Dodge, B.H.; Kruzic, P.G.; Miller, D.C.; Schwartz, P. and Suta, B.E. Handbook of Forecasting Techniques Stanford Research Institute Report to U.S. Army Corps of Engineers Institute for Water Resources, AD-A019 280; available from NTIS, Springfield, VA, 1975.

Mitroff, Ian I. "On the Error of the Third Kind" in Harold A. Linstone and W.H. Clive Simmonds (eds.). Futures Research: New Directions Reading, MA: Addison-Wesley, 1977.

- "The Philosophy of Modeling and Futures Research: A Guide to Different Models," Technological Forecasting and Social Change 21, 267-280, 1982.

Murdock, Steve H. and Leistritz, F. Larry. "Selecting Socioeconomic Assessment Models: A Discussion of Criteria and Selected Models," Journal of Environmental Management 10, 241-252, 1980.

National Academy of Engineering. Committee on Public Engineering Policy, A Study of Technology Assessment, Committee on Science and Astronautics, U.S. House of Representatives, July 1969.

National Academy of Science. United States Congress, House, Committee on Science and Astronautics; Technology: Processes of Assessment and Choice, report of the National Academy of Science, Washington, D.C., Government Printing Office, July 1969.

National Science Foundation (NSF). "Recent NSF Studies in Technology Assessment," Futures 14(1), 62-69, 1982.

Nehnevajsa, Jiri and Menkes, Joshua. "Technology Assessment and Risk Analysis," Technological Forecasting and Social Change 19, 245-255, 1981.

Novaky, Erzsebet and Lorant, Karoly. "A Method for the Analysis of Interrelationships Between Mutually Connected Events: A Cross-Impact Method," Technological Forecasting and Social Change 12, 201-212, 1978.

O'Brien, David M. and Marchand, Donald (eds.). Politics of Technology Assessment: Institutions, Processes and Policy Disputes. Lexington, Mass.: Lexington Books, D.C. Heath and Company, 1982.

Office of Technology Assessment (OTA). Annual Report to the Congress for 1979, 61, Washington, D.C., 1979.

Office of Technology Assessment (OTA). Background and Status, report to the Committee on Science and Astronautics, prepared by the Science Policy Research Division of the Congressional Research Service. U.S.G.P.O. 10-19, 1973.

Organization for Economic Co-operation and Development (OECD). Methodological Guidelines for Technology Assessment, Paris, 1975.

- (OECD). Social Assessment of Technology. Paris, 1978.
- (OECD). Assessing the Impacts of Technology on Society, Paris, 1983.

Otway, H.J. and Pahner, P.D. "Risk Assessment" in Futures, 122-123, April 8, 1976.

Paschen, Herbert. Technology Assessment: Creative Futures (Perspectives From and Beyond the Second International Congress). Mark A. Boroush, Ken Chen and Alexander N. Christakis, eds. New York: North Holland, 1980.

Peat, Marwick & Mitchell Company. A Study of Technology Assessment Today, prepared for the NSF RANN Program, Washington, D.C., 1972.

Porter, Alan and Rossini, F.A. Integrated Impact Assessment. Boulder, Co.: Westview Press, 1983.

Porter, Alan L., Rossini, F.A., Carpenter, S.R. and Roper, A.T. A Guidebook for Technology Assessment and Impact Analysis. New York, North-Holland, 1980.

Porter, Alan L. and Rossini, Frederick A. "Evaluation Designs for Technology Assessment and Forecasts," Technology Forecasting and Social Change, 10, 369-380, 1977.

Program of Policy Studies in Science and Technology. Technology Assessment Applied to Urban Solid Waste Management, Summary Report. The George Washington University, Washington D.C., November 1971.

– Readings in Technology Assessment. The George Washington University, Washington, D.C., August 1975.

Ramanujam, Vasudevan and Saaty, Thomas L. "Technological Choice in the Less Developed Countries: An Analytic Hierarchy Approach," Technological Forecasting and Social Change 19, 81-98, 1981.

Randolph, Robert H. and Koppel, Bruce. "Technology Assessment in Asia: Status and Prospects," Technological Forecasting and Social Change 22, 363-384, 1982.

Reddy, A.K.N. "The UNCSTD Trial: Deprived Humanity vs. Science and Technology," New Scientist, 26 October 1978.

Rescher, Nicholas. "Methodological Issues in Science and Technology Forecasting: Uses and Limitations in Public Policy Deliberations," Technological Forecasting and Social Change 20, 101-112, 1981.

Ribeiro, Carlos, C. Environment and Technology Assessment of New Sources of Energy. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 3 December 1982. United Nations Environment Programme, UNEP/WG.80/10, 1 December 1982.

Richardson, H.W. Elements of Regional Economics New York: Praeger, 1969.

Riggs, Walter E. "The Delphi Technique: An Experimental Evaluation," Technological Forecasting and Social Change 23, 89-94, 1983.

Rohatgi, K. and Rohatgi, P.K. "Delphi as a Tool to Identify Future Appropriate Technologies in India," Technological Forecasting and Social Change 14, 65-76, 1979.

Rohatgi, Pradeep. Environmental Dimensions in Technology Assessment for Industrial Development: The Case Study of India. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 4 December 1982. United Nations Environment Programme, UNEP/WA.80/3, 19 October 1982.

Roper, A.T. and Dekker, D. "Values: a simulation of values impact of technological activity." Terre Haute, Indiana: Center for Technology assessment and policy studies. (1978)

Rossini, Frederick A. and Porter, Alan L. Integrated Impact Assessment. Boulder, Colorado: Westview Press, Social Impact Assessment Series, No. 8, 1983.

Rossini, Frederick A.; Porter, Alan L.; Kelly, Patrick and Chubin, Daryl E. Framework and Factors Affecting Integration Within Technology Assessments. Georgia Institute of Technology, Atlanta, December 1978.

Rossini, Frederick A.; Porter, Alan L. and Zucker, Eugene. "Multiple Technology Assessment," Journal of the International Society for Technology Assessment 2, 21-28, 1976.

Rowe, William D. The Anatomy of Risk. New York: John Wiley & Sons, 1977.

Sagasti, Francisco R. "Towards Endogenous Science and Technology for Another Development," Technological Forecasting and Social Change 16, 321-330, 1980.

Sage, A.P. Methodology for Large Scale Systems New York: McGraw-Hill, 1977.

Sagoff, Mark. "The Limits of Cost-Benefit Analysis," Philosophy and Public Policy 1, 9, Summer 1981.

Sallam, A.M. "Technology Assessment for Development in the Field of Health," Technology Assessment for Development, UN, 1978.

Sassone, P.G. and Schaffer, W.A. Cost-Benefit Analysis: A Handbook. New York: Academic Press, 1978.

Schuman, Jack N. "Assessing Technology Assessment," Futures, August 1976.

Schwing, Richard C. and Albers, Jr., Walter A. Societal Risk Assessment: How Safe is Safe Enough? New York: Plenum Press, 1980.

Sharif, M. Nawaz. Environment, Technology Assessment and Technology Planning in Asian Developing Countries. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 4 December 1982. United Nations Environment Programme, UNEP/WC.80/2, 19 October 1982.

Sharma, B.P. "Technology Assessment in Industry," Technology Assessment for Development, UN 1978.

Standke, K.H. "The United Nations and Technology Assessment" in P.D. Wilmot and A. Slingerland. Technology Assessment and the Oceans. Boulder, Co,: Guildford, pp. 22-27, 1977.

Stober, G.J. and Schumacher, D. (eds.). Technology Assessment and Quality of Life. Amsterdam: Elsevier, 1973.

Strasser, C. OECD Seminar, Paris, January 1982.

Swaminathan, M.S.; von Weizsacker, E.U. and Lemma, Aklilu (eds.). New Frontiers in Technology Application: Integration of Emerging and Traditional Technologies. United Nations, Science and Technology for Development Series, Volume 2. Tycooly International Publishing Ltd., Dublin, Ireland, 1983.

Thiriet, L. and Sugier, A. "Comments on the Concept and Methodology of Technology Assessment," Technology Assessment, Vol 2, No. 4. Gordon and Breach Science Publishers Ltd, London, 1974.

Tiebout, C.M. The Community Economic Base Study Washington Committee for Economic Development, 1962.

Torgerson, Douglas. Industrialization and Assessment. York University Publications in Northern Studies, Toronto, Ontario, Canada, 1980.

Trak, Ayse and MacKenzie, Michael. "Appropriate Technology Assessment: A Note on Policy Considerations," Technological Forecasting and Social Change 17, 329-338, 1980.

Tribe, Laurence H. "Technology Assessment and the Fourth Discontinuity: The Limits of Institutional Rationality," South California Law Review 46, 627, 1973.

United Nations. Report of the United Nations Seminar on Technology Assessment for Development, Bangalore, India, 30 October - 10 November, 1978. Department of International Economic and Social Affairs, New York, 1979.

United Nations Secretariat. Report of the Expert Group on Technology Assessment, convened under the auspices of the Office of Science and Technology of the United Nations Secretariat, New York, 23-27 June 1975.

Ventura, Arnoldo K. Environment, Technology Assessment and Technology Planning: The Case of Carribean Islands. Seminar on Environment Aspects of Technology Assessment, Geneva, 29 November - 4 December 1982. United Nations Environment Programme, UNEP/WG.80/8, 4 November 1982.

Wakeland, W. "QSIM 2: A Low Budget Heuristic Approach to Modeling and Forecasting," Technological Forecasting and Social Change 9, 213-229, 1976.

Warner, M.L. and Preston, E.H. A Review of Environmental Impact Assessment Methodologies. U.S. Government Printing Office, Washington, D.C., 1974.

Warwick, D.P. and Lininger, C.A. The Sample Survey: Theory and Practice New York: McGraw-Hill, 1975.

Watson, R.H. "Interpretive Structural Modeling: A Useful Tool for Technology Assessment," Technological Forecasting and Social Change 11 (2), 165-185, 1978.

White, Jr., Lynn. "Technology Assessment from the Stance of a Medieval Historian," American Historical Review, Vol. 79, No. 1, 1974.

Wood, Fred B. "The Status of Technology Assessment: A View from the Congressional Office of Technology Assessment," Technological Forecasting and Social Change 22, 211-222, 1982.

Wynne, B. "The Rhetoric of Consensus Politics: A Critical Review of Technology Assessment," Research Policy, Vol. 4, p. 108, New York, 1975.

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