PART TWO

seminar on
MANAGEMENT OF R&D INSTITUTIONS

BANGALORE : AUGUST 1-10, 1976

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THE CENTRE FOR THE STUDY OF SCIENCE, TECHNOLOGY AND DEVELOPMENT
CSIR, NEW DELHI

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Bangalore, August 1-10, 1976

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Editors' Note

In recent years, the countries of the developing world have been giving increasing attention to the problems of 'Management'. They have noticed that despite the resources available they have not been able to obtain the best possible results. Further, they have also begun to realise that much of this is due to lack of proper management. Realising the impact which proper management would have on the developing world, Unesco came forward to convene an International Seminar on MANAGEMENT OF R & D INSTITUTIONS.

The proceedings of this Seminar are presented in two parts: Part I includes the proceedings of the inaugural and final sessions, science organisation in the participating countries, discussion on theme papers and recommendations; Part II contains papers presented at the Seminar.

While organising this Seminar, Unesco had taken special care in selecting and inviting some of the eminent and experienced R & D managers and social scientists from the developing countries to take part in the Seminar. Some of these invitees had contributed background papers which resulted in a series of lively discussions.

The discussions, instead of confining to the points discussed in each paper, went far beyond as to include the points discussed in other papers. This necessitated the editors to present the summary of the discussions as a separate chapter in Part I of the Seminar Report rather than present them at the end of each paper in Part II.

ACKNOWLEDGEMENTS

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Typing of the entire manuscript was shared jointly by three colleagues at the Centre for the Study of Science, Technology and Development, Mr R. P. Thakral, Mr K. Srinivasan and Mr Avtar Singh. Mr Srinivasan also lent a helping hand in preparing the manuscