EVALUATION OF TECHNOLOGY AND TECHNOLOGY ASSESSMENT (TA)

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"If the man of science of our own days could find the time and the courage to think over honestly and critically his situation and the tasks before him and if he would act accordingly, the possibilities for a sensible and satisfactory solution of the present dangerous international situation would be considerably improved."

Albert Einstein *(Ideas and Opinions).*

1. INTRODUCTION

Can we afford to stand aloof from technology while living immersed in an artificial environment that is more and more the child of big industry based on scientific and technological research? Although we are increasingly aware that technology is instrumental for both welfare and warfare, do not most of us —including many technologists— ignore what technology is? The fact is that not even technologists are always acquainted with the nature of their own products, the methods by which they obtain them, or the historical root and social setting of their own work. It is true that some people are specialists in the history of technology or in the sociology of technology realizing that it is difficult to isolate the economic, social, and political consequences of technology *(1)*. But technology is not only a subject for scholarly specialization, and this simply because the future of mankind depends, to an increasing extend, on the results, methods, valuation, and uses of technology.

Nowadays metatechnology cannot contribute to the control of tec/hnology for the benefit of humankind, because research is now a power and an industry. Moreover, it is mostly a military powerful industry. But meta-

(1) Actually, economic and social factors cannot be dissociated from political and cultural factors for we consider society as a system of systems (Braudel 1982: Ch. 5; Tobar, 1983).

technology *does* contribute to the understanding of the tree of good and evil and cannot be absent from any adequate evaluation of technology —as metascience, in turn, cannot be absent from any evaluation of science—, and, consequently, of modern culture. Metatechnology offers a quite different picture of technological knowledge and research from the hanging in the offices of industrialists, managers, politicians, and military men *(2).*

The intrinsic cultural value of technology is often neglected by those who esteem it for its practical exploits. This is mistaken, because technology, though oriented to practical efficiency and usefulness, cannot be confused with its misuses and abuses. (In fact, the clarifying and stressing of this distinction is one of the goals of this work). As to science, it is "useful" to the extend to which is truthful, not the other way around.

Metatechnology, on the other hand, helps to understand the features that make technology culturally valuable *(3),* (as metascience does so with science), hence educationally indispensable. Gone are the days of classical studies and scholars *(4):* ours is the Age of Science and Technology, and both are a compelling force for improving present knowledge, and present living conditions.

As for philosophy, at least as it is practiced by most academic philosophers —inasmuch as they are concerned with pseudoproblems or repeating old texts in the search for the total and unchangeable truth—, it has nothing of real importance to say to our atomic age (Schilp, 1961: 245). If there was a time when "philosophy not merely did have something to say, but said it so emphatically that it cost Socrates his life, Spinoza his religious affiliation, and Kant his right to write and publish" (Schilp, 1961: 239), present-day philosophy, the "love of wisdom", has become a (well paid) job in the so-called First World, and an ideological tool in the Second, while problems grow bigger and bigger (not only in the so-called Third World) and the international relations between the two superpowers are even worse than after World War II. However, while philosophy is dead at the academic level, it is alive in modern schools of engineering (Bunge, 1977a: 271), and in whatever place in which science is alive. This because we know

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(2) *As far as technology is an action-oriented knowledge (Tobar, 1984a) its rules unlike the laws of nature, can be obeyed or broken. Therefore the side effects of technology can be avoided either by not applying that specific knowledge or by studying the same problem at deeper levels. Hence, the need of more pure or basic science. Therefore, the need of more basic research in the* R & D budgets. (See Tobar, 1984b,c).)

(3) *The impact of modern technology in society has been very significant (think of the implementation of atomic energy for instance). Greater impacts can be foreseen on the horizon: fusion plants, undersea mining, economically useful desalinization of sea water, new synthetic materials, and so forth.*

(4) *As Kotarbinski (1965: 197) points out, "Until quite recently, there were to be found perfect example of routinism [which consists according to him in replacing creative invention by the automatic replication of previous actions] in the form of traditional curricula, overloaded with the classical languages, whereas the need of life had long requiredfrom pupils a knowledge of at least two modern languages and a fair orientation in the natural sciences, technology, and the national economy".*

that there is no demarcation line between science and philosophy, not even between technology and philosophy (see Bunge (1977b) for a programmatic paper to analyze the philosophy of technology). On the other hand, the great tradition of philosophy is not dead. On the contrary, the aim of philosophy remains what it was in Ancient Greece, namely somehow to describe how all knowledge fits into a system, into a permanently open system because knowledge from the different sciences and technologies continues to increase and changes with time. Since some philosophers have blame technology for (all) the problems our society has to face, we need to take a look at the evaluation of technology, and, in particular, at the so-called 'technology assessment', TA for short. Moreover, scientific and technological research can be guided (or stopped) by good (or bad) philosophy.

2. TECHNOLOGICAL FORECASTING

Technological forecasting is different from scientific prediction *(5)*. Technological forecasting is a prelude to operational activity (Roman, 1980: 121). Technological objectives should be reviewed and modified for compatibility with potential accomplishement. After this, a procedure strategy can be derived to guide planning, programming, implementation, control, and evaluation. This last stage constitues the so-called 'technology assessment' or TA, which shall be analyzed below.

As Roman (1980: 123) points out, "forecasting is far from an exact science, so much so that standards methods and procedures have not been generally established,... network construction are most commonly used. More exact and understandable techniques must be developed which are practical and provide management with reasonable confidence in their accuracy". In line with this assertion, Bunge (1973 : 212 ff) analyzes the different varieties of forecasting, from nonscientific (wild guessing, prophesing, common sense forecasting, and expert prognostication) to scientific (scientific prediction, technological forecasting).

The differences between scientific forecasting or prediction and technological forecasting are conceptual (the theoretical models employed in technological forecast are usually simpler and more superficial than those occurring in scientific prediction), methodological (technological forecast are supposed to be nomological rather than tentative, whereas scientific predictions can be either) *(6)*, practical (whereas scientific pradictions are

(5) In both technological forecast and scientific prediction the predicative statement is a conditional proposition and a logical consequence of hypothes (or theories at best) and data. While a scientific prediction has the form: If A happens at time t_1, then B will happen at time t_2 *($t_2 > t_1$) with probability P, the technological forecast has the form: If the goal B is to be achieved at time t_2 with probability P, then A should be done at time t_1 ($t_1 < t_2$).*

(6) Technological forecasting employs only well corroborated hypotheses for its aim is not to find the truth but to apply it. If tentative the forecast would put the model to test, not to work.

value neutral, technological forecasts are value laden and moreover they can have and effect on those who are cognizant of them.

The accuracy, hence the reliability of the projections involved in any course of rational action will depend on the state of the disciplines involved as well as on the nature of the goal. We know many physical, chemical, and biological laws, and psychological and social trends or quasi-laws. We have to use those laws and trends if we are dealing with technological forecast, i.e. to forecast the behavior of a man-robot system. (This reminds us that technological forecast is interdisciplinary). Technological forecasting is used in design problems everywhere (Tobar, 1984b), and since it is a rational action we must take into account its relation with praxiology, if only because technological planning is based on technological forecast. (See Fig. 1, adapted from Bunge (1973: 208).

As for the specific role of technological forecasting organizations, there are some advantages to having technological forecasting as an independent operation and functional entity if the size of the organization or firm warrants technological forecasting. Among them the following ones: a) it can be used by management for checking and balances in assessing the validity of long-range planning and objectives; b) it can help in determining what emphasis to place in research and development; c) however, it must be guarded against excessive cost generated by possible operational practice inconsistent with the organization's need and capacity.

Although technological forecasting is a young kid, its present structure took shape aroud the 1960s (Jantsch, 1967: 17) *(7),* so far the greatest application and methodology development has been military oriented (Roman, 1980: 125), as some other branches of technology since the earlier Latin engineers up to now. In fact, nearly half of the world's scientists and technologists were engaged in military works during the 70's. (More on Forecasting and Planning can be seen in Roman (1980: Ch. 10, on the use of the PERT method) and in the journal *Technological Forecasting. Social Change).*

3. TECHNOAXIOLOGY

While axiology or value theory is the branch of philosophy concerned with the nature of values, their origin (biological, social) and their impact on human action, technoaxiology can be conceived as the study of the valuations performed by technologists in the course of their profession.

For the scientist all concrete objects are equally worthy of study and devoid of value: even pollutants, for in pure science valuation bears not on

(7) Technology forecasting differs from technology assessment (Rossini, 1979: 346) in that technology forecasting focuses on the future of technologies rather than on their future consecuences. Technology forecast relies on quantitative and qualitative techniques such as trend extrapolation. (See Bright, 1972; Hencley and Yates 1974).

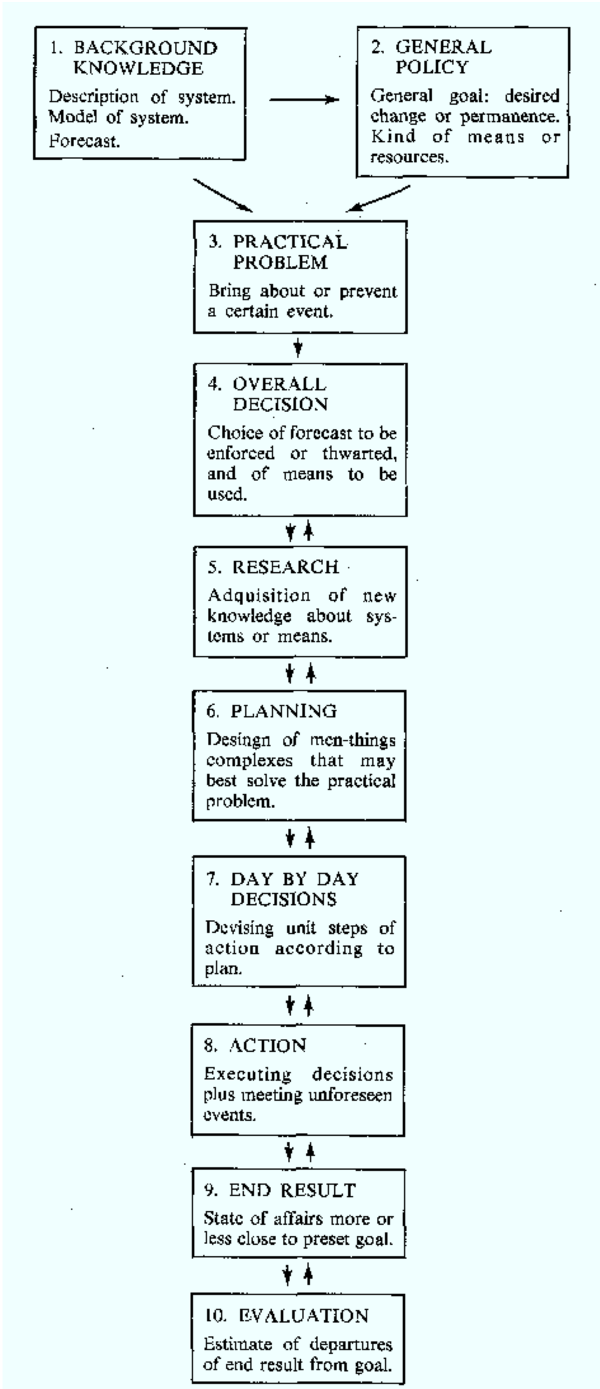

Fig. 1.—Diagram of rational and informed action.

the objects of study but on research tools (e.g. measurements or computation techniques) and outcomes (e.g. data and theories). However, this is not so to the technologists. The technologist evaluates everything: she partitions reality into resources, artifacts, waste products, and useless things. She values artifacts more than resources (because her task is the design of artifacts to improve living situations), and resources more than the rest. This valuations occur as a human activity performed in a concrete socio-historical context done in the light of definite knowledge and desiderata *(8).*

The value orientation of technology raises some problems to be elucidated by the technophilosopher or metatechnologist. Here a sample of them (Bunge 1977b: 165-166):

TAP1. What kind of values (or value functions) does the technologist handle: economic, social, political, cognitive, aesthetic, or moral —or all of these?

TAP2. What technological value indicators (or estimators) are the most reliable: benefit / cost ratios, time saved, satisfaction of social needs, or what?

TAP3. The values occurring in decision theory and its implications (e.g. to management and engineering) are subjective. Would it be possible and desirable to replace them with objective values, such as the degree to which a basic need has been satisfied? Or with objective-subjective pairs of values?

TAP4. How could one define the concept of objective value - i.e. what set of axioms might characterize it unambiguosly (in contrast to the utility or subjective value)?

TAPS. Would it be possible to formulate decision rules based upon value theoretic axioms or theorems relating the values of the goals and side effects to those of the means?

TAP6. The technologist lacking in social sensitivity, just like the politician without scruples, may ignore the noxious side effects of the means she employs to attain her goals —or rather those of her employer, and concern solely with achieving technical excellence. Is this one-sideness unavoidable or could it be corrected— e.g. by adopting a global technological approach, rather than a piecemeal one?

TAP7. Technologist make, or ought to make on the strenght of laws and value judgments. Would it be possible and desirable to generalize this procedure to approach moral, legal, and political issues?

TAP8. What is the precise role of value judgments in the drawing up of urban developments plans, educational projects, health care systems, or plans for the development of a country?

