ELEMENTS

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technology, development and the environment: a re-appraisal

AMULYA KUMAR N. REDDY

united nations environment programme

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Introduction

Development must be viewed as a comprehensive and global process, embracing all aspects of the social system and its interrelationship with the natural environment. In this dynamic interrelationship, technology is the fundamental link between the social system and the natural system—at the same time, it is the essential instrument for the achievement of sustainable and environmentally sound development in the long run. In fact, each technological pattern implies specific approaches to management of resources and is associated with a given value system and lifestyle. Thus it is through improved technology that development can be achieved but it is also through the application of such technology that man has most impact on the environment.

The last 50 years have witnessed the most impressive technological development in human history. Our natural habitat is in great measure a man-made environment, resulting from the transformation of nature by practical and systematic application of scientific and technological knowledge. But, it is not only the natural system which has been modified. Society and its institutions, values, patterns of development and life styles, also reflect the characteristics of technological development.

However, it seems that uncontrolled introduction of technology, the lack of consideration for its adaptability to specific situations, and especially the unawareness of its impacts have produced negative effects. Thus, technology application has on the one hand created new opportunities and fostered development and on the other hand created new problems. Environment and Development problems are of a specific character, in different parts of the world. Technological development is originated in highly industrialized countries, according to their needs, to solve their particular problems. Those technologies are frequently ill adapted to the specific environment and development problems of the Third World, which feels left out from technological development. So it is not strange that criticism of technology is arising in countries where a large part of the population is excluded from the benefits of technological development, but suffers from the negative effects of its application. Criticism of technology is also arising in developed countries, but here the criticism is more specific, and directed towards concrete environmental problems.

In recent years the debate between those against and those in favour of technology has increased and gained a larger audience. The first approach tends to see technology as the motor for progress which holds the solution for mankind's problems, and the instrument to dominate nature. The opposite approach is viewing technology as an uncontrollable process which creates a technocratic state in which the individual is alienated. Both approaches tend to view technological development as an autonomous process, with its own dynamics. The process is viewed as a linear one, and the social repercussions as a reaction against an autonomous dynamic technological process. Both approaches tend to ignore that technology is a social product, and therefore its virtues and weaknesses must be evaluated in the framework of the social and natural system in which technology has been created, and to which it is applied.

Social systems are not deterministic, and their development is not linear. The process of development can and must be oriented, but such orientation requires the control of technological development as well as of its application. In fact it requires a clear process of technological assessment and technological choice. Technology should be developed and applied according to the dynamic characteristics of each social and natural system, aimed at the achievement of its environmentally sound and sustainable development.

It is precisely in the framework of the relationship between environment and development, and of the role of technology as an instrument of social change, that the concept of environmentally sound and appropriate technology is examined. Thus, every concern for society and its environment finds expression in the assessment and choice of technology. From a theoretical point of view we are in a weak position because prevailing theories that attempt to explain the functioning of social systems do not offer any explanation of technological change. Therefore, the attention paid to the conceptual and theoretical basis does not stem from scholarly and speculative preoccupations, but from the fact that the very concept of appropriateness implies a value judgement and, therefore, any consideration of the appropriateness of technology will inevitably reflect a given set of ideas and assumptions about development and the benefits and drawbacks of actions oriented to development.

Whereas none of the organizations of the UN system is excluded from doing some work on appropriate technology, only a few of them have attempted to investigate the conceptual content of this notion.[1] The present book is an attempt to clarify the meaning of appropriateness and consequently the methodology for selecting such technology. The Governing Council of UNEP at its Third Session requested the Executive Director to initiate, as soon as possible, programme activities on environmentally sound and appropriate technology.[2] Under this mandate two expert groups were organized in 1975 and 1976. Professor A. Reddy chaired both of them and prepared two reports that are now presented in an integrated version. The mandate was stressed at the Fifth and Sixth Sessions of the Governing Council[3].

The rationale of UNEP's conceptual effort is that any programme or activity in the field of technology research, development and dissemination largely depends on the understanding of the substantive issues underlying these activities.

Discussion on concept and criteria for appropriateness of technology is an endless process. The problem of generation of appropriate technology is only a part of a much larger problem, a problem which is evolving continuously. So the concept of environmentally sound and appropriate technology has a meaning only in the context of a given concept of development. UNEP's understanding of the environment-development relationship has led to the concept of environmentally sustainable development. Such development can only be achieved through the development of environmentally sound and appropriate technology. Accordingly the importance of the concept of environmentally sound and appropriate technology lies in the fact that, in taking insufficient cognizance of the ecological and socio-economic impact of technology, there is a risk of running into environmental degradation beyond the reproductive capacity of the environment. This would jeopardize future development in general, and the expected achievements of a new international economic order. Thus, concern for society, and for the environment in which this society exists, must find expression in the assessment and choice of technologies. This means that discussion on the assessment and choice of technology must be an inseparable part of any plan that involves either the environment or socio-economic objectives. UNEP sees its catalytic role as that of strengthening and amplifying such awareness where it exists, and of initiating and generating awareness where it is absent.

[1]See UNEP Report No. 3, "Environmentally Sound and Appropriate Technology", Nairobi 1979.
[2]Res. 29(III) 9.b. Report of the GC at the work of its Third Session.
[3]Res. 82(V) Section VI Report of the GC and Res. 6/6 para. 10 and 11.

1. Criticisms of modern technology

Over the past few years, the case for environmentally sound and appropriate technologies has been repeatedly stated in different ways and from various standpoints. This quest for alternatives has invariably been based on implicit or explicit criticisms of the pattern of technologies now current in the industrialised, developed countries and in the process of massive transfer to the developing countries. These are the technologies which have been developed with staggering and increasing rapidity, particularly over the past thirty years.

Since these technologies will necessarily have to be referred to very frequently throughout the course of this report, it will facilitate exposition to refer to them with the term *modern*. Other terms have also been used in the literature, for example, "western" and "conventional". But, the term "western" ignores the fact that some eastern countries are involved as heavily in the development, use and transfer of "modern technologies"; and the term "conventional technologies" which connotes the widespread belief that the technology of the developed world is the only acceptable brand, is liable to be confused with "traditional technologies" which are in fact being displaced throughout the developing countries by the modern technologies characteristic of the industrialised countries. On the other hand, the unsatisfactory feature of the term "modern technologies" is that it may suggest that the proposed or desired alternative technologies (which constitute the subject matter of this report) are the antithesis of modern in the sense that they do not take advantage of the heritage of accumulated knowledge and that they are bereft of the theoretical and experimental power of modern science. In fact, however, it is intended that alternative technologies be developed by as modern and sophisticated a methodology as the "modern" technologies of the developed countries. Thus, it is only for want of a better term that the technology of the developed world will be referred to as "modern technology".

The mounting criticisms of modern technology that have emerged not only from the developing countries, but as strongly from the developed countries, constitute the basis for the recommendation of an alternative pattern of technologies. Hence, a description of these criticisms must serve as an introduction to the concept of environmentally sound and appropriate technologies.

The various criticisms of modern technology can be classified into three broad categories: (1) Environmental; (2) Economic; and (3) Social;

but the overlap between these categories prevents an unambiguous classification. Further, it is often difficult to establish the precise extent to which modern technology is the sole causal factor responsible for the effects eliciting the criticisms, and the extent to which the overall social structure in which technology operates is in fact the crucial factor. But such difficulties are inevitable when two systems, such as technology and society, are closely interrelated, strongly interacting and dynamically involved. Thus, in many respects, the classification of criticisms is essentially heuristic.

1.1 Developed Countries

Environmental criticisms

The prolific advances of modern technology in the developed countries have led to spectacular increases in affluence, but it has been asserted that this affluence has not necessarily resulted in an environment more conducive to the physical and mental well-being of man. Indeed, with the increasing deployment of modern technology, man's welfare has been threatened by escalating levels of pollution—pollution of the air that he breathes, the water that he drinks, the food that he eats, the quietness that he needs (instead of "the decibel inferno") and the beauty of nature that he enjoys. This tragedy of progress in technology being associated with deterioration of the environment has been too well documented to need repetition here. It suffices to quote from the series *Man's Home*[4] "The industries that pollute the most tend to grow rapidly, . . . New production technologies that pollute more tend to replace older, cleaner production methods".

At the same time, the nature of these technologies (their scale, their demands on energy, water, etc.) has a determining influence on the structure and functioning of human settlements. In particular, urban gigantism has become increasingly predominant; and with it, has followed the aggravation of psychological stresses and social tensions, until many a famous metropolis has been left with a decaying core of slums, crime and insecurity. Simultaneously, these giant cities have had major environmental impacts arising from their exhorbitant demands for water, energy, sanitation, transportation and housing.

All this hyper-activity of production and consumption has involved a scale of "exploitation of natural resources"—the telling phrase used in common parlance—unprecedented in human history. The word "ex-

[4] "Man's Home", prepared with the co-operation of the Secretariat of the United Nations Conference on the Human Environment, Stockholm, 1972, "Pollutants: Poisons around the World", page 19.

ploitation", which accurately describes the essence of the man-nature relationship implicit in modern technology, connotes the very opposite of efficient resource management. No wonder there is alarm at the rapid rate with which non-renewable resources are being depleted. The story can be and has been illustrated with innumerable examples, for example, petroleum and minerals. This mismanagement, which it is argued is an inherent feature of modern technology, extends even to the renewable resources of air, water and land. In short, modern technology has been criticised because it is based on the assumption that nature is an inexhaustible source for the satisfaction of man's escalating resource needs and a limitless sink for his wastes. Modern technologies do not explicitly concern themselves with "the full and heavy responsibility of managing all the resources—human and natural—of this planet".[5]

The effects of this irresponsibility are already evident in the disturbance of the finely adjusted ecological balances of nature through pollution, reckless use of resources, elimination or near elimination of various species (blue whales, for instance), destruction of forests, etc. The question is not one of the intrinsic value of stability in ecosystems, but of the inevitably engendered risks that modern technology brings in its wake. These risks derive from the fact that the effects of these technologies are invariably multiple, often uncontrolled and rarely predictable and foreseen. Further, the gravity of the risks vary from relatively trivial ones like automobile accidents to potentially catastrophic ones such as all-out nuclear warfare or destruction of the life-sustaining properties of the biosphere. Some of these risks may be cumulative, such as the build-up of nuclear wastes or of optically active pollutants in the atmosphere, or they may be discrete risks, like genetic engineering accidents.

In the absence of detailed estimates of the probability of the risks, one can only guess at the shape of a *schematic* risk distribution curve (see Figure 1).

Two comments need to be made about this curve: firstly, "progress" in modern technology tends to move it upwards, so that the probable frequency of occurrence of any category of risk will increase in time unless alternative technological options are adopted; and secondly, before the advent of modern technology, there was a virtually zero probability of any risks graver than the acceptable.

According to the critics, these diverse, but deleterious, environmental consequences stem from the following fundamental characteristics of modern technology:

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[5] *Ibid*

i) its pursuit of economies of scale leads to an ever-increasing size of the productive units; and this obsession with large-scale production results in a constantly increasing magnitude of perturbation of natural ecosystems through the spatial localization of pollutant sources and the temporal increase of the rate of emission and discharge of these pollutants;

ii) These gigantic productive units are highly interdependent by way of inputs and outputs, and they also place stringent demands on infrastructures; hence, these units must be agglomerated into small areas of intense industrialization, and thus compel the concentration of millions of working people into crowded metropolises which then display the well-known environmental problems of excessively large human settlements;

iii) The constant urge to satisfy the needs of individual consumption and sustain the large productive units results in a continuous drive to develop and distribute luxury products, which are ever changing in appearance and form, but essentially similar in function and content; and this obsession with product technology is the root cause of the rape and exhaustion of resources, the high degree of product obsolescence and the culture of throw-away objects;

iv) The major role of military objectives in determining the development of technology has resulted in the arsenals of many developed countries being filled with weapons so terrible that, if ever used, all life on earth can be destroyed;

v) Its growing energy intensiveness leads, on the one hand, to centralized energy production with an increasing environmental impact, and on the other hand, to a reckless prolificacy in the use of energy sources, particularly fossil fuels.

Economic Criticisms

From the economic point of view, the major criticism of modern technology is that it tends to magnify inequalities between countries, and within countries (including developed ones!). Thus, it plays a crucial role in making inequality recursive and increase with time.

The contention underlying this criticism is that an inequality in the distribution of purchasing power leads to a skewed demand structure, which in turn influences technology to respond more avidly to the needs of the rich while assigning lower priority to the needs of those who exert weaker demand. The result is the emergence of technologies of products, technologies of production and technologies of resource use that are more responsive and accessible to the privileged than to the under-privileged. And thus, one comes to the next turn of the spiral . . . the increased inequality resulting from the initially unequal access to the new technologies stimulates the development of further advances in technology which will then accentuate the inequalities even more.

Technology has perhaps always played this divisive role, but in the past, the low levels of capital and energy intensity characteristic of primitive technology facilitate virtually equal access. In contrast, modern technology, associated as it is with its high capital and energy intensity, tends to be intrinsically incompatible with equality of access.

This inequality-magnifying effect of modern technology has become particularly evident in the relationship between developed and developing countries, which has its historical roots in the era of the exploitative domination by imperial powers over colonies. Today, modern technology has become the principal instrument for widening the disparities between these two sets of countries and for exacerbating their relationship into an irrational and unjust economic order. This economic order involves a "world market system . . . (which) . . . has continually operated to increase the power and wealth of the rich (countries) and maintain the relative deprivation of the poor (countries)", according to the Cocoyoc Declaration.[6] And, in this world market system, those who control modern technology acquire the power to dictate prices. Thus, the volume of exports by the poor world increased by one-third over the past 20 years, yet the value of these exports increased by only 4 per cent.

Further, the development and control of modern technology today is largely in the hands of the multinational corporations, which originate from and often represent the developed countries, but are increasingly taking assistance of profit-motivated, self-interested independence with respect to their countries of origin. The necessity of bridling these multinational corporations and redressing the inequality and injustice in the relationship between developed and developing countries, has led the poor nations of the world to demand the establishment of a New International Economic Order,[7] but this demand has not yet exposed the umbilical link between the current economic order and modern technology.

It is not as if modern technology has not had its tell-tale inequality-magnifying effect within the developed countries too. It has been argued[8] that almost every developed country has its own poor (these may be racial minorities, or immigrant workers or inhabitants of a backward

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[6]UNEP/UNCTAD Symposium, Cocoyoc, Mexico, 1974.

[7]Resolutions (3200 (S-VI)–3202 (S-VI) adopted by United Nations General Assembly during its Sixth Special Session.

[8]*Man's Home* series. "The Art of Progress: Development and the Environment", page 11, " . . . all developed countries include distinctly underdeveloped geographic areas, socia classes, or economic sectors—often underdeveloped in absolute and relative terms".

region), and the disparities between the rich and the poor in affluent countries are accentuated by modern technologies which tend to cater to the privileged. The under-privileged are thus "left behind to observe vicariously on television how the lucky three-quarters live"[9]. The social effects of this process are another matter which will be discussed below (Section 2.5(c)).

There are two other criticisms of the economic consequences of modern technology which deserve mention. Firstly, modern technology has been designed to process cheap raw materials, which are mostly imported from the developing countries. It has also been wedded—as pointed out earlier—to economies of scale, and has, therefore, resulted in the gigantism of highly capital and energy-intensive production units. These units because of their very size cannot adjust to sudden or prolonged cessation in raw material or energy supplies, or for that matter to major escalations in the prices of these supplies. And thus modern technology has conferred upon the industries based on this technology a vulnerability to drastic changes in international trade. For the same reason, the industries are equally vulnerable to internal disturbances, for example, strikes and sabotage.

Secondly, notwithstanding the apparent economic efficiency of production units based on modern technology, the fact remains that the calculus can be misleading and many costs are ignored because they are externalized and borne by society or by future generations. For example, a factory may discharge its wastes into a river, leaving a township downstream with the cost of purifying the water; or a mine may reduce the cost of mining by working the richest or most accessible strata, but such a procedure only results in future increases in extraction costs which are not reckoned with in the costing.

The economic criticisms outlined above have reiterated a point which emerged from the environmental criticisms: the trend of modern technology to establish larger and larger production units in the name of "reduction of unit costs" sets off a number of unwelcome consequences. In addition, it appears that the capital–and energy-intensiveness of modern technology, and the orientation of its product technology towards luxury goods for private consumption, give it the highly undesirable characteristic of accentuating economic inequalities between and within countries, and of increasing disparities between the rich and the poor.

Social criticisms

The tendency of modern technology to respond to the needs of the rich and to accentuate inequalities has proved a highly divisive and disruptive

[9]Barbara Ward.

force in the societies of developed countries. By denying the underprivileged access to its constantly publicized benefits, and at the same time forcing them to live check by jowl with its unpleasant features such as pollution, modern technology aggravates their feeling of being dispossessed. The ensuring social stresses and tensions constitute an ideal breeding ground for violence. And when these people are also forced by the technology of transportation and human settlements to concentrate in central slums, the city begins a process of decay which spreads outwards from the core. "The turn of the century could see total disintegration in many of the world's already troubled cities".[10]

To worsen the whole situation, modern production technology has relentlessly pursued the so-called economies of mass production and automation. In doing so, it has generated a highly-skewed pattern of demand for skills, in which only a few are required to possess a high degree of intellectual capacity and/or manual skills, while only the barest minimum of intelligence and dexterity is expected from the vast majority of the working force. To this majority, "soul destroying, meaningless, mechanical, monotonous, moronic work is an insult to human nature which must necessarily and inevitably produce either escapism or aggression".[11]

The successful exclusion of craftsmanship and creativity from work in factories based on modern technology results in the sharp separation of work from leisure, and facilitates the spread of the technology of automated entertainment, where participants are replaced by spectators.

The picture is not much rosier at the opposite end of the income spectrum. Modern product technology is specifically designed, on the one hand, to respond to, and on the other hand, to deliberately evoke and stimulate, demands from those privileged with purchasing power. The result is the proliferation of luxury goods for individual consumption and the generation of overly consumption-oriented lifestyles. But "Man has a limited capacity to absorb material goods. It does not help us to produce and consume more and more if the result is an ever-increasing need for tranquilizers and mental hospitals".[12] Another result is the uncritical acceptance and slavish following of oriental entrepreneurs and salesmen of "peace" and "bliss".

The emphasis on a product technology for individual consumption associated with a production technology in which machines play the dominant role has led—so the critics argue—to alienation of men from

[10]"Exploding Cities Conference", Oxford, 1974.
[11]E. F. Schumacher, "Small is Beautiful".
[12]UNEP/UNCTAD Symposium, Cocoyoc, Mexico, 1974.

each other and from their work. And "... (thus) you have a different kind of poverty. A poverty of loneliness and being unwanted, a poverty of spirit, and that is the worst disease in the world today".[13] No wonder that "half the hospital beds in Europe and North America are occupied by mental and psychiatric patients".[14] "One is bound to conclude that the whole thing is not worth the effort and that in the end it can only produce a state of things which no individual will be able to bear".[15]

At the same time, there looms in the background the technology-power equation. Nations and groups which control modern technology wield powei of a magnitude unparallelled in human history, power which has often been used against majorities and for questionable ends. Further, the spectre of technologies of mass communication, of mass persuasion, of surveillance, and of armed coercion, have produced visions of "1984" come true. And the intrinsic inequalities in access to technology has inevitably led to disparities in access to power. Thus, modern technology makes the goal of social control over the directions of social change fade into the distance.

These social criticisms of modern technology in the context of the developed countries stem from:

a) Its capital-intensiveness and its responsiveness to the demands of affluence, which together have a dispossessing effect upon those who cannot back up with purchasing power their desire for its benefits;

b) Its technologies of housing and transportation, which by tending to be oriented towards wealthy private consumers, concentrate the poor and deprived into urban slums inevitably pushed to the centres of large cities;

c) The emphasis in modern production technology on mass production and automation, which produce alienation through the rigid routine of work and "leisure";

d) The unceasing tendency of modern technology to bombard satiated buyers with new products, which leads to the enjoyment of the simple, inexpensive and intangible being devalued, undermined and replaced by the consumption of the elaborate, conspicuous and material, i.e., modern technology gives rise directly to the consumption-obsessed lifestyles which generate profits for the producers, but rarely peace and contentment for the consumers;

e) The preoccupation with military technology which confers on those who control technology a disproportionate share in the exercise of power—

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[13]Mother Teresa of Calcutta, Quoted in "Study and Action Pack for World Development".

[14]Erik Damman, "Future in Our Hands".

[15]Sigmund Freud. Quoted in "Study and Action Pack for World Development".

power for the external coercion of recalcitrant countries and the internal control of dissenting groups.

1.1.2 Developing Countries

Environmental criticisms

One would not expect the environmental effects of modern technology to be as serious in developing countries, which are not as heavily industrialized. However, this expectation is not borne out in reality. This is because the industrialization of most developing countries has been based on the import of modern technology, which by being highly capital and energy-intensive gravitates to regions where such capital and energy are best mustered, i.e., the urban metropolises. One observes, therefore, large concentrations of modern technology in the cities, and in these limited regions the intensity of industrialization can be of the same order as in the developed countries. As a consequence, such urban concentrations of modern technology often have levels of pollution as high as in the developed countries.

In some cases, the levels of pollution are even higher than in the developed countries because not only is there much less lobbying against environmental degradation, but there may in fact be a view that . . . ' all (debate over) environmental problems may . . . be potential threats to . . . domestic development"[16] and that developing countries "must not and will not allow themselves to be distracted from the imperatives of economic development and growth by the illusory dream of an atmosphere free from smoke or a landscape innocent of chimney stacks . . .".[17] Such views bring to mind a century-old statement from the then industrializing, now polluted, developed countries: "Smoke is an indication of work . . . Therefore, we are proud of our smoke".[18]

The viewpoint that environmental degradation is a necessary and unavoidable stage in development can be criticized on two counts. Firstly, it implies the questionable assumption that development must inescapably follow the path used by the developed countries and involve the deployment of modern technologies; and secondly, it does not reckon with the fact that the poverty-stricken inhabitants of developing countries are more adversely affected by pollution because of their much lower level of nutrition and health. Hence, the under-privileged in poor countries can afford pollution even less than the healthier and better nourished people in rich countries.

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[16] *Man's Home* Series, "The Art of Progress: Development and environment", page 7.
[17] *Ibid*, page 8.
[18] *Ibid*, page 8.

Further, the non-existent or far weaker environmental lobbies in the developing countries permit many modern technologies based on the plant or mineral resources of the region to use these resources irrationally and wastefully. Serious environmental effects follow, e.g., rayon factories denuding a whole region of its bamboo forests. Such environmentally unsound irrational and wasteful use of resources can also arise from another effect of the introduction of modern technology in developing countries. This effect stems from the creation of urban markets for rural products coming in the wake of rural impoverishment to upset the ecologically sound traditions of resource management. A revealing example of this process is the way urban markets for charcoal have led (and are leading) to rapid deforestation, soil erosion and desertification and the manner in which metropolitan demand for cash crops have resulted in taking away land from food crops and using it for cash crops.

Finally, the introduction of modern technologies into developing countries has also been claimed to be directly responsible, through the well-known sequence of rural impoverishment, mass migration to cities and uncontrolled urbanization, for festering slums which have become major problems from the human settlements and environmental point of view.

Another environmental effect of modern technology in developing countries is an indirect one. It arises because, as already argued, this pattern of technology accentuates inequalities and thus links together affluence and poverty in a cause-effect relationship. The consequence is the perpetuation of underdevelopment. And the "... environmental ills of the developing countries are rooted primarily in poverty and underdevelopment".[19] To illustrate: the poorest in the land-ownership scale often exploit their limited land so intensively that they cause soil erosion and deforestation, and their counterparts in the cities establish squatter colonies on the most valuable land in the central areas of big cities.

Thus, criticisms of the environmental consequences of modern technology in developing countries run along lines basically similar to those from the developed countries. However, an extra dimension arises from the role of modern technology—see Section 2.6 (b)—in impoverishing the countryside. This results, firstly, in setting up the unending exodus to cities that then cannot cope with the resulting environmental problems and, secondly, in upsetting the traditionally sound ways of managing rural land.

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[19]Maurice Strong.

Economic criticisms

The most significant criticism of the establishment of modern technology in a developing country is that it triggers off a chain of consequences, the most direct one being a shattering of the traditional rural industries. As a result, many of the occupations traditional in the countryside cease to exist, and vast numbers of people are thrown out of work. The problem is then aggravated by the fact that the urban industries are based on imported modern technology, which by being highly capital-intensive and labour-saving restricts the increase of employment per unit of extra investment. Since unemployment aggravates poverty, and since it is only employment at the higher levels of the capital-intensive modern sector that permits entry into the market of the luxury goods produced by modern industry, the gap between the affluent and the poor increases. Modern technologies of consumption are increasingly energy-intensive, and the inability of the poor to enter the market for commercial energy accentuates disparities. And thus, one observes the well-known phenomenon in the developing countries of inequalities growing with increasing industrialization on the basis of modern technology. Further, rural impoverishment leads to increasing mass migration to the metropolitan centres. This aggravates the problem of slums and shanty towns, which are festering sores of unbelievable poverty frustrating the best intentions of urban planners.

Simultaneously, the traditionally simple and contented ways of life succumb before the onslaught of the consumption-oriented lifestyles stimulated and catered to by modern technology. The demand for a new product-mix gets generated, and this product-mix invariably has a higher import content than the traditional mass-consumption goods which are usually based on local resources. Thus, the balance-of-payments situation of developing countries worsens with increasing industrialization along modern lines. At the same time, the import of modern technology requires payment—for technical fees, royalties, services of foreign experts, license fees, etc. And with the continuous advance of modern technology, the number of payments for the import of technology keeps on escalating. With increasing technical dependence, self-reliance is thwarted more and more.

Thus, industrialization on the basis of modern technology has been criticized because it usually consists of a package-deal involving, on the one hand, increasing income disparities, growing unemployment, rural impoverishment, mass migration to urban slums, and on the other hand, increasing import bills, worsening balance-of-payment crises, increasing technical dependence, decreasing self-reliance and frustration of the goal of development.

In the last analysis, this package-deal originates from the fact that capital-intensive, labour-saving modern technology is fundamentally inconsistent with the factor proportions of most developing countries, *viz.*, a shortage of capital and an abundance of manpower. The deal is worsened due to two further features of the technology of developed countries: firstly, this technology relies on a global resource-base, rather than on locally available resources, and therefore, a developing country which adopts this technology has necessarily to import many raw materials; secondly, the deliberate bias of this technology towards meeting elite demand has the twin effect of eccentuating disparities in consumption and increasing imports. In short, the content of the package deal makes modern technology incompatible with development.

It is the realization of these harsh facts that has moved local and national groups in developing and developed countries, and also many international agencies, to urge an alternative strategy of development based on a pattern of technologies different from modern technology.

Social criticisms

Further criticisms of modern technology arise from the social effects that it produces in developing countries. These criticisms focus on two main processes: (1) The disintegration of established social forms of organization which have been interwoven through centuries of evolution with ancient modes of production; and (2) The generation of a dual society involving urban islands of affluence amidst vast seas of rural poverty.

The disruption of traditional social forms resulting from the drastic changes in modes of production introduced by modern technology has a telling effect on the family (e.g., the trend away from extended families with their type of social security and towards nuclear families), on structures of authority (e.g. the displacement of village elders by literate entrepreneurs), on traditions of village self-reliance (e.g., the strength of collective self-help giving way to the weakness of dependence on urban-based aid and external development agencies), on social mores (e.g., contentment with one's lot being rejected in favour of acquisitive greed), and so on. It is not suggested here that all was perfect in the ancient social forms, but that usually the "good" in traditional societies has also been rejected along with the "bad" and that modernization (customarily equated with westernization) is not necessarily conducive to social harmony and individual peace.

The dissolution of the traditional society through the process of modernization is associated with the polarization into a dual society: a society, mainly urban, of the affluent 10–20 per cent of the population, and a society of the underprivileged 80–90 per cent, consisting mainly of the rural poor but also including the urban slum-dwellers. The elite largely controls the political decision-making machinery, with so-called "politics" becoming equivalent to wrangles between various sections of this elite. The market economy, the social services and the educational system are almost wholly dominated by the elite, leaving the poor (in particular the poorest 50 per cent) in abject poverty with regard to essential goods, services and knowledge. It has been argued that this polarization is the consequence of all modern technologies for goods or services (e.g., health, transport, education) being accessible only to those with purchasing power, renders all modern technologies, therefore, inherently elitist.

The polarization of the society of a developing country into a dual society with a small, affluent, acquisitive, conspicuously consuming, city-centred elite drawing its ideas, values and lifestyles from the developed countries, and a large mass of poor people left out of the circle of production and consumption by the lack of employment and purchasing power, is an intrinsically unstable situation. It is fertile soil for alienation, tension and aggression. The instability is amplified by the constant exposure to the overwhelmingly greater affluence of the elite who practise conspicuously a philosophy which can be summed up thus: "all that is rural is bad, all that is urban is better, and all that is foreign is best". Several obvious questions follow: "Can we rationally suppose that (the poor) will accept a world "half slave, half free', half plunged in consumptive pleasure, half deprived of the bare decencies of life? Can we hope that the protest of the dispossessed will not erupt into local conflicts and widening unrest?"[20] If social participation and control over their future cannot assume peaceful forms, it can only lead to explosions of violence

These potentially explosive social effects of modern technology originate mainly from the incompatibility of modern technology with the factor proportions of a developing country. The exhorbitant demands which these technologies make on scarce capital and energy resources has the inevitable result of developing urban pockets at the expense of the countryside, and it is this unevenness in development which is the causal basis for the polarization into a dual society. At the same time, the absence of an evolutionary link between modern and traditional technologies leads to the destruction of traditional rural industries, and thus to the damage of the fabric of social life. This damage is aggravated by the intrinsic tendency of modern technology to respond to, and stimulate, lifestyles modelled on those prevalent in the developed countries. But, the inherently inequality-magnifying feature of these technologies mean that they can only be accessible to an elite. Thus, modern technology spreads the desire for

[20]"Only One Earth".

affluent life styles while restricting to a small elite the means of satisfying these stimulated desires, and thereby lays the foundation for alienation and social conflict.

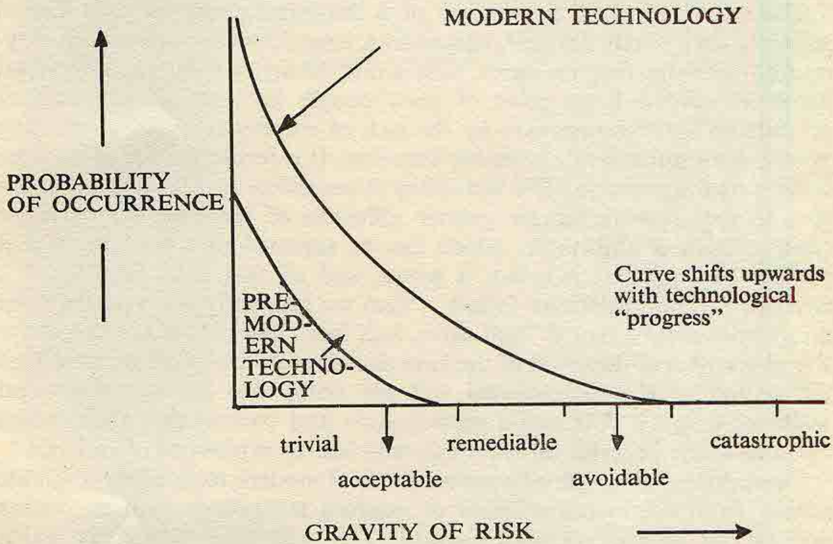


Figure 1: Probability of occurrence of risks of differing gravity.

2. Environmentally sound and appropriate technology

The gathering storm of criticism of modern technology has resulted in an increasing number of appeals and demands for a new pattern of technologies, and therefore in a proliferation of new terms to designate it. Apart from "alternative", "appropriate" and "intermediate" technologies, some of the other adjectival terms in use are "soft", "humane", "liberatory", "rational", "equilibrium", "convivial", "careful", "radical", "inequality-reducing", "people's", "progress", "utopian", "environmentally sound" and "low- and non-waste". This affluence of jargon can prove an embarrassment (of terminological riches!), because the various terms differ in the characteristics considered essential for the new technology to be proposed as a contrast to modern technology; and even more because the set of complete characteristics associated with each term is difficult to identify amidst explicit statements and implicit views to be read between the lines.

A scrutiny of the various terms shows, however, that most of them fall into three broad categories:

a) Those in which economic goals predominate;
b) Those in which environmental concerns are crucial; and
c) Those in which social goals are emphasized.

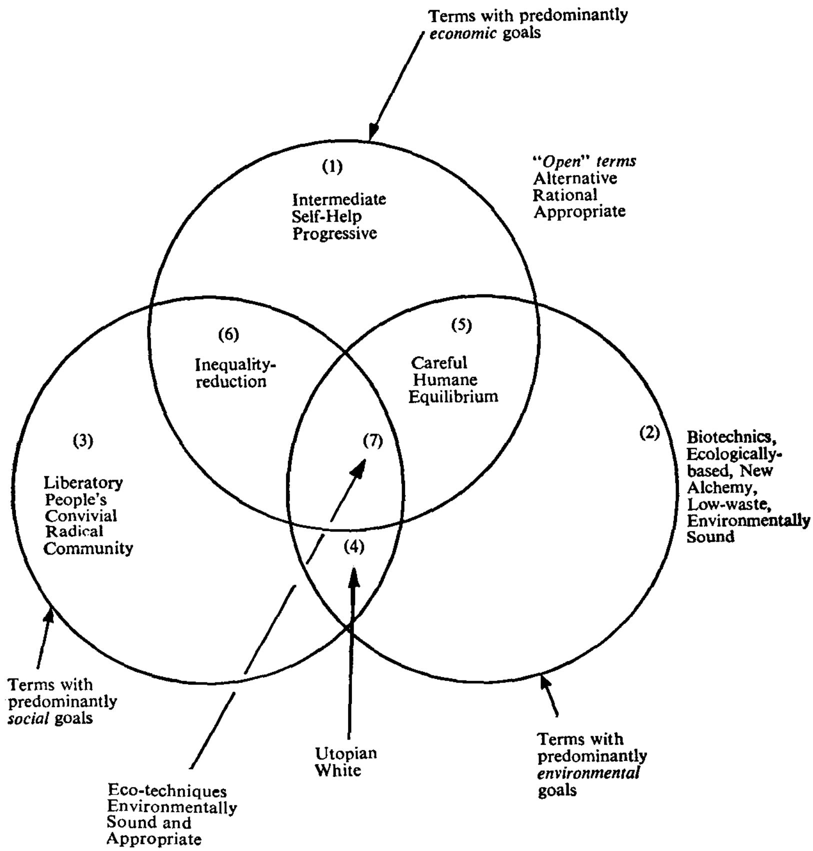
Unfortunately, some of the terms have never been clearly defined; and others may have been defined in one way, used in another way, and understood in yet a third way. Further, the intended 'scope' of the various terms is quite different. While some envisage the achievement of fairly limited transitional objectives, others, with an Utopian grandeur, seek to achieve all conceivable goals and thus "never put a foot wrong".

More importantly, the three broad categories of goals may partly overlap and partly conflict, and therefore the terms are best laid out in the form of a Venn diagram (Figure 2).

Fortunately, it is not necessary to enter the morass of terminology because, notwithstanding the many differences of emphasis, priority and strategy, there is a "shifting core" of agreement underlying the various terms. In particular, it is the agreement that technologies must be chosen by taking into account environmental, economic and social goals.

There is also a broad domain of implicit accord regarding these goals: harmony with the environment, reduction of inequalities (between and within countries) and participation and control by the people are the environmental, economic and social goals. All this is very much in tune

Figure 2 Terminology of new technologies



with the three guiding principles contained in the 1975 Dag Hammarskjold Report *What now*, viz., harmony with the environment, need orientation and endogenous self-reliance.

Such a thrust is very much in tune with UNEP's view of the relationship between environment and development. According to this view, the relationship between environment and development is inevitable, intimate and inseparable. If concerns are restricted purely to development objectives, and the environmental context of society is disregarded, then the consequential deterioration of the habitat leads to an indirect, but nevertheless serious, frustration of those very objectives. Thus, if environmental considerations are ignored, development cannot be sustained in the long run, and development goals are imperilled.

There is also another side to the coin. If the sole preoccupation is with the physical environment, and the society which pursues its aims and endeavours in that milieu is amorally forgotten, then the prevailing economic disparities between and within countries may lead to a situation where both the affluent and the needy despoil the environment. The affluent often damage their surrounding through irrational and wasteful consumption, and the poverty-stricken may have to ensure their survival even at the expense of the environment. Both luxury and poverty can have undesirable environmental consequences. Thus, if development tasks are forsaken, the environment is jeopardized.

It is such a view of the environment-development nexus which has led to a re-statement of development objectives. According to this re-statement, development must be directed primarily towards:

a) the satisfaction of basic human needs (material and non-material), starting with the needs of the neediest, in order to achieve a reduction of inequalities between and within countries;

b) endogenous self-reliance in order to promote social participation and control; and

c) ecological soundness in order to attain harmony with the environment and make development sustainable over the long term.

This view of development is fundamentally different from one in which development is equated with growth. It is focussed on human beings, rather than only on goods and services. It is principally concerned with the quality of life, and not merely with the quantity of goods and services. It is deliberately directed towards the neediest, instead of hoping that the benefits of growth, will automatically and spontaneously trickle down to the under-privileged. Not merely growth (and the magnitude of the GNP), but also the structure and benefits of growth (and the composition and distribution of the GNP) are of central importance.

This view of development is global in scope and validity. It is as applicable to the industrialized countries as to the developing countries, though the precise priorities and programmes for these two categories will obviously be profoundly different. Thus the industrialized countries, which have already satisfied the minimum material needs of their populations, have major development tasks pertaining to basic non-material needs; while developing countries must necessarily place over-riding emphasis on the satisfaction of minimum elementary needs such as food, clothing, shelter, health, education and employment.

The advancement of the differing development objectives of industrialized and developing countries requires the establishment of a New International Economic Order, for it is only an order which can make these differing objectives compatible with each other.

It is in this context that technology has an essential role to play, for it is man's crucial instrument for introducing environmental concerns and for the achievement of socio-economic objectives. However, to perform such a role, it is vital that, not only the selection of technologies (from those currently available), but also the generation of new technologies must be linked to Development and the New International Economic Order. For, it must not be assumed that all available technologies (however modern they may be) and all future technologies (likely to emerge in the guise of "technological progress") are necessarily consistent with development objectives.

In fact, there is widespread concern that many of the technologies currently being used and generated in diverse parts of the world are unsatisfactory. It is not merely that these technologies make insufficient use of local factors (which is the usual formulation of the concern), but also that their environmental impacts are often highly unpleasant and undesirable, and that they are associated with many social effects which are considered to be unwelcome. Further, it is sometimes argued that these technologies are umbilically linked to the old international economic order between developed and developing countries and also to the dual societies into which many developing countries are polarized.

It is these concerns which lead to the definition of environmentally sound and appropriate technologies as: those technologies which, in general, advance development and the New International Economic order and which, in particular, promote the development objectives outlined above. In so far as these objectives apply throughout the world, the concept of environmentally sound and appropriate technologies is also global validity. But, what is appropriate in developed countries need not be appropriate for developing countries, and vice versa—and what is appropriate for one developing country need not be so for another.

Finally, the extreme urgency and importance of Development and the New International Economic Order makes the methodology of selection of environmentally sound and appropriate technologies an issue of the highest priority and gravity.

3. Some conceptual clarification

Though the clamour for the deployment of appropriate/alternative/ intermediate and so on, technologies has been rising over the past decade or two, the concept of environmentally sound and appropriate technologies is of recent origin. It is no surprise, therefore, that the concept has sometimes led to unforeseen apprehensions and unintended impressions. Some clarification is, therefore, in order.

At the outset, there are the semantic issues arising from the word "appropriate", which acquires meaning only when one specifies "appropriate to what or to whom?". Too often, the sole concern is with appropriateness in relation to the capital and laboui endowments of a region or country, but this purely economic view is a narrow, restricted and one-dimensional theory of appropriateness. In contrast, the assessment of appropriateness from the standpoint of development objectives necessitates a three-dimensional view in which the environmental and social dimensions are no less important than the economic one.

Sometimes it has been assumed that the case for environmetally sound and appropriate technologies, particularly for developing countries, is built upon a rejection of industry and industrialization. Nothing could be farther from the truth. In fact, it is considered self-evident that industrialization is essential for meeting the basic needs of growing populations. The case in appropriate technologies based on the development of those products, patterns and forms of industrialization that will advance the type of development described in the paper. It is implicit in such a view that a great deal will have to be learnt from the industrialization process of the developed countries. But, that process—it must be noted—includes both successes and failures, with corresponding lessons. Hence, development does not have to consist of a slavish imitation of the type of industrialization followed by the developed countries.

Similarly. it has often been assumed that the proponents of environmentally sound and appropriate technology demand a total rejection of the so-called "modern" technology of the developed countries. In fact, what is demanded is a careful scrutiny of the economic, social and environmental implications of modern technology from the standpoint of the objectives of Development and the New International Economic Order, and an unqualified acceptance of such of these technologies (in original or adapted forms) which advance those objectives. Thus, what is rejected is the blind faith that all the technologies of the developed countries are universally appropriate, despite the specificity of the historical circumstances which spawned them and the particularity of the demands in response to which they were evolved. Also discarded is the naive belief that these technologies are always an unmitigated blessing, equally satisfying the interests of those who sponsor, hawk, and vend them, as of those who intend to use them to fulfil national development objectives.

In some quarters, the argument for environmentally sound and appropriate technologies has been misunderstood as a plea for a total return to, and dependence on, the traditional technologies of ancient peoples. In fact, the plea is quite different. Traditional technologies have undergone a selection process over centuries of empirical testing; hence, they are very likely to represent optimum solutions. But they are optimum only for the particular conditions, constraints, materials, and needs in response to which they were developed. With the emergence of new conditions, constraints, materials and needs, it is likely that their applicability will have been eroded and the technology rendered invalid. Nevertheless, it is quite possible that these traditional technologies can undergo qualitative changes through minor modifications. These improvements can be brought about by the use of modern science and engineering to understand and clarify the rational core of ancient practices. Such transformed traditional technologies may well qualify as environmentally sound and appropriate.

In addition to the possibility of "modern" technologies and transformed traditional technologies being environmentally sound and appropriate, there is also the possibility of alternative technologies being specifically designed *ab initio* to meet the criteria of environmental soundness and appropriateness.

Since there are three main sources for the selection of environmentally sound and appropriate technologies, viz., "modern", transformed traditional, and alternative technologies, it is very likely that the optimum pattern of technologies to advance the development objectives of a country will consist of a mix or blend of technologies from the various sources. The possibility of this mix making up the whole package of environmentally sound and appropriate technologies refutes the alleged bias wholly in favour of traditional technologies or wholly against modern technology.

Another important clarification relates to the dynamic nature of the concepts of environmental soundness and appropriateness. This dynamism follows inevitably from the continuously changing nature, on the one hand, of the physical environment in a country, and on the other hand, of the structure of its development goals. Thus, what is environmentally sound and appropriate at one juncture of history may not be so at a later time. As a result, the concepts of environmental soundness and appropriateness cannot be static; they must evolve with the state of the environment and with the nature of development tasks. It also follows that the composition of the mix that constitutes the total package of environmentally sound and appropriate technologies may have to change with the passage of time.

Still another issue which needs clarification is the scope of technology. Too often the advocates of appropriate technology have restricted their concerns to production technology. However, if technology is to be an instrument of environmentally sustainable development, it must be understood in a much broader sense as encompassing both product and production, and both software and hardware. That is, the technologies under discussion must include what type of goods and services are produced, in addition to how they are produced. They must include software or disembodied technologies concerned with ways of utilizing existing men, machines, devices and materials, in addition to hardware or embodied technologies concerned directly with machines, devices and materials. Thus, all types of technologies, and not merely production technologies, must be scrutinized for environmental soundness and appropriateness.

There is also the question of the advanced character of technologies. This character should derive not from the trivial criterion of scale of production, but from the extent to which the technologies embody modern scientific and engineering thinking.

From this standpoint, it is possible that both transformed traditional technologies and alternative technologies need not be primitive; they can turn out to be as "advanced"—and "modern" in the literal sense of the word—as the technologies of the developed countries. In fact, this possibility must be associated with a high degree of probability because, unlike the technologies of the developed countries, there is no crowded and beaten path for the generation of transformed traditional and alternative technologies, and therefore, the dependence on fundamental science and engineering must be even stronger

For a similar reason, it is unfortunate that the technologies of the developed countries are invariably described as "high" technologies, in contrast to alternative and transformed traditional technologies which are pejoratively referred to as "low" technologies. But, the terms "high" and "low" should depend on whether there is a high or low science and engineering input, and not upon whether the technology originates from the developed countries or not. Invariably, however, it is this geographical origin of a technology which determines the terms of common parlance—advanced/primitive and high/low. The underlying subconscious belief or conscious policy is the equating of all that is good with what emanates from the industrialized countries.

Finally, some votaries of appropriate technology have themselves been responsible for creating the impression that technology alone can remove poverty, redress injustice, solve development problems, and prove a universal panacea (provided it is the right brand!). But, technology is only a sub-system of society, and the development of society hinges not on only technology, but also on the other crucial sub-systems—the political, economic and social sub-systems—as well as on the physical environment of society.

In other words, technology is only an instrument for the development of society. Like all instruments, it must be specifically chosen and/or designed to fulfill its intended function. But, the will to use the instrument and the skill to wield it effectively does not depend so much on the instrument itself as upon the user.

Thus, the right type of technology (an environmentally sound and appropriate technology) is a necessary condition for development, but not a sufficient condition. It is also essential that the political structure and the socio-economic framework are both committed to development goals, and that the environmental context can sustain these goals.

Further, technology must always be seen in relation to the social setting, and the question of appropriateness is necessarily specific to the particular social context.

Technology, therefore, has both power and limits. But its power to advance development is drastically reduced if it is not environmentally sound and appropriate; hence, the paramount importance of selecting environmentally sound and appropriate technology.

4. Criteria for environmental soundness and appropriateness

Having attempted to clarify some of the misconceptions about environmentally sound and appropriate technology, attention will now be turned to the methodology of selection of such technologies. In particular, this attention will focus on two crucial aspects of this methodology;

(1) the *criteria* to be used; and

(2) the *procedure* for using these criteria.

The criteria used in the choice of technologies are important for several reasons.

(1) When criteria are explicitly stated, they have to be reckoned with, and this enforced reckoning tends to counteract arbitrariness in policy- and decision-making.

(2) The spelling out of criteria facilitates their publication. Also, the more broadcast an awareness of the criteria is, the less the risk of their being ignored in policies and decisions; and when they are ignored, the greater the consciousness that this is being done, and the greater the need for an open justification of the omission, deletion or suppression of criteria. Hence, criteria have an impact both on policy-makers and decision-makers, and on those who are affected by policies and decisions. From this point of view, the purpose of setting down criteria is to broaden the base of policy- and decision-making.

(3) An increase in awareness of the criteria to be used in the choice of environmentally sound and appropriate technologies will, on the one hand, generate a widespread demand for such technologies, and on the other hand, guide those who generate technologies. The significance of this consciousness among scientists and engineers must not be underestimated, because the definition and appreciation of criteria is an inhibiting factor against the development of environmentally unsound and inappropriate technologies.

(4) Notwithstanding the obvious importance of establishing criteria for the choice of environmentally sound and appropriate technologies, it is interesting that no explicit list of criteria exists today. This only means that the criteria are usually implicit. Nevertheless, even implicit criteria can be deciphered from the technologies in vogue and from the decisions that ushered in these technologies. And, if many of these technologies are environmentally unsound and inappropriate, then it follows that the explicit statement of criteria is a vital step in generating and adopting environmentally sound and appropriate technologies.

In so far as criteria must be derived from objectives, the criteria for the choice of environmentally sound and appropriate technologies must emerge from the development objectives indicated earlier. This is undoubtedly a normative approach to the definition of criteria. The approach is based on the following value judgements:

(1) that economic development, particularly of the developing countries, is an urgent objective of the highest priority, and that this development is contingent upon the establishment of a New International Economic Order which must, above all, include a new relationship between developed and developing countries;

(2) that, in the ultimate analysis, it is a basic need of human beings to participate in the decisions and processes concerning their destiny and to exercise increasing control over these decisions and processes;

(3) that the environment is the sole irreplaceable habitat of man and must therefore be jealously protected and husbanded.

Stimulated by such a perspective, a list of preferences to be used in the choice of technology can be proposed.

The economic dimension of development requires the exercise of preferences for technologies which are need-based, rather than those that amplify inequalities between and within countries, for example:

(1) a preference for technologies which are consistent, rather than incompatible, with the basic factor proportions of particular countries. This means, for most developing countries, a preference for energy-conserving, capital-saving and employment-generating, rather than energy-extravagant, capital-intensive and labour-saving, technologies;

(2) a preference for the technologies of goods and services relevant to mass consumption, rather than to individual luxuries;

(3) a preference for technologies based on local materials, rather than materials which have to be imported from abroad or transported from distant parts of the country;

(4) a preference for technologies which generate employment for under-privileged masses, rather than for privileged elites;

(5) a preference for technologies which produce for local consumption, rather than for remote markets;

(6) a preference for technologies which promote a symbiotic and mutually reinforcing, rather than parasitic and destructive, inter-dependence. This would be, on the one hand, the metropolises of developing countries on their rural hinterlands and on the other, the developed countries on the developing countries.

The social dimension of development necessitates the exercise of preferences for technologies which promote endogenous self-reliance by increasing social participation and control, for example:

(1) a preference for technologies which lead to an enhancement of the quality of life, rather than merely to an increase in the consumption of goods;

(2) a preference for production technologies which require satisfying creative work, rather than boring routine labour, i.e., for technologies which relate men to work, rather than alienate them from it;

(3) a preference for production technologies in which machines are subordinated to, rather than dominate, the lives of people;

(4) a preference for technologies which lead to human settlements being designed to suit the collective and individual lives of people, rather than the requirements of agglomerations of productive units;

(5) a preference for technologies which promote ease, rather than sophistication, of operation;

(6) a preference for technologies which blend with, rather than disrupt traditional technologies and the fabric of social life;

(7) a preference for technologies developed endogenously from the local context, rather than transferred from alien settings;

(8) a preference for technologies which facilitate the devolution of power to the people, rather than its concentration in the hands of elites.

The environmental dimension must be concerned with the rational sustained use, rather than indiscriminate rapid devastation, of the resource-bestowing and life-supporting bio-geophysical environment. Hence, this dimension must involve, the exercise of several preferences in the choice of technologies, for example:

(1) a preference for energy-production technologies based on renewable rather than depletable, energy sources (e.g. sun, wind and biogas, rather than oil or coal);

(2) a preference for resource-and energy-saving, rather than resource-and energy-intensive, technologies;

(3) a preference for technologies which produce goods that can be re-cycled and re-used, rather than used once and thrown away, and that are designed for durability, rather than obsolescence;

(4) a preference for production technologies based on raw materials which are replenishable (e.g., wood and cotton), rather than exhaustible (e.g., steel or petroleum-based synthetic fibres);

(5) a preference for technologies of production and consumption which inherently minimise noxious or dangerous emissions and wastes, rather than those which require 'fixes' to curb their intrinsically polluting tendencies;

(6) a preference for technologies of production and consumption which incorporate waste minimization and utilization procedures as integral components, rather than those which require them as appendages;

(7) a preference for technologies which blend into natural ecosystems by causing them minimal disturbance, rather than those which threaten the biosphere with major perturbations.

Since every preference implies a criterion and, indeed, can be rephrased as a criterion, the above list of preferences are in fact a set of criteria for the choice of environmentally sound and appropriate technologies. For example, the "preference for the technologies of goods and services relevant to mass consumption, rather than to individual luxuries" can be stated as the criterion: "Does the technology produce goods and services which are within the means of the masses?". Or, the "preference for energy-production technologies based on renewable, rather than depletable, energy sources" can be transformed into the criterion: "Is the energy production technology based on renewable energy sources?".

An obvious short-coming of a set of criteria as large as the one presented above is that it is likely to inundate—and perhaps confuse—even the makers of policies and decisions, let alone laymen. Further, after a choice of technology has been made, it will not be easy to detect whether one or more criteria have been omitted, deleted, suppressed or ignored. On the other hand, the large set has rightly elaborated upon and made explicit the crucial economic, social and environmental dimensions of development. The conclusion is that a list of explicit criteria is vital for selecting technology, but the list must be much shorter, more manageable and less complex.

Of course, the other extreme is a very short list which can be generated naturally from the development objectives:

(1) does the technology advance the satisfaction of basic human needs, starting with the needs of the neediest; and does it reduce inequalities between and within countries?

(2) does the technology promote endogenous self-reliance through an increase of social participation and control?

(3) does the technology increase harmony with the environment?

This list is obviously far too brief to facilitate detailed interpretation and unambiguous use.

What is required, therefore, is a short list with some number of criteria in between three and twenty nine. It should be neither too brief and vague, nor too long and cumbersome. The list should be compact, and preferably presentable on a single page. One such list is presented here.

CRITERIA FOR THE SELECTION OF TECHNOLOGY

(1) SATISFACTION OF BASIC NEEDS

(a) does the technology contribute, diıectly or indirectly, immediately or in the near future, to the satisfaction of basic needs such as food, clothing, shelter, health, education, etc. ?

(b) does it produce goods and/or services accesible particularly to those whose basic needs have been least satisfied ?

(2) RESOURCE DEVELOPMENT

(a) does it make optimal use of local factors (manpower, capital, natural resources, etc.) by
   - (i) sustaining/generating employment;
   - (ii) saving/generating capital;
   - (iii) saving/generating raw materials, including energy;
   - (iv) developing skills and R & D and engineering capabilities ?

(b) does it increase the capacity to produce on a sustained, cumulative basis ?

(3) SOCIETAL DEVELOPMENT

(a) does it reduce debilitating dependence and promote self-reliance based on mass participation at the local/national/regional levels, enabling the society to follow its own path of development ?

(b) does it reduce inequalities ? between occupational, ethnic, sex and age groups ? between rural and urban communities ? and between (groups of) countries ?

(4) CULTURAL DEVELOPMENT

(a) does it make use of and build on endogenous technical traditions ?

(b) does it blend with/enhance valuable elements and patterns in the local/national/regional culture ?

(5) HUMAN DEVELOPMENT

(a) does it lead to creative mass involvement by being accessible, comprehensible and flexible ?

(b) does it liberate human beings from boring, degrading excessively heavy or dirty work ?

(6) ENVIRONMENTAL DEVELOPMENT

(a) does it minimize depletion and pollution by using renewable resources, through built-in waste minimization, recycling and/or re-use and blending better with existing eco-cycles ?

(b) does it improve the natural and man-made environment by providing for a higher level of complexity and diversity of the eco-systems, thereby reducing their vulnerability ?

The list of six criteria (each in turn being subdivided into two, making in all twelve) may well be the first of its kind, but it is certainly not proposed with any aura of finality. In fact, it is in the nature of such lists that they generate more controversy than consensus, but that is as should be, for it is by a process of contention and testing that their revision and refinement will take place.

The tentative list proposed here is based on a condensation of the long lists found on pages 38–41 and on an elaboration of the basic development criteria described on page 42. The list covers economic, social and environmental criteria. No attempt will be made in this report to provide a detailed justification for the criteria, because they are based on the conceptual framework for environmentally sound and appropriate technology, dealt with earlier in the text. Hence only a brief description of the list is provided below.

The first criterion relates to *the satisfaction of basic needs*, of which the most important are food, clothing, shelter, health, education and transport/communication. This criterion compels a scrutiny of the products and/or services that emerge from the technology.

There is no objective justification for any particular set of products and/or services, but if the normative goal of development (as defined on page 26) is accepted, then several conclusions follow.

(1) The simple development=growth equation becomes valid only after ensuring that the pattern and content of growth corresponds to increasing satisfaction of basic needs, with maximum emphasis on the needs of the neediest. Similarly, the development=production equation is justified only after confirming that the goods and/or services that are produced are accessible to those whose needs have been least satisfied.

(2) Though a vast number of technologies do not satisfy basic needs directly (e.g., energy production technologies), they can do so indirectly if their outputs (e.g. energy) can become the inputs for technologies which directly satisfy basic needs. Whether this indirect contribution to basic needs is the case or not, is the question which emerges from the first criterion.

(3) The existence of technologies (e.g. iron and steel) which lead indirectly to the satisfaction of basic needs implies that the time horizon must stretch beyond the immediate present. In other words, many technologies imply a postponed satisfaction of basic needs. It is obvious, however, that if the time horizon stretches idefinitely and the postponement is *sine die*, then the failure to fulfil basic needs is bound to prevent several other criteria on the list from being satisfied. The failure will increase inequalities, for instance, or diminish creative involvement on a mass basis, or degrade the environment (see page 44). The conclusion

is that the deferment in meeting basic needs must not extend beyond the near future.

(4) Finally, the basic needs criterion implies a categorical rejection of the current practice, in countries with highly skewed income distributions, of gearing technologies to the demands of those groups with purchasing power and to ignore such needs of the under-priviledged as cannot be backed up with this purchasing power.

The utilization and development of local resources is the essence of the second criterion. The term "resources", which is intended to cover the usual economic factors of labour, capital, natural resources and land, has been deliberately chosen to emphasise that manpower too is a resource which must be utilized and developed. Within the scope of this criterion fall the usual concerns about using capital-saving, employment-generating technologies in countries with shortages of capital and abundance of manpower. But, the criterion used here is more general from several points of view.

(1) The criterion seeks to determine whether the technology makes use of all local resources including raw materials, energy and skills, as well as capital and labour.

(2) It probes into whether these resources are being developed, as distinct from being used. This aspect is particularly important for manpower (skill development) and natural resources. It is this development of resources which decides whether the capacity to produce on a sustained, cumulative basis is increasing or decreasing.

(3) The question of whether the mix of resources being used is optimum must also be scrutinized. Since different local/national/regional environments may require different resource mixes, a mix is perfect for one particular environment may become less than perfect when transferred to other (and perhaps radically different) environments. The usual example cited for such an erosion in the optimum features of technologies of is that of capital-intensive, labour-saving technologies generated in capital-rich, labour-short developed countries being transferred to capital-starved manpower-rich developing countries.

The third criterion concerns *societal development* and explores two categories of relationships displayed by a society:

a) *external* relationships between the particular society under consideration and external societies with which it is in interaction; and
b) *internal* relationships between sub-societies or groups within the society.

With regard to external relationships, the criterion seeks to determine whether the technology strengthens the society's capacity (vis-a-vis external societies) to determine and to follow its own path of development.

This capacity is decided by the extent to which the society is self-reliant and to which its relationships with external societies do not involve a debilitating dependence. Self-reliance in turn is measured by autonomy, and by the extent to which people participate in and control the decisions which affect their lives. Of course, the possibility of mass participation in and control of decisions depends upon the size of the autonomous group, but emphasis should be placed on increasing mass participation and control. Thus, the criterion requires an examination of whether the technology promotes self-reliance by increasing mass participation in decisions and control over them.

In the matter of internal relationships between the constituent sub-societies of the society, the criterion is directed towards ascertaining whether the technology tends to reduce inequalities between the sub-societies. In particular, does the technology promote equality between occupational, ethnic, sex and age groups? between rural and urban communities? between (groups of) countries?

This concern with inequalities stems from the 'state of affairs' *between* countries, leading to the demand for a New International Economic Order, and *within* countries, leading to a plea for Development.

The fourth criterion concerns *the impact of the technology on the cultural fabric of society*. The technology is bound to bring about changes in culture, and it is the nature of these changes that deserves consideration.

For instance, what effect does the technology have on the endogenous technical traditions, i.e. the non-formalized knowledge and know-how (particularly in relation to the environment) which is invariably an acquisition of stable communities? Does the technology build upon these traditions; or does it ignore them so that they are eroded and gradually lost?

Again, it is important to determine whether the technology blends with and enhances, rather than disrupts and destroys, valuable elements in the local culture. For example, does the technology reinforce, rather than undermine, a custom which acts as a cohesive force in the society (e.g., shared labour or shared use of facilities)?

These concerns arise from a host of anthropological and sociological studies that document the cultural damage and chaos resulting from the uncritical import and introduction of technologies from alien settings.

The fifth criterion relates to *the impact of the technology on individual man*, who is considered as the focus of interest, but living in symbiosis with his fellow-men and his environment. The criterion demands an enquiry into whether the technology leads to human enrichment.

Creative involvement in social activities, be they of a physical, artistic or intellectual nature, is essential to the spiritual well-being of man, and should, in fact, be considered a basic human need (albeit a non-material one). So, the question is, does the technology facilitate and promote this creative social involvement, and thereby enrich the individuals who become thus involved?

The criterion becomes especially significant in view of the importance of employment as a basic need. There should be a constant drive to make this employment meaningful. Hence, it is essential to ask whether the technology tends to liberate human beings from boring, degrading, excessively heavy or demeaning work.

These issues are related to the problem of the alienation of man from his fellow-men and from his work.

The sixth and final criterion involves *the preservation and development of the environment* and the impact of the technology on the environment. It is necessary to ask: does the technology (to use the words of an old song) "accentuate the positive . . . (and) eliminate the negative" . . . environmental impacts? It is not merely a matter of technological "fixes" which minimize pollution and resource depletion through anti-pollution and recycling measures. The technology should be inherently designed to blend with natural eco-cycles and to miminize waste at all stages of production, distribution and consumption.

All this has to do with the protection and preservation of the environment, but the objective of improving and developing the natural and man-made environment is as important. This is particularly so because a definite tendency of modern technology is to reduce the complexity and diversity of eco-systems. But, simplicity in eco-systems often leads to vulnerability and breakdown of eco-cycles. For example, the reduction of complexity associated with mono-cropping systems increase their vulnerability to attack and failure. Hence, it is important to determine whether the technology under consideration is improving the environment by enhancing complexity and diversity and thereby reducing vulnerability.

It is obvious that there is a great deal of overlap in the list of six criteria described above. The criteria are not exclusive, and one criterion may involve another through close interaction. This is inevitable, because the economic, social and environmental aspects of development are inter-related and, in fact, components of a single process.

In so far as the process is the reality, and its resolution into components an analytical device, the criteria must be considered together as an integral set. Thus, the strong coupling between criteria necessarily requires a holistic, rather than piece-meal or sectoral, approach to the choice of environmentally sound and appropriate technology.

Such a holistic set of criteria—of the type described above—has not been proposed hitherto. There may be several reasons for this lacuna, but one cannot ignore the fact that excessive specialization and professionalization have led to such divergent approaches of the economic, social and environmental disciplines that a common language for transdisciplinary discussions is difficult to maintain. Yet, it is precisely such an integrated approach that must be taken to the selection of technologies designed to serve development goals, because development itself is a unified process, albeit with economic, social and environmental facets. In other words, the economic, social and environmental categories of criterial must inter-lock and converge to promote development.

Hence, any methodology which excludes one or more criteria from explicit consideration must be viewed as *ipso facto* misleading, however rigorous it may appear. In particular, this statement refers to methodologies which only confine themselves to the quantifiable criteria because some of the criteria, e.g., those relating to self-reliance or human enrichment, may be inherently non-quantifiable.

The six criteria constitute an extremely demanding and exacting list. Hence, an obvious objection to the list is that few technologies will satisfy all criteria, making the whole travail a worthless exercise. Such an objection is indeed tenable if the criteria are interpreted in a passive, static manner, in which selection is made from a set of existing technologies, and the issue is then closed. But, the objection subsides if the criteria are used in a dynamic perspective as a heuristic device leading to the generation of new technologies. Thus, at any one time, few technologies may satisfy all the criteria, and there may always be scope for improving them even if they do. But the testing of technologies against the criteria will reveal reasonably clear guidelines for innovation and modification. From this standpoint, the list of criteria is a long-hoped-for yardstick for innovations of environmentally sound and appropriate technology.

The obvious implication of the above discussion is that until the new or modified technologies make their appearance, the best has to be made of the "bad bargain" of existing technologies. This can be done by weighing the criteria and settling for trade-offs amongst them. There should be little objection to such choices based on weights and trade-offs as long as all the criteria are explicitly and seriously considered and the processes of weighing and trading-off clearly revealed. But perhaps what is of greater importance is that efforts should be made to generate new technologies that allow all criteria, or a greater number of them, to be satisfied at the same time and that lessen the extent of trade-offs. In fact, since most choices of technology imply trade-offs between criteria and since most currently available technologies have been developed without reckoning with a set of criteria of the type proposed here, it is likely that more attention will have to be paid to the generation of new technologies than to the choice between existing ones. Thus, the selection and generation of technologies constitute a dialectical unity, either one implying the presence of the other and being meaningless in the absence of the other. In particular, the selection of technologies has little meaning unless set in the context of the generation of technologies.

To state the issue differently, it is almost certain that, from the standpoint of the list of criteria proposed here, few current technologies are perfectly environmentally sound and appropriate. It is only a matter of some technologies being more environmentally sound and appropriate than others. But, the revelation of the gap between the ideal and the actual provides the motivation for attempting to narrow the gap, i.e., for increasing the environmental soundness and appropriateness of technologies. In so far as the list of criteria has revealed both the goal of environmental soundness and appropriateness as well as how far away from the goal current technologies are, the list may be viewed as a distinct step forward.

5. Constraints on the technology selection process

Before turning to the methodology of using the list of criteria for the selection of environmentally sound and appropriate technology, the autonomy of the selection process merits discussion.

A consideration of production technologies cannot take place without *a priori* specification of the product or service. The point is that basic human needs are few in number and there is no sanctity, except native custom or foreign influence, in any particular bundle of goods and services that can fulfil these needs. For example, an element of sweetness may be necessary in the human diet. In all developed countries, and in the cities of most developing countries, crystallized white sugar is produced to satisfy this need. But this is only one way, among many, of providing sweetness to the diet—other ways include jaggery, berries, artificial sweeteners, etc. Hence, the sweetening agent must be decided upon before a selection can be made of a technology for producing it.

The distinction between product specification and selection of production technology generates an important question: is the product specification within the scope of the technology selection process, or is it externally imposed? The answer, of course, depends upon the autonomy of the selection process.

In turn, this autonomy depends upon the particular level—local, subnational, national, regional—at which the technology selection takes place and the relationship between this level and the higher/lower level.

Two cases can be distinguished

In the first case, the level at which technology selection is being made is in a position to determine the product. Here, the product specification is part of, and internal to, the technology selection process which, therefore, enjoys autonomy in this matter.

In the second case, technology selection is done at one level, e.g. the local level, but specification of the product is determined by a higher level, e.g., the national level. Here, the technology selection process is not autonomous in the matter of product specification, and the latter is imposed as an external constraint on the process.

Depending, therefore, on the extent of autonomy with regard to product specification, the selection process can be either free or externally constrained.

A similar situation can obtain with respect to the growth rate for products and services, i.e., the rate at which the production output is expected to change over the years. This growth rate has an important bearing on the selection of production technology and, therefore, the crucial question is whether the technology selection process enjoys the autonomy to decide the growth rate, or whether the latter is fixed as an external constraint at a different level.

The category of externally decided constraints which affects the technology selection process must also include certain macro-decisions regarding production technology. For example, there may be national decisions regarding the role of centralized, large-scale industries, and these decisions may circumscribe and limit the autonomy of the technology selection process at lower levels.

THE TECHNOLOGY–PROFILE APPROACH FOR SELECTION

Once there is an understanding of the extent of autonomy of the technology selection process, and in particular, an identification and definition of the externally imposed constraints (viz., product specification, growth rate, role of centralized production), the selection process can be undertaken.

Assessment of technologies vis-a-vis criteria: Since development is a process which depends upon an integration of economic, social and environmental activities, the selection of technologies to advance development objectives must be based on an integrated use of economic, social and environmental categories of criteria. The exclusion of any one or two categories of criteria may well lead to a choice of technology, but such a selection is only likely to distort the development process because crucial aspects of this process are ignored.

All this means that the technologies contending for selection must be assessed against a total set of criteria of the type set down on page 44.

Sequential selection of technologies: One possible approach to this assessment is to take the whole set of candidate technologies, to pass them through what may be called "decision filters", each filter based upon one criterion, and to eliminate at each stage those technologies which fail to survive the criterion.

Unfortunately, such a *sequential* elimination of technologies suffers from a number of drawbacks. Firstly, the criteria are such that they do not permit a sharp pass/fail judgement; the result of the test is often unclear, making the elimination process very difficult and awkward. Secondly, a particular technology may only get rejected because of, for example, the second criterion in the sequence, even though from a total point of view it may be more environmentally sound and appropriate than a technology which barely scrapes through all filters. Thirdly, the sequencing of criteria encourages the decomposition of the total view represented by the whole set of criteria into narrow, specialized, discipline-based viewpoints. The situation can be caricatured by imagining that the responsibility of wielding different criteria is allocated to different agencies, —different ministries for example. Finally, the sequencing of criteria confers a great deal of significance to the particular order in which the criteria are arranged. A different arrangement may lead to the selection of a different technology. The way to guard against this possibility of non-commutativity of decision filters, i.e., different arrangements giving different results, is to finalise the selection of technology only after trying out all possible sequences. But the larger the number of criteria, the larger the number of possible arrangements, e.g., 720 possible arrangements with 6 criteria.

The technology profile approach: Not only does the last-mentioned criticism of a sequential use of criteria indicate a ridiculous situation, it also suggests an alternative approach. Instead of assessing all technologies against criteria taken one at a time, the alternative approach involves using all criteria against technologies taken one at a time. That is, instead of a sequential decision-making on technologies, the alternative is to postpone the decision of selection until each technology in turn is scrutinized with the aid of the entire set of criteria. Such a scrutiny will result in an assessment or profile for each technology with regard to the extent of its environmental soundness and appropriateness. Only when the profiles of all the contending technologies have been made and compared with each other, can the process of selection proceed further.

The construction of technology profiles: Attention must now be turned to the construction of technology profiles for the selection of environmentally sound and appropriate technologies.

At the outset, it is clear that some criteria, especially the economic ones, can yield quantitative answers, whereas others are difficult to quantify or have not yet been quantified. In fact, some of these other criteria, for example the social ones, may be inherently non-quantifiable. However, even in the case of a criterion that does not generate quantitative answers, it is almost always possible to judge whether the technology under scrutiny can be rated qualitatively as "satisfactory", "ambiguous" or "unsatisfactory", from the standpoint of the particular criterion. Thus, every criterion in the list can be made to yield either a quantitative or qualitative judgement.

Further, the whole list of criteria will generate, for each contending technology, a profile consisting of a set of as many component judgements as there are criteria.

There may be various ways of presenting such profiles and sets of judgements, but a simple method involves a bar-chart display.

Figure 3: Technology profiles bar-chart

TECHNOLOGY	CRITERIA 1		2		3		4		5		6	
	a	b	a	b	a	b	a	b	a	b	a	b
1	G	G	$x_{11} \cdot\cdot x_{1n}$	$y_{11} \cdot\cdot y_{1n}$	O	N1	R	R	O	O	G	R

G=Green O=Orange R=Red N1=See Notes 1

In such a display, the profile for a particular technology is represented by the whole bar, which can be divided into segments, with one segment for each criterion or sub-criterion. Also, the segments can be numbered in the same way as the criteria are numbered in the list proposed for the selection of technology. Further, the rating of the technology with reference to each criterion can be indicated within its corresponding segment. This indication can be shown either with numerical information, (or references to appended notes) if the segment corresponds to a quantitative criterion, or with a simple colour code—for example, green for "satisfactory", orange for "ambiguous", and red for unsatisfactory"—if the segment represents a criterion which only permits qualitative judgements on the technology.

In so far as some criterion permit quantitative judgements, and others only qualitative ones, it follows that the profile for a technology will inevitably consist of a mix of quantitative and qualitative components, and the corresponding bar-chart representation will have numbers in some segments, and colours in others.

Profiles involving such mixes of quantitative and qualitative components are unavoidable. Or rather, mixes can be avoided today only by suppressing those criteria, e.g. the self-reliance one, that do not yield quantitative answers. But, a bias of this type against non-quantitative criteria will only lead—as already stressed—to the selection of technologies which distort development objectives because they eliminate some of its vital dimensions.

On the other hand, however unconventional they may be, profiles of the mixed type described above have an outstanding virtue—they always include judgements with respect to all criteria. This advantage of totality of view is a recompense for the qualitativeness of some aspects of the composite view. Further, by stimulating a holistic assessment of each technology, these profiles prevent rigorous quantitative judgements on a few criteria from blinding the assessor to the fact that other criteria have been completely ignored. In the bar-chart representation, judgements are indicated (either with numbers or colours) in all the segments, so that if any criteria are ignored, the corresponding segments will remain *blank*, and therefore, attract instant attention. Also, these empty segments will immediately reveal the incompleteness of what would otherwise appear as a highly sophisticated and rigorous assessment of the technology.

The question of quantification and quantifiability: Because qualitative judgements must not be given a lower standing in the technology profile than quantitative ones, it must not be concluded that the attempt to quantify can be either abandoned or downgraded. Whatever can be quantified, must be quantified; and whatever quantification can be done more precisely and rigorously, must be done more precisely and rigorously. In other words, there must be a continuous drive to replace colours with numbers in the bar-chart representation for a technology profile.

An important step in quantifying the judgement of any technology is to measure, wherever possible, the physical transformation of inputs into outputs. Such measurements are very significant, because the input-output relationships indicate the impact of the technology. Hence, an accurate knowledge of these transformation relationships constitutes an invaluable element of the technology selection process.

A number of techniques exist for manipulating these measurements towards an assessment of technologies, and among them are cost-benefit analysis and linear or parametric programming. Of these techniques, cost-benefit analysis is the most widely used quantitative technique. It has a positive role to play in technology selection, and therefore, merits a brief discussion even though it is only one among many techniques which can be used to set out the basic measurable parameters.

In essence, all decisions are based on the weighing of benefits (material and/or non-material) against costs. Further, in all cases, the concept of time-preference is involved, since the distribution of these costs and benefits over time will have some bearing on the decision. Also relevant to the decision are the questions of risk and uncertainty. Cost-benefit analysis is designed to reflect all these elements, viz., costs and benefits, time-preferences, and risks and uncertainties.

However, there are a number of problems associated with the use of this technique.

The first is that of the so-called *externalities*. These may be economic (e.g., the impact of a large project on local wage rates), social (e.g., the displacement of a community in the construction of a dam) or environmental (e.g. pollution of rivers), i e., externalities as seen from the viewpoint of a particular project, plant or enterprise. From the point of view of society, however, these impacts are no less "internalities" than various factors such as, labour productivity, which are deemed "internalities" by the project, plant or enterprise. To include all these impacts in the reckoning, it is necessary to use social cost-benefit analysis, which attempts to cope with these externalities by the use of shadow prices. But, these shadow prices are only approximations and/or proxies, and often lend themselves to such arbitrariness that the cost-benefit analyst can produce whatever result his sponsor or patron (usually the politician) wants, or that his own social conditioning and/or vested interests bias him towards.

This suggests the second limitation of cost-benefit analysis, viz., it is so attracted by numbers in trying to reach the mirage of quantitative results that it tends to exclude from the analysis all or most non-quantifiable factors (such as the loss of communal solidarity when the population displaced by a dam is moved to a new environment), even though these latter factors may be as relevant to development than the quantifiable factors.

A third limitation of the technique is that it requires a decision with regard to how far the net of analysis is to be spread. Second-round effects may be considered, but are third-round effects to be considered, if, in fact, they can be identified?

Fourthly, there are the very real problems of risk and uncertainty. There may be some uncertainty with regard to the effect of a particular project on the environment, or there is a risk that the expected outcome may not occur in the predicted way. Both of these factors undermine the precision of cost benefit analysis.

Fifthly, there is the very real danger that the technique can be manipulated in such a way as to be used to rationalise decisions reached for other reasons.

Finally, a very important drawback of cost-benefit analysis is that it assumes that unlike things (such as apples and oranges) can be compared with a constant unit of measurement, and that equal differences on the scale of cardinal measurement have the same significance, e.g., the difference between ten and eight has the same significance as the difference between four and two.

The level at which such an analysis is undertaken is also of great importance, since by its nature it is much more suitable to micro—than to macro-problems. Further, it is possible to undertake an analysis with data of a very 'soft', or a very 'hard' nature, and this will determine the degree of trust to be placed in the analysis. Both of these aspects follow from decisions made before cost-benefit analysis is undertaken.

Notwithstanding these limitations of cost-benefit analysis, it has an important role in quantifying the judgements with respect to some of the criteria relevant to the selection of technology. The important thing is that the technique should be used in an unjaundiced *ex-ante* framework, rather than as an *ex-post* rationalizing, where spurious quantification is undertaken in order to justify a decision taken on other grounds. There are two other main advantages to be derived from the use of cost-benefit analysis. The first is that it forces the systematic quantitative consideration of a number of criteria, and the second is that the technique serves as a heuristic device with regard to quantification of other as-yet-unquantified criteria.

The above discussion shows that the constant drive for quantification of judgements, for example, using cost-benefit analysis, though absolutely essential and imperative, must be tempered with a clear appreciation of its current drawbacks and limits. However, there is a time element here. Today, the profiles for technologies may necessarily consist of mixes of quantitative and qualitative judgements; but future innovations in analysis may well confer a quantitative character on judgements which are now perforce qualitative.

Comparison of technology profiles: Once profiles are built up for all the various contending technologies, the next step is to compare these profiles in order to make a selection of the most environmentally sound and appropriate technology. The comparison is facilitated by the bar-chart representation. What is required is an arrangement of the representations of the profiles of all the contending technologies, so that the juxtaposition highlights the differences between the technologies as differences in either magnitudes of numbers (in the case of quantitative criteria) or colours (in the case of non-quantifiable criteria). It is these differences which must provide the basis for the selection of the most environmentally sound and appropriate technology.

The simplest, but rather unlikely, situation involves a technology which is superior to the others on all counts. Here, selection is a straightforward matter. Slightly more complicated is a *ceteris paribus* (other things being equal) situation in which the contending technologies differ only with respect to one criterion, but are otherwise equally environmentally sound and appropriate. In such situations, the deeper the analysis with respect to the particular criterion that generates differences, the easier the selection procedure. And when the criterion permits quantitative differences, the situation is particularly suitable for cost-benefit analysis.

The problem of weighing criteria and making trade-offs: The real problem, however, arises when contending technologies differ with respect to two or more dissimilar criteria, but are otherwise just as environmentally sound and appropriate. For example, one technology may have a higher capital-output ratio, but the other stimulates much more self-reliance; or one leads to greater human enrichment, but the other is not only less polluting but also less depleting with regard to resources.

The essence of these very common situations is the necessity of choosing between impacts which cannot be compared. In other words, the process of selection cannot avoid assigning weights to each criterion and making trade-offs. In terms of the bar-chart representation for technology profiles, the weight assigned to a particular criterion can be indicated by the length of the corresponding segment. Since, however, numerical weights cannot be assigned to non-quantitative criteria, little significance must be attached to the precise length of segments, though some idea of the relative weights may be given by the relative lengths of segments.

There may, in fact, be a subjective element in the relative weighting of criteria, but there should be no objection to such trade-offs as long as all the criteria are given explicit and serious consideration. There is a very important qualitative difference between, for example, completely ignoring the extent to which a technology facilitates self-reliance, and taking the contribution to self-reliance into account, but giving it low weight—or giving it a high weight, but explicitly stating that the technology does not satisfy the self-reliance criterion. In the former case, the decision-making agenda does not even include the self-reliance item; in the latter case, it is on the agenda and compels attention, even though it may be given little emphasis in eventual trade-offs.

At the other extreme, there is room for making a particular criterion, e.g., employment generation, an absolute condition for selection in the sense that if it is not satisfied, the technologies under scrutiny are rejected. But, even here, the total profile for every contending technology must be considered and its other virtues noted.

The context and standpoint in decision-making: The weights attached to the various criteria, and therefore, to the corresponding judgements in the technology profiles, are bound to vary with the historical, geographical, economic, social and environmental context, i.e., with where and when the technology selection is being made. In addition, the weights given to the criteria, i.e., to the numbers and colours in the bar-chart representation of technology profiles, depend very much upon the individuals and groups who are involved in the assessment. Thus, a community which is displaced by a large dam may attach a totally different weight to the effect of a resettlement technology on their culture, i.e., to the cultural criterion, than a group of human settlements experts in a remote capital to whom the economic criteria, e.g., the costs of technology, are the crux of the technology selection issue. As stressed earlier, it is inevitable that different criteria are emphasised differently and that trade-offs are made, but what is essential is that the emphases and trade-offs are explicit and open.

Social participation in technology selection: Even this explicitness and openness does not guarantee that the most environmentally sound and appropriate technology has been selected, for that is a matter that only the future can judge. But, the probability of a "correct" decision may be enhanced by ensuring the participation, in the selection process, of those directly involved in the implementation of the selected technology and of those who will be affected by its implementation. Even if this increase in probability is not achieved, the widening of participation in technology selection, particularly by the procedure of constructing, comparing and assessing technology profiles, will certainly increase the extent of economic, social and environmental consciousness. This is likely not only among policy-makers, but also among scientists, engineers, technicians, and above all, the population at large. Technological consciousness is bound to become more broad-based and generate demands not only on those who select technologies but also those who develop them, making these two groups more accountable in terms of the criteria discussed here.

The iterative process of technology selection: The comparison and assessment of technology profiles is not a "one-shot, once and for all" process. It must be dynamic in three ways.

Firstly, the selection that is made at any juncture must be viewed as tentative, rather than final. It should be considered as the "best" understanding of the possible effects of various contending technologies, rather than as the "correct" understanding. In that sense, technology selection is part of a social process involving technology-induced change. As the results of social change manifest themselves, they can be gauged from the standpoint of development objectives. This information can then be used to modify the technology profiles, particularly the profile of the technology which was selected. The point is that information on the actual effects of an implemented technology will reveal far more clearly (than theoretical expectations) how environmentally sound and appropriate it is. If, therefore, the technology selection process is repeated, with actual, rather than expected, technology profiles, it is likely that a more realistic or assured selection can be made.

Secondly, it has been stressed that the selection of technology is a heuristic device for the generation of new and/or modified technologies. This means that technology profiles will alter as a result of changes in the contending technologies. Not only the numbers corresponding to quantitative criteria, but also the colours corresponding to qualitative criteria, undergo transformations as a result of research and development. The well-known example is that of technologies with malignant environmental effects being made benign by inputs of science and engineering—in the bar-chart representation of the profiles for these technologies, erstwhile reds can become orange or even green. The implication is that the results of the comparison of technologies will change because of R&D-induced changes in profiles.

Thirdly, the list of criteria proposed here are certainly not the last word. As experience with technology selection grows, and as understanding of the interplay of economic, social and environmental factors increases, it is inevitable that the list of criteria will be refined and improved. As a consequence of changes in criteria, the profiles which have been generated by these criteria will also undergo changes, necessitating new comparisons of contending technologies and fresh selections.

Thus, the selection of environmentally sound and appropriate technologies must be an *iterative* process, with the iteration being compelled by:

a) improved information on the effects of implemented technologies, and/or

b) the continuous influx of new or modified technologies into the arena of selection, and/or

c) the refinement and improvement of the criteria for selection.

Problems of iteration: The iteration sequence can be as follows: tentative selection of technology implementation of selected technology in society study of impacts of technology improved criteria and/or technologies and/or information on impacts better selection of technology. . . .

Real-time iteration may well be more acceptable, but it is associated with several problems:

a) technologies have a gestation time before they reach full effectiveness, and the larger the scale of technology, the larger the gestation time, which means that real-time iteration may be an agonizingly long process;

b) technologies have a momentum of their own because of the capital investments made in them. The larger these investments, the more painful and unlikely the process of withdrawing technologies, however environmentally unsound and inappropriate they may prove to be, and the stronger the tendency to live with technological "frankensteins";

c) some impacts of technology require such long times to manifest themselves—e.g., environmental impacts may take decades—that, unless ingenious techniques of monitoring incipient trends are devised, it would be too late and futile to wait for real-time manifestations before taking corrective action;

d) if the pace of technological advance is faster than the pace of the iterative selection process, then real-time iteration becomes virtually endless.

If, on the other hand, the iterative selection of technologies is done on simulated models of the society, then the validity of selection depends wholly on the validity of the model. It is a moot point whether the state-of-the-art in model building justifies confidence in such an approach. There is, however, a possibility that a simulation approach to technology selection can be combined with real-time testing of short-gestation, low-momentum, small-scale technologies, but this may lead to built-in biases against large scale technologies.