TAP9. Assuming that every member of a community can assign his

(8) This is so because every deliberated human action is value-oriented. Technology is an oriented knowledge to achieve some goal or other (Tobar, 1984,a,b). However, the objects of human action —the things upon which we act— need not always be valuable or disvaluable.

or her value to every initiative or action in a social scope, is it possible to form an aggregate value for the community as a whole and thus be able to speak of the value it assigns to the idea or action?

In general, whereas natural sciences is presumably value-free, technology and social sciences are arguably value-laden. In what manner and why?

4. AXIOLOGY OR VALUE THEORY

We have been taught that valuation is beyond the reach of science, even that it is irrational. But we can argue about value judgments. Actually, contemporary physiological psychology teaches us that every animal has an inherited mechanism enabling it to distinguish, not without error, what is good, bad or indifferent for it.

We must distinguish between the concept of biovalue (Bunge 1979: 89-90) and the concept of phychovalue (Bunge, 1979: 160). The biovalue of a subsystem a for an organism *b* at time *t* is the objective value that a possesses for *b* at *t*. The psychovalue of item a for organism *b* at time *t* is the value *b* assigns to *a* at *t*. This assignment may be biologically mistaken even though it is a biological event, namely, an animal may attribute great value to biologically harmful items and little value to biologically valuable ones. Psychovalues may conflict with biovalues. Let us elucidate the notion of value system and choice following Bunge (1980: 131-133):

Postulate 1.— All animals are equipped with a value system, and those capable of learning can modify their value system.

Definition 1.— Let S be a set of items and *b* an animal. Further, let $\gtrsim_b$ be a partial order on S. Then the structure $V_b = < S, \gtrsim_b >$ is a *value system* for *b* at a given time *t* iff.

(i) *b* can detect any member of S and discriminate it from all other items in S;

(ii) for any two members *x* and *y* of S, *b* either prefers x to y ($x \gtrsim_b y$) or conversely ($y \gtrsim_b x$) or both ($x \sim_b y$) at the given time.

Definition 2.— Let $V_b = <S, \gtrsim_b>$ be a value system for an animal *b* at a given time t, and call AcS a set of alternatives open to *b,* i.e., belonging to the behavioral repertoire of *b* at the time. Then *b* chooses (or *selects)* option xEA iff (i) it is possible for *b* to pick (i.e. to do) any alternative in A (i.e. *b* is free to choose);

(ii) *b* prefers *x* to any ather options in A; and

(iii) *b* actually picks (i.e. does) *x*.

(Note the difference between preference and choice: the former underlies and motivates the latter. See more in Mosterin (1978: 56-57).)

Since higher animals, and in particular humans, live in society, we characterize culture as one of the main subsystem of society (Tobar, 1984b). The culture of any society is the subsystem of the society whose members engage in mental activities that control (or are controlled by) some of the activities of other members of the society. We distinguish the creative process (which is a process in some brain or other) from its public materialization. These mental processes are externalized as physical things or artifacts which, when perceived by competent observers, elicit in their brains processes similar to those underwent by the creators. As Bunge asserts (1980: 172), "Nothing is more dependent and vulnerable —less autonomous— than the "world" of culture... Culture lives neither, in cultural artifacts, such as books, nor in an immaterial and autonomous world of ghosts: it lives in the brains of those who care about it —who cultivate it." (About the ontological status of artifacts see my *Ontology of Artifacts* (Tobar, 1984b).)

We do not hold the idealistic point of view according to which "Culture is but a body of ideas and values". There is no such thing as disembodied values: there are only concrete people who think up ideas and evaluate. All the activities that characterize a culture are guided (or misguided) by beliefs and values belonging to culture.

Values, then, are not autonomous entities, as idealists claim, constituting a realm of their own opposed or distinct from the world of facts. Values are properties, not entities. We assign values to things, events, and ideas. Once values are recognized as an outcome of the valuation activity of an organism, they become aspects of certain facts. Moreover, in decision theory values joint with another property of facts, namely their probability. In fact the very definition of rational decision as that which maximazes the expected utility (or subjective value) *(9)* involves such a synthesis of fact and value. So, the value of an item depends on the item itself and upon the evaluating organism.

(We shall deal with a value theory transparent to logical analysis and amenable to empirical control, a value theory of means, goals, and side-effects elsewhere (Tobar forthcoming). More on value theory in Hartmann (1969) from a Platonic point of view; in Rescher (1969); and in the journal *Journal of Value Inquiry.)*

5. EVALUATION OF TECHNOLOGY

Technology has been seen as the motor of all progress, as a source for human hapiness, as a promise of utopia (Kahn, 1967). But also as the sour-

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(9) Our elucidation of value system is a preference relation. A quantitative concept is elucidated by utility theory occurring in decision theory as follows (Bunge, 1980: 131): "Utility may be construed as a function U: AxBxT R whose value U (a, b, t) = u *for an object* a *E A and an organism* b *E B at time* t *E T is the value* b *assigns to* a *at* t. *With the help of this function we can redefine the concept of a value system, namely thus:* The value system of a group of animals B *(species, population, community, or whatnot) is* V_B *= < A, U >, where A is the set of objects (things, states, events) valued by the B's".*

ce of society's problems (Ellul, 1967; Mumford, 1967, 1970; Dubos, 1968; Reich, 1970; Roszak, 1972), as a means for dehumanization. Ours, however, will be a critical approach far away from the optimistic and pesimistic views quoted above.

There was a time —the 60's and 70's— in which some people blamed science and technology for the ills of our society. In doing so, they confused on the one hand science with technology, and, on the other, technology with its misuse and abuse, even confusing technology with its products.

The antitechnological pivotal (Ellul, Mumford, Dubos, Reich and Roszak, the last two apostles of "counterculture") movement can be characterized as follows (Florman, 1976: Ch. 2):

(i) a primary characteristic of the antitechnologists is the way in which they refer to "technology" as a thing that has an existence of its own, an existence separate and distinct from human beings;

(ii) the average citizen is driven by this force, "technology", to perform work he detests;

(iii) he is driven to consume things he does not want;

(iv) they place the blame on a particular group of individuals, namely the establishement assisted by technology. Technology creates an elite class of technocrats;

(v) technology has cut man off from the natural world in which he evolved;

(vi) technology provided man with technical diversions which destroy the "existential" sense of his own being.

In addition, antitechnologists are against tourism (while, of course, they practice it), and in politics they advocate for disengangement (when times demand more and deeper citizen activity).

In contrast, the primitive tribe, the peasant community and medieval society are considered preferable. But since there is no possibility of going backward, a reorientation along "human nature" is needed, a return to man's "true nature". The arcadian days (that never were) are missed *(10).*

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(10) Even Skolimowski who considers (1968: 435) that the philosophy of technology is still in its infancy, and clearly distinguishes science from technology ("While in science we investigate the reality that is given in technology we create reality according to our designs" (1968: 434)), noting the dispute on technology and values ("The major adversaries in the disputes on technology and values are the optimists on the one hand, the pesimists on the other. The optimists, whose views are usually expressed in pamphlets published by big industrial corporations, see in technology a condition sine qua non *for, and often the embodiment of, human happiness. The pesimists, who are usually found in the academic world, envisage technology as devouring human values and consequently as dehumanizing our lives" (1968: 429), and takes "Philosophy of technology (as) the philosophy for our times" (Skolimowski, 1976: 459), however, later on (Skolimowski, 1979: 331) he claims that "'Philosophers, futurologists, and all other people who are concerned with the future of technology and thus the future of our culture should be sent to Indian reservations* [to alternative life styles]: they should be sent to oriental societies and cultures in which alternative ways of interpreting the world are still viable and form alternative basis of knowledge and of life styles". Enthusiastic as we are with the Indian affair (see Matthiesen,

However, it is true that "there are aspects of earlier cultures that seem appealing, and to which we can usefully look in structuring our own lives. But the antitechnologists have distorted the picture shamelessly, glorifying the earlier cultures and at the same time defaming ours. Then, with the air of protecting the higher values and the nobler pursuits, they blame the fancied deterioration in society on the role supposedly played by technology" (Florman, 1976: 73).

Although there are formidable problems which must. be met head-on *(11)* and solved, new knowledge in form of deeper science and right appli-

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1983), we cannot agree with Skolimowski. On the contrary, we submit that we need more and deeper science, more and better technology than ever if we want to solve the problems that present-day society faces (Tobar, 1984b,c). Nevertheles, we do agree with him when he asserts (Skolimowski, 1979: 329) that "the philosophy of technology must not be conceived as a mere scholastic discipline. Of course, a scholastic approach does give comfort and aesthetic pleasure to those engaged in it, and these satisfactions are important. However, let us be aware above all that the philosphy of technology emerged as a result of a critical appraisal of the state of our civilization. It did not evolve to provide analytically minded philosophers with an arena in which to perform their marvelously effective analytical pirouettes". On the contrary, the philosophy of technology has emerged "because of the urgency and magnitude of social and human problems arising from the interaction of society with technology" (Skolimowski, 1979: 334). In creating the philosophy of technology "we might be able to awaken philosophers and students of philosophy from their analytical slumber and show them once more what an exciting subject philosophy is... The philosophy of technology is not the panacea which will cure all ills, but it might become a most illuminating, exciting, and significant intellectual endeavor for our times" ((Skolimowski, 1979: 335).

Florman (1976: 98) is asking the same: "Somehow the engineer will find a philosophical platform from which he can once again view the world with zest. He need not choose between the roles of discredited messiah and plodding technician.

"The time has come for us to end with defending ourselves against spurious criticism and to start in search of an engineering philosophy for our age". The wrong choice is existentialism, pace *Florman himself.*

And Feibleman (1982: 6) reminds us that the great tradition of philosophy is not dead. On the contrary, the aim ofphilosophy remains that it was in ancient Greece, namely, somehow to describe how all knowledge fits into a system, though now it would have to be an permanently open system because knowledge borrowedfrom the sciences continues to increase for ever, So, as far as the epistemologist —the meta-technologist or technophilosopher in this case of the study of technology— has to take sides, we do take sides with critical and scientific realism and emergent and scientific materialism as the ground for the Philosophy of Technology for our times (see Tobar, 1984b).

(11) Here are some of specific future prospects that need more and deeper science, and more and better technology:

- *(i) improved education. New fields and career patterns create interdisciplinarity;*
- *(ii) less human physical work and more leisure time:*
- *(iii) internationalism. Increased travels and mobility. Technology transfer. Technological consortiums and multi-national organizations;*
- *(iv) improved communications;*
- *(v) longer life expectancy;*
- *(vi) recognition of individuals rights, and social rights, democratic participation;*

cation of it —via technology— taking into account side effects and social consequences may, and eventually can, help us in handling them. As a rebuttal of antitechnologists, compared to conditions of a hundred years ago, human life is much dearer today. The environmental crisis is clearer than ever (DeVore 1980: 304-308) and ecological studies spread everywhere. As DeVore (1980: 338-339) points out, the study of technology requires the study of the interrelation of various systems: technical, social, ideological, and ecological (see Fig. 2):

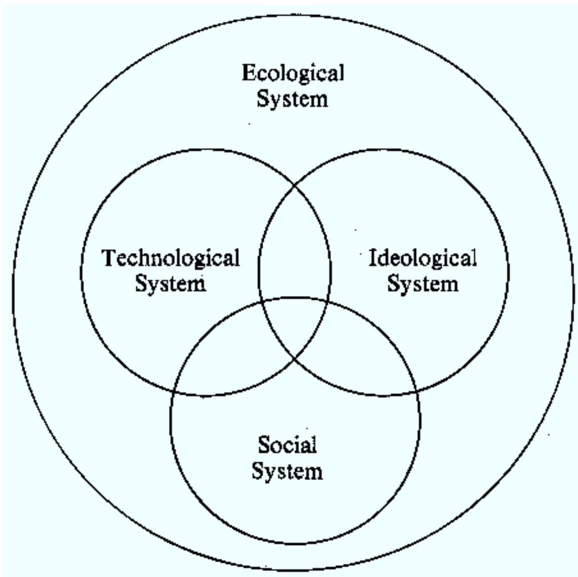

Fig. 2.— Interrelation of systems.

Technical components consist of resources, materials, tools, machines, energy, power, and information. Social components consist of human elements including work skills, intellectual processes, occupations, environmental relationships, and organization and management of technical systems. Social components include social systems, ideological systems, and ecological systems. See, in Fig. 3, the evolution and relationship of technological systems and social purpose:

(vii) rational economic use of ocean resources. Minerals, food, water;
(viii) change in women's role in society:
(ix) improved health care. Better medicines, new drugs, artificial organs;
(x) Improved waste disposal, recycling;
(xi) constant evaluation of technological priorities:
(xii) universal prosperity and peace;
(xiii) stop of arms race.

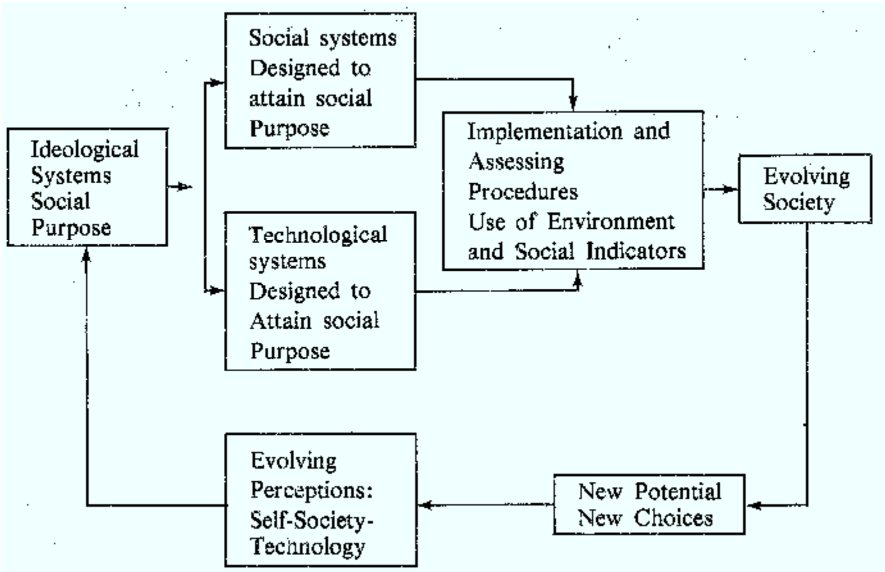

Fig. 3.— Evolution and relationship of technological systems and social purpose. Adapted from DeVore (1980: 340).

The destruction of the natural environment must be halted. The damage may not be irreversible and irreparable. So, we need a realistic assessment of technological processes, via technology assessment, TA for short, so that we can use appropriate technologies— soft, intermediate, or hard technologies because *Small is beautiful* and also *Large is beautiful* depending on the importance and magnitude of the problems to be solved. (More on that in a while).

There is a dangerous descent from antitechnologism and antiscienticism to antiintellectualism and irrationalism. Blaming technology is, most of the times, an irrational scapegoat (Florman, 1981; Tobar, 1984c). Only reason and intelligence can solve our problems: if we turn against them, we are totally lost. As Rescher (1980: 20) observes, "Science and technology will not, cannot, produce the millenium. And yet in a crowed world of very limited resources we cannot create an adequate setting for human life without them... The poor workman always blames his tools; but the difficulties lie not in the tools but in our capacity to make intelligent use of them". The cruel fact is that instead of stressing the importance of basic science, therefore basic investigation in R & D budgets, a society that spends many billions of dollars on a various cornucopia of deleterious trivia, to say nothing of untold on military outlays, assumes an unconfortable moral posture in deciding that science —even big and expensive science— is a game that is not worth the candle (Rescher, 1980: 103-104). A cutting of pure investigation budgets, will not only be a sin against our seek for truth but also a substantial stagnation in the pace of progress.

6. TECHNOLOGY ASSESSMENT (TA)

In seeking to clarify the issues involved here, our aim is to do the job of a metatechnologist or technophilosopher: to raise questions, to sharpen our focus on the issues, and to indicate the considerations that must be taken into account. This does not necessarily imply to provide answers and solutions. It seems to be a preliminary.

Technology has had a strong exogenus effect on environment. Until very recently, technology assessment, TA for short, was based on narrow considerations of technical efficacy and immediate, direct and observable results. TA is a child of the 1960's (see Settle (1976)). However, increasing knowledge of the indirect impacts of technology upon society and the environment has led to systematic study of the effects of technology. As Rossini (1979: 342) observes, "TA is systematic, higher order, interdisciplinary, action oriented, and future oriented". The main task of TA is to forecast the range of possible effects of technology so as to clarify society's choices before options. TA systematically examines the possible effects on society and on its ecological environment when a technology is introduced, extended, or modified. Therefore, the interest of the study of the so-called "appropriate technology". While technologists are divided over the hardness of technology —advanced, appropriate, or soft—, a deep study of the possible effects of technology implementation can lead to the appropriate choice.

Nowadays the whole bulk of TA reports are related to all the different branches of technology. Hetman (1973) points out that in the United States the main areas in which technology studies have been undertaken are food, housing, biomedicine, energy, transportation, and nuclear energy. The objective of TA is the systematic examination of a specific technology as a component, subsystem, or system of a concrete social system, and the evaluation of implications which include but extend beyond technological accomplishemeny. As Kiefer (1970) says, "Technology assessment is an attempt —still halting and uncertain—to establish an earlywarning system to control direct, and, if necessary, restrain technological development so as to maximize the public good while mini/mizing the public risk. It is, no less, a new approach to allocating scientific resources, setting technological priorities, and seeking more beningn alternatives to the technology already at hand".

In this sense, it can be said with Skolimowski (1976: 460) that TA is a social critique of technology at large. In fact, technologies can be assessed from different points of view:

(i) from a technological point of view: Is this technology functional? Is it supported by scientific knowledge? What are the alternative technologies? Which are the related technologies?;

(ii) from an economic point of view: Does this technology affect the economic structure? What economic system does this technology develop: public or private?;

(iii) from a sociological point of view: Does technology create a need for new professional categories and make some other categories obsolete? What is the relation between the implementation of technology and unemployement? How does technology affect the composition of the population and the availability of human and material resources? How does technology affect community, family, property? What are its legal constraints;

(iv) from the individual point of view: Does this technology affect health and life expectancy? How does the technology affect experience and social status? Does it make any difference to the quality of life or in the education of the individuals? Does the technology affect participation and social commitment?

(v) from an environmental point of view : Does technology affect environmental quality or the ecological balance? Does the technology affect environmental resources and man-made environments such as urban areas?;

(vi) from the point of view of the values and social responsibility of the decison maker: Does technology affect other goals or the national interest? What vested interest may appear in the course of the implementation of such technology? What interest may press for the adoption of the technology? Is the government involved?

(See more on that in Hetman (1913).)

TA is usually performed by a team containing representatives of different disciplines. The tasks of TA are typically the folloving ones (Rossini, 1919: 344-345):

1. Defining and bounding the assessment focus (including the comprehensiveness and depth of coverage).
2. Describing the technology to be assessed (including a discussion of technological alternatives).
3. Forecasting the development of the technology (technology forecasting).
4. Describing the most important features of the context (social, economic, environmental) with which the technology interacts most closely.
5. Forecasting the development of the technology's context.
6. Identifying direct and, were possible, higher order consequences or impacts of the interaction between the technology and its context.
7. Analyzing these conquences (economic, environmental, social, institutional, etc.) by various quantitative and qualitative techniques.
8. Evaluating the impacts and integrating the findings.
9. Identifying and analyzing the policy issues and options involved and possible making recommendations.
10. Communicating the results of the assessment *(12)*.

(See an alternative list in Hetman (1913: Ch. 3).

(12) In turn, Jones (quoted in Roman, 1980: 120) suggest seven major steps in making TA:

(i) Define the assessment task

Present-day TA is more of an academic concern than a practical and effective tool for decision making. It is important to develop a body of knowledge on TA including methodology, procedure and applications. Because TA may be too costly, controversial, vague, and academic, it is also important to develop realistic indicators for the different impacts of technology and their evaluation. In this sense, Carpenter (1911: 588 ff) sees some unresolved philosophical issues in TA along the following lines:

Epistemology of TA.—Clarification of impacts and social indicators. Interdisciplinary communication. Need of a philosopher on TA.

Axiology of TA.—Clarification of the implicit norms which are brought to the team of TA practitioners.

Ontology of TA.—Clarification of the notion of society.

7. APPROPRIATE TECHNOLOGY

We have seen above that technology implementation must be planned. To plan technology, there must be some level of expectations from technology. This is where technological forecasting comes into the scene. Technological feasibility, by itself, is not sufficient. We must also know if a technological innovation is economically justifiable and socially and politically acceptable. When we consider the social consequences, it becomes technology assessment. TA goes beyond self-interest evaluation of such factors as technological feasibility and profitability. Furthermore, it has been pointed out that TA would involve several disciplines and would seek a cross-impact analysis of the technology under investigation.

We have refused to takes sides in the debate about pessimism versus optimism in evaluating technology, although something has already been said (see a rebuttal of antitechnology in Florman (1916: Ch. 3) *(13)*. Ins-

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(ii) Describe relevant technologies.
(iii) Develop state-of-society-assumptions.
(iv) Identify impact areas.
(v) Make preliminar impact analysis.
(vi)) Identify possible action options.
(vii) Complete impact analysis.
And Coates (quoted in Roman (1980: 129) identifies ten modules of a TA:
(a) Definition of the problem, the technology, issue or project to be assessed.
(b) Definition of alternative systems to be examined.
(c) The unfolding of impacts.
(d) Evaluation of the significance of impacts.
(e) The decision apparatus.
(f) Defining options and alternatives,
(g) Parties at interest with regard to a particular technology.
(h) To recognize and analyze the impacts of variation on the technology under consideration.
(i) Exogenous factors should have a prominant place in any TA.
(j) One must examine all the above to come to some set of conclusions.

(13) To make thing worse, many defensors of technology are indeed philistines of first order with a fatuous overoptimism on technology.

tead of vendettas we should face the problems. Distateful as it may be to some people, it is clear to us that our survival, and the salvaging of our environment, are dependent upon more and better technology, not less (Tobar, 1984c). We do not agree with the apocalyptic view of the antitechnologists. Nor with the apologetic view of prophets like Kahn. Ours is one in-between view, more critical than those two views. When blaming someone, we can and must blame the technologist's bosses, namely the politicians and entrepreneurs. Florman (1976: 34) clearly points them out: "Government traditionally has shown little interest in long-range planing (except for the military) and little concern for the preservation of natural resources". It is irrational to blame technologists for things that were done at the behest of society. Technologists do not have the power to make major decisions for society *(14)*. "The big question of what to do next are not technical, or only partly technical. They are primarily *political...* The world is run by politicians and entrepreneurs" (Florman, 1976: 38). (See more on that in Agassi (1983).) We all do agree that the public interest is very important, public welfare would lead our actions. But how do we determine what the right is? While the thought of technologists designing nuclear weapons is horrifying some of us, many technologists (and scientists) consider such activity necessary and proper for the sake "of freedom and defense of Western-civilization" in the West, or for the sake "of defense of socialism and against possible aggression of imperialism" in the East, whatever both may be. Even within technologists we do have debates on pollution control *(15),* on energy conservation *(16),* on some technological actions and their side effects *(17)*. These are some of the difficulties in assessing the impact of technology *(18),* and in the search for a technological ethics *(19)*.

(14) See in Florman (1981: Ch. 3) the "power" of engineering in social and political affairs. If blaming somebody, we must look at politicians and entrepreneurs. Technologists have no power whatsoever in decisions that can affect society.

(15) See Florman (1976: 27 ff). An increase of interest and activity by technologists in the public arena should be good for society. The technological approach cannot solve all social problems. However, it can make an extremely valuable contribution to the public discourse and debate.

(16) See Florman (1976: 33-35) and DeVore (1980: 282 ff). DeVore also deals with energy choices: solar energy, nuclear energy, and alternative energy sources (pp. 293 ff).

(17) Would the supersonic transport affect the upper atmosphere, allowing an excess of hamfull ultraviolet rays to reach the earth? Will the large-scale use of nitrogen fertilizers or ordinary aerosol cans do the same effects? Has the total banning DDT been precipitate, and done more harm than good? What about the problems raised by genetic engineering? How do we avoid the fussion troubles (see Lidsky 1983)? Incredibly, more than three decades into the atomic age, and the necesary research and development on nuclear waste have not been performed. Even the problem of how to finances TA organizations and their control or not by Governments is debatable.

(18) Although careful and multidisciplined studied, using techniques of modeling and systems analysis, must be supported, even these reports must stand the test of public and political debate. As pointed out in Tobar (1984d) ends, social, political and cultural ends, and the means to attain them have to be chosen through democratic participation.

However, we must try to define our basic needs —for we submit that basic needs have not changed substantially through history— and some approach to public services and public welfare (see Rescher, 1972). We are in need of love, food, clothing, work, play and fun among other things. To satisfy these needs, technologists —and engineers in particular— play an increasingly important rule. If there were golden years for engineering (between 1850 and 1950), after 1950 engineering "entered into a dark age of criticism and self-doubt" (Florman, 1976: Ch. 2), while, in turn, "enginneers again and again found themselves subservient to finances and businessmen" (Florman, 1976: 9).

There can be no denying that with the nuclear arms race, the coming of the environmental crisis and whatnot, our relationship to society has changed. We cannot —should not— pretend that it has not happened. We must face all those problems. Man, via technology and the creationof artifacts, has raised problems which in turn react against man himself changing his behavior and some of his needs. Some of us, nevertheless, (Agassi, 1983; Bunge, 1977b; Florman, 1976, 1981; Tobar, 1984c), maintain that we need more and deeper science, more and better technology to try and solve those problems. Here the "cultural" challenge of our times.

If the term 'technology' is a concept that is constantly being defined and redifined (Tobar, 1984b: Ch. 1), nowadays the debate among technologists is on the appropriateness of technology.

The term 'appropriate technology' has evolved from intermediate. technology, which in turn is found in Schumacher's *Small is beautiful.* Although the terms 'intermediate' and 'appropriate technology' are frequently used as synonymous, in fact there are substantial differences. A technology can be poor (soft) or advanced (hard). Intermediate technology represents some middle ground between these extremes. (It is worth noting that an intermediate technology may not be an appropriate one. On the other hand, not all small is beautiful *(20).* As Roman (1980: 138) observes, "In evaluating an environment to attempt to determine the appropriateness of a

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(19) See a first approach to technoethics in Bunge (1977c) Gravender (1981), Hodges (1981), and Rogers (1981). Although this subject will be treated elsewhere (Tobar, forthcoming;), it is worth noting that practically every description of the practice 'of engineering has stressed the concept of service to humanity as Florman (1976: 19) shows: "Thomas Tredgold's classic definition dates from 1929: 'Engineering is the art of directing the great sources of power in nature for the use and convenience of man". The definitions have been pouring forth ever since, most of them saying the same thing with just a few words changed here and there: "...for the benefit of the human race" (Henry G. Scott, 1907); "...for the general benefit of mankind" (S. E. Lindsay, 1920); "...for the good of humanity" (R. E. Hellmund, 1929); "...applying ...to the needs of mankind "(Vannevar Bush, 1939)". However, most of the times these beautiful words have just been words.

(20) Some of the "small" technologies introduced into nations such as India have also been fiascos: wind-powered water pumps installed in areas where are long seasons of windlessness, bio-gas generators that fail to work in the cool of winter and so on. (See more in Florman (1981: Ch. 8).)

technology, a broad range of factors must be considered. A technology that might be appropriate at a given time or place might not be appropriate at a different time or at a different place".

A concern for appropriate technology would seem to call for both large and small solutions in an ever-changing flux *(21),* taking into account the appropriateness (i) to goal (Does the technology support the goals of development policy?), (ii) of product (Is the final product or service delivered useful, acceptable and affordable to the intended users); (iii) of process (iv), of culture and environment (Are the product-process, the product delivered, and the institutions arrangements compatible with local environment and cultural setting?). In reaching possible agreement as to what constitutes an appropriate technology, consideration must be given to such elements as social and environmental goals, evaluation of technological impact, compatibility of the technology with needs; in relation to social and economic conditions, the availability of capital, the type, quantity and quality of indigenous labor —minimizing unpleasant aspects of work—, the cost of the technology and its subsequent dispersion, the scale or size of the technology and the existence and accessibility of natural resources —optimizing the use of indigenous resources and protecting environment (People participation in decission process which affect their daily lives is, of course, very important when determining the appropriateness of technology. See Alexander (1975, 1979).) When developing appropriate technology, then, environmental conditions are critical. It would provide a fair economic environment by supplying food, services, and jobs *(22).* Another environmental condition is overpopulation (or inequitable distribution of population with problems of hunger, malnutrition, misuse of available land, and unemployment *(23).* The cultural environment is crucial to technological development (illiteracy, wrong educated systems can retard such imple-

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(21) Or as Roman (1980: 138) points out, "appropriate technology incorporates soft or social technology, as well as hard or engineering technology. Appropriate technology, to be effective, must accomodate custom and tradition. There must also be recognition that in a given society the level of appropriate technology may, in the short run, be lower than technology in other societies due to differing environmental requirements".

(22) Contrary to what could be expected, many developed countries (Roman, 1980: 139), "'the United States in particular, have false economies of excess waste and consumtion. The economic system has been unable to promote prosperity and jobs "for people without exaggerated and often, unnecessary obsolescence or war-type production". The whole of economic theories do not work: "Unfortunately, there does not appear to be much long-range planning directed to developing appropriate technologies for technologically advanced nations (Roman, 1980: 139)".

(23) "Each nation must evaluate environmental conditions relative to its existence. Each nation must determine what technologies are necessary, have promise, and are appropriate. The technology, the developmental level of that technology, and the degree of appropiateness will vary from environment to environment. National and local planning is essential as a prelude to the promotion of appropriate technology" (Roman, 1980: 140).

mentation of technology (24). (See Roman (1980: 142-143) for designing the system to achieve appropriate technology objectives, and (1980: 143-145) for decisional factors in promoting appropriate technology taken into account national and world problems.)

When technologists are confronted with a problem of design, in which the goal is to satisfy certain needs, often the solution most effective, economical, elegant, satisfactory, suitable, fit, proper, "appropriate" is a technology that is large in scale (think of the problems raised by the consume of water for instance). So, in our view the debate large / small, hard / soft, high / low is a false one (parallel to the debate on pessimism / optimism when evaluating technology in general). We need *Small is beautiful* and *Large is beautiful* (most times even both at the same time) according to the magnitude and kind of problems to be solved, according to the social, political, and cultural constraints. (This clarification is critical when dealing with developing countries and the so-called "technology transfer". More on this in a while.) Consequently the notion of welfare, public welfare (Rescher, 1972) must also be clarified, and technology assessment must be taken into account.

8. TECHNOLOGY TRANSFER

A nation undertaking technological development should consider various possibilities, or levels, of national technological capability. Technological capability can vary from total self-sufficiency in a given technology to complete dependence in other technologies. It is highly improbable that a nation can be totally self-sufficient or totally dependent in all technologies. Sufficience or dependence levels will vary according to resources, priorities, and the state of national development.

Before any operation in technology transfer, existing and potential capability must be determined. For this task there are same factors (Roman, 1980: 108) that can be used to serve as general guidelines for evaluating technological capability:

1. The number of researchers.

a) The quality of education.
b) The number of advanced degrees.
c) The currency and applicability of education.
d) Expertise.

2. The number of support technicians.

(24) However, since (Roman, 1980: 141) "The ruling cadre or economic elitists invariably have a strong core of people who have been university educated in Western countries... the results is often a bias... toward Western technology. Western technology, as practiced in Western countries, may not be appropiate to developing countries".

a) The ratio of technicians to scientists / engineers.
b) The quality of technicians training.

3. Facilities.

a) The quantity and quality of existing facilities including test equipment.

b) Provisions for facility maintenance and modernization.

4. Educational support.

a) Interface with national universities.
b) Relevance and capability of universities programs to technology.
c) Availability of educational resources to qualified students.

5. Budget.

a) The amount of existing obligations and the level of financial commitment a nation is willing to make to sponsor technological development.

6. Research results.

a) Actual recognized scientific accomplishment.
b) Research applied to practical technological problems.
c) Internationally recognized scientific leaders.
d) Publications.

7. Growth of technology.

a) Technologists as a percentage of the work force.
b) The percent of research and development expenditures to gross national product.
c) Technological utilization.

Basic science has to be developed also in developing countries (Salam, 1984). For arguments supporting consensus in ends or goals, and the democratic participation of these ends see Agassi (1983), and Tobar (1984d) where I submit that also the means have to be democratically decided.

Employing technology forecasting and technology assessment prove useful in the decision process of whether to embark or not on technological development. See in Fig. 4 a systems approach to Science and Technology policy, S & T policy, determination (addapted from Roman (1980: 110). (For forecasting and planning at microlevel see Roman (1980: Ch. 10).)

Decision making is chiefly concerned to politicians or managers. Scientists and technologists are not involved in making business or political decisions, but make numerous technological decisions based on facts.

As has been seen in the previos section, a technology can be inappropriate if it is either too advanced or not sufficiently advanced for the specific social, political, economic, and cultural environment. Many forces are compelling in pulling inappropriate technology to developing countries (think of the power of the multinational firms). So, imported technologies may be inappropriate, and this for different reasons (Roman, 1980: 146). Moreover, there are also ideological factors: many critics in less developed countries view appropriate technology as "technological imperialism". Because of that the appropriateness of a technology in a society must be sensitive to political receptivity, among other factors. However, what is good and relevant in one society may not be relevant in another. That is why appropriate technology must be clarified before technology transfer processes can be rightly employed. (For details in technology transfer see Roman (1980: Ch. 9), Gruber and Marquis (1969), *Research in Phil. and Tech.* (1983, Vol. 6), Seurat (1979))

In technology transfer nonprofit organizations (UNESCO, OECD) have an increasing role to play. See in Fig. 5 (adapted from Roman (1980: 211) some of the benefits of technology transfer and the process to facilitate it:

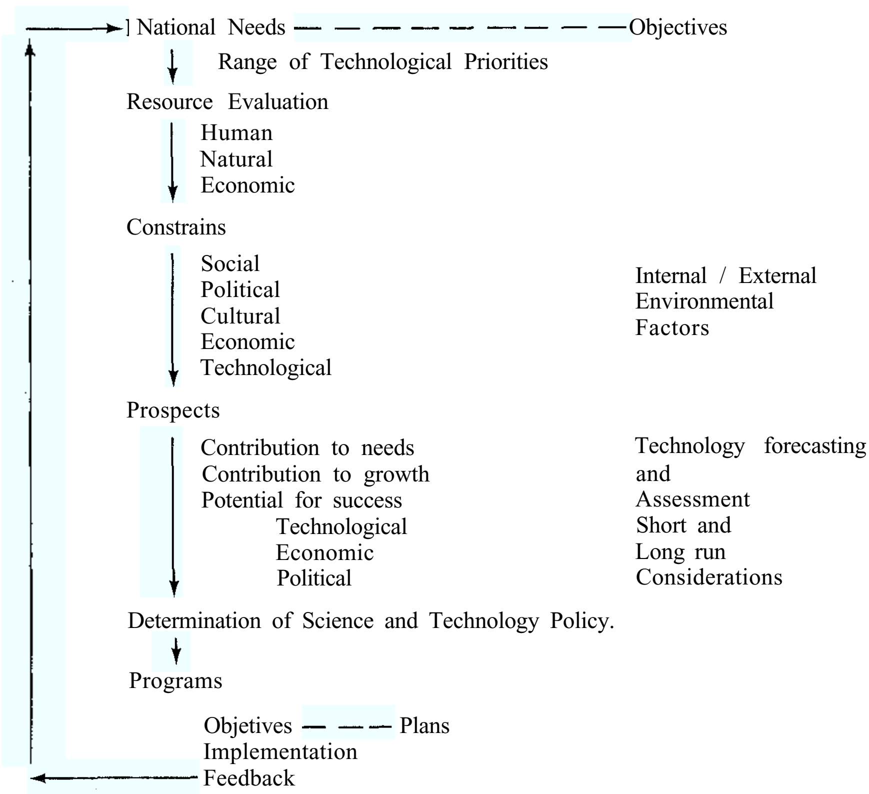

Fig. 4.— Science and Technology policy.

NEED

↓

Social-Political-Cultural-Economic

↓

Technology Utilization and Transfer

↓

Products - Processes

Government
Consumer

Government
Consumer

Process for Transfer. →

Education, people exchange programs, scientific journals, scientific conferences, seminars, multi-national firms, international agencies, joint economic ventures, patents and licensing arrangements.

Benefits of technology transfer.

1. Improve production, capability, improved skills and techniques, overall improvement in the level of science and technology.

2. Economic benefits such as increased employment opportunities, increased income, purchasing power, reduction in product prices, more easily obtainable products.

3. Social and cultural effects improved living standars, change in thinking and changing attitudes toward life.

← Obstacles to Technology.

Reluctance to share. Technology no promise for adequate return if technology shared, fear of ultimate competition, exporting of unemployment, cost or price for use of technology, nationalism, language, trade restrictions or barries.

Procedures to facilitate technology transfer.

Meeting of qualified people in relevant technology, international sponsorship of technology.

Meeting between nations on subjects which have higth national priorities, Encourage publication and international recognition.

Short and frequent meeting of people in related disciplines to foster communication and encourage continuing communication.

Fig. 5.— Technology Transfer Model.

Technology transfer, can, as in the case of Japan, afford the opportunity for technological acceleration and the subsequent attainment of technological parity.

As Roman (1980: 212) observes, “The transfer of appropriate technology can lead to political and sociological benefits. The technology should be utilized for community needs and interest. It should use human and natural resources for sociologically benefit purposes. If there are improved economic standards leading to a better life with relative freedom from sickness, hunger, and material needs along with an expanded life expectancy the economic attainments are consistent with sociological benefits. To accomplish economic objectives and social well-being there must be the right political climate”. This climate implies political freedom. Otherwise, it would be impossible the discussion on the appropriateness of technology.

Any honest technology transfer deal stipulates that the customer will get not only artifacts and the corresponding operating and service manuals but also experts capable of teaching by example how to handle and service the system. This not only because not everything can be put into manuals, but also because *know-how* cannot be wholly transmited except by example. Although for some purposes we feign that cognitive processes have a "content" that can be communicated to other brains or externalized as artifacts such as computers or plannings, actually there is no such content and, no such transfer. Acquiring knowledge is learning something, namely going through a certain brain process, hence not the same as acquiring a machine or some other instruction book. The manipulation of artifacts, reading, or drawing involve sensory-motor activities. But all those artifacts, when used, are used as adjuncts to the nervous system of somebody: they enjoy no autonomy in their use, neither in their creation (see Tobar (1984b). Even the most automatic of computation is but a link in a cognitive process ocurring in some brain. There is no robot work but only robot-aided work, and there is no automatic cognition but only computer-aided cognition.

Knowledge is encoded in cultural artifacts that circulate through the community. This facilitate the storing, sharing, and enriching knowledge. However, there in no independent "content" of knowledge, independent from the inquiring subject. Yet from a methodological point of view it is convenient to feing that cognitive process do have a transferable content, so that we may think of the latter separately from the former. This, of course, is a fiction, not an ontological thesis on ideas. (More on the ontological status of formal artifacts in Tobar (1984b).)

When dealing with explicit versus tacit knowledge a problem of interest is whether there are neurophysiological conditions that impose the disotiation between knowing how and kowing that or whether, with some effort we could render explict every bit of tacit knowledge. This problem is of interest to educationist and experts in technology transfer. Both groups would like to know whether every bit of knowledge can eventually be poured into a manual or tape.

While in science there is no problem of "science transfer" because in basic science we are interested in the search for truth for its own sake and dealing with models of reality, technology has to touch the real, noisy, and "imperfect" world. So, our technological models must be evaluated in specific socio-politico-economico-cultural environments. Once they are proper, they can be transferred to similar conditions and environments.

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