Trade-offs and the mix of technologies: The economic, social and environmental criteria are so diverse and stringent that—as stated earlier—few technologies are likely to meet all the criteria.

Further, the criteria relating to local self-reliance, human enrichment and cultural compatibility are likely to be best satisfied by technologies associated with relatively small-scale industries and restricted production-distribution-consumption economic cycles. At the same time, these technologies are also likely to satisfy the environmental criteria.

On the other hand, many of the economic criteria will possibly be best met by the technologies associated with large-scale industries ("economies of scale") and extended production-distribution-consumption economic cycles operating at national, regional or even global levels.

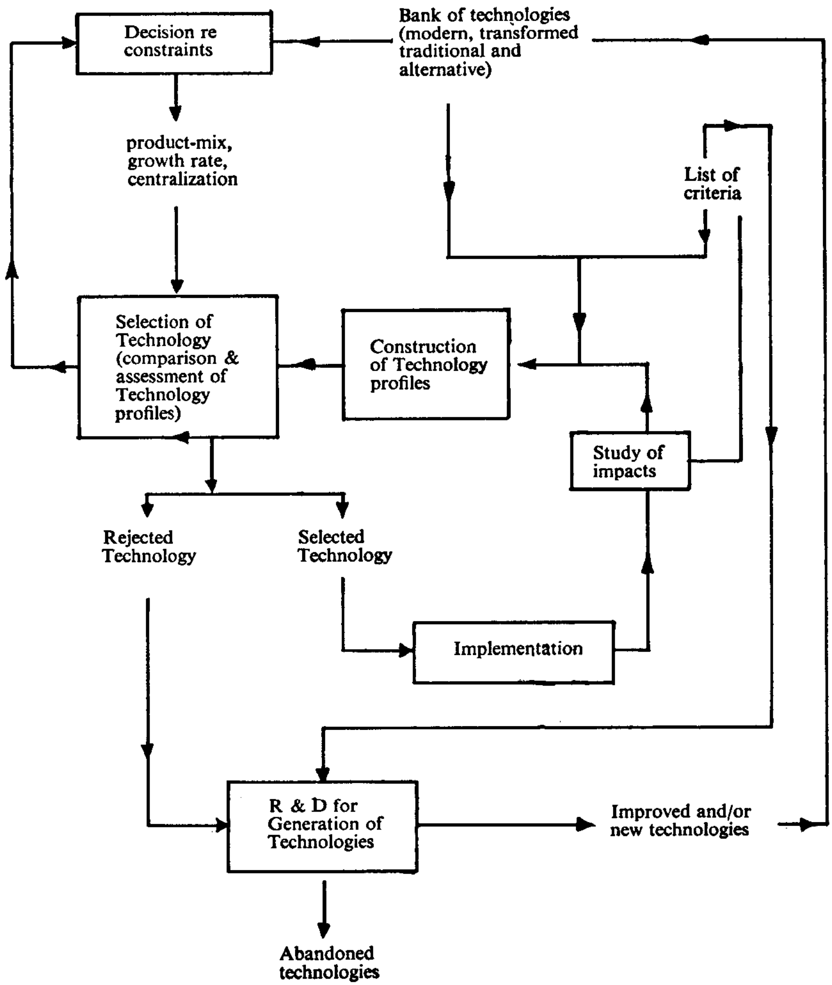
With this perspective, it is clear that constraints imposed externally on the selection process (e.g. of growth rates) and trade-offs between criteria will automatically result in a mix of large-scale and small-scale technologies. But, the mix itself may be more rational and optimal than that arrived at without the development-oriented criteria proposed here.

Further, the dialectical link between the selection and generation of technologies should lead, in some countries, to the strengthening of small-scale technologies for the local level, and in others, to an improvement of large-scale technologies for national, regional or global levels.

What is excluded is any naive wholesale rejection of large-scale modern technologies or total acceptance of small-scale traditional technologies. The criteria, and therefore the technology profiles, are not only an elimination mechanism; they are also a constructive device for modifying and improving the "modern" technologies of the developed countries and the traditional technologies of developing countries, as well as for generating new technologies.

In this process, it will not be sufficient only to examine the technology with its hardware and software components; in addition, the total social structure and process which incorporates this technology will also need scrutiny. In this sense too, the selection of technology is part of the wider development process.

Figure 4. Methodology of Selection of Environmentally Sound and Appropriate Technologies



6. Methodology of selection of environmentally sound and appropriate technologies

Structure of methodology: Several elements of the methodology of selection of environmentally sound and appropriate technologies have been discussed in the preceding sections. In particular, consideration has been given to the constraints on the selection process, the set of economic, social and environmental criteria, the dialectical link between the selection and generation of technologies, the construction and comparison of technology profiles, the trade-offs between criteria and the iterative character of technology selection.

The inter-relationship between these elements can be displayed in a diagram (Figure 4) which also reveals the organization of the elements and the structure of the selection methodology. The diagram has been drawn for the case where the decisions on constraints (such as product-mix, growth rate and centralization) are made outside the technology selection process. If, however, such divisions are within the scope of the selection process, the diagram must be amended so that the decision-making on constraints and the selection are within the same activity box.

Feed-back loops: Though the methodology diagram is self-explanatory and in fact summarizes in pictorial form the discussion of chapter 5 the feed-back loops in the methodology need some attention.

One feed-back loop links the bank of available technologies to the decision-making on the constraints to be imposed on the selection process. The basis for this link is that informed decisions on product-mix, growth rate and centralization can be made only with a full knowledge of available technologies. For instance, a decision on the product-mix for sweeteners (jaggery or crystallized white sugar) must involve an awareness of the range of technologies available for all the various sweetener products. In fact, this awareness may be far more important than an understanding of the different technologies for a particular sweetener product, e.g., crystallized white sugar. All this means that information on these technologies must flow from the bank of technologies to the decision-making apparatus—hence, the feed-back loop.

Another feed-back loop connects the selection process back to the decision-making on constraints. The aim here is that the constraints must reckon with the selection process, so that the constraints may be realistic and catalytic. For instance, a constraint of centralization may be externally imposed on the selection process in the belief that only centralized technologies meet objectives, but the selection process may reveal technologies which are adequately environmentally sound and appropriate despite the fact that they are small-scale decentralized technologies. Such information must obviously be fed back to the decision-making on constraints.

Some other feed back loops leading to revised technology profiles through modified criteria and/or technologies and/or information on technology impacts have already been described in chapter 5, and will therefore not be discussed again.

PROBLEMS WITH THE PROPOSED METHODOLOGY

The methodology proposed here for the selection of environmentally sound and appropriate technologies is substantially different from the methodologies currently in use. This very novelty may retard its acceptance. In addition, the delay may be extended for other reasons.

Firstly, even without intending to exaggerate the virtues of decentralized local technologies and the drawbacks of centralized technologies operating at higher levels, the thrust of the whole methodology is likely, in many countries, to strengthen the local level. Quite understandably and predictably, this thrust may be construed as a threat by groups with vested interests in the higher levels and in current systems of technology selection.

Among these groups are those engaged in centralized decision-making, management and resource control (including the control over capital), and also perhaps those who are involved in the generation of technologies. Scientists and engineers tend to be universalistic and to search for generalized solutions. Local quirks of needs, conditions and materials are difficult to tackle from far-off laboratories and workshops because they demand intimate field experience. Central administration tends to look for nationally operated systems of resource allocation and control and nationally standardized solutions. The power of such an administration derives from glossing over local peculiarities, and its limits are exposed when grappling with grass-roots problems. Professionals find that rewards, prestige and power increase in the same measure as the centralization of the decision-making. Finally, those who control and run profit-seeking enterprises tend to promote the expansion, integration (vertical and horizontal), and centralization of these enterprises.

There is considerable convergence and harmony of interests of all these groups, not only at the national, but also at the regional and global levels. This unity of interest may operate against the local level and, therefore, against the methodology of technology selection proposed here.

Secondly, it may be argued that the current mode of technology selection has a momentum of its own and the costs of moving to a new system are too great to warrant such a transition. There is, it is stated, an ongoing system of technologies which is increasingly large-scale and centralized, and "the monster has to be fed"; otherwise, there will be a serious loss of output.

Thirdly, the constraint of time is frequently invoked to perpetuate current methodologies of decision-making and technology selection. There is no time, it is argued, to search for environmentally sound and appropriate technologies, and therefore it is best to adopt technologies used elsewhere. Sometimes, the time constraint is real, i.e., there is a genuine emergency such as flood, famine, drought or disaster. But, very often, the time constraint may only be imagined, i.e., the urgency is illusory; or it may even be contrived, i.e., decisions on technology are deliberately delayed to force a particular decision.

Fourthly, there is the question of imperfect information flow resulting in the selection process only looking at—or being allowed to look at—a restricted set of contending technologies. By the time the other possible technologies enter the arena of selection, there is a *fait accompli* type of situation in favour of current patterns of technologies.

Finally, there is the fact that some technologies cater to restricted constituencies, in the sense that they benefit preferentially certain sections in society. If, therefore, the selection is in favour of technologies which overwhelmingly benefit currently underprivileged groups, the groups in power may not always take kindly to this new distribution of the cake.

Notwithstanding these various problems, the methodology of technology selection proposed here has one important factor in its favour—it is an integral part of the development process. The criteria of environmental soundness and appropriateness have been specifically chosen for consistency with development objectives. Thus, the attempt to select environmentally sound and appropriate technologies is a crucial aspect of the drive for development within countries and for a New International Order between countries. Seen in this perspective, the obstacles facing the methodology of technology selection urged here are only a technological dimension of the obstacles which must be overcome to achieve development and a New International Economic Order. And to the extent that these national and international objectives are historical necessities, the new methodology of technology selection is inevitable.

No claim is made that this new methodology will be precisely of the form set out in this report. On the contrary, the methodology sketched out here is far from complete. It is embryonic in form, tentative in approach and exploratory in spirit, and is primarily meant as a scheme submitted for improvement, modification and refinement. It must be seen as a further step in UNEP's work on environmentally sound and appropriate technologies, which in turn is an expression of UNEP's commitment to the environment and to development.

Annex

The Governing Council of UNEP, at its third session, requested the Executive Director "... to initiate as soon as possible programme activities on environmentally sound and appropriate technologies".[1] This interest was reiterated at the fourth session[2].

Accordingly, the UNEP initiated an internal project on "Environmentally Sound and Appropriate Technologies" (FP/0402–75–02 (820)).

This project was planned to culminate in the establishment of a network of demonstration projects on these technologies. Since, however, the success of such programme activities depends largely on a clear understanding of the substantive issues underlying these activities, an effort was made to evolve a conceptual and methodological framework for environmentally sound and appropriate technologies.

In particular, attention was addressed to three issues:

(1) *the conceptual framework* for environmentally sound and appropriate technologies;

(2) the problems and methodology of *generation* of these technologies; and

(3) the criteria and methodology for *selection* of such technologies.

To facilitate the elaboration of the conceptual framework, an expert group meeting was convened from December 1–4, 1975, at Nairobi, and a detailed report[3] prepared on the basis of discussions at that meeting.

The methodology of generation of environmentally sound and appropriate technologies was treated in a paper[4] for the Working Meeting on "Human and Social Development" organized by the United Nations University from June 6–11, 1976, at Tokyo. In addition, the problems in generating such technologies were elaborated upon in a two-part paper[5] presented at the International Economic Association Conference on "Economic Choice of Technologies in Developing Countries", Teheran, September 18–23, 1976.

The criteria and methodology of selection of environmentally sound and appropriate technologies were considered at an Expert Group Meeting held in Nairobi from August 30 to September 3, 1976, and a report is based on the discussions at that meeting.

In so far as there was considerable overlap between the reports prepared on the basis of discussions at the two meetings, it was decided to integrate the two reports into a single presentation which would deal both with the conceptual framework as well as the methodology for selection of environmentally sound and appropriate technologies. It is this integrated treatment of the subject of environmentally sound and appropriate technologies which is presented above.

[1]UNEP/GC/55,29(111)9(b).
[2]UNEP/GC.
[3]Report on "A Conceptual Framework for Environmentally Sound and Appropriate Technologies", United Nations Environment Programme, 1976.
[4]"The Transfer, Transformation and Generation of Technology".
[5]"Problems in the Generation of Appropriate Technologies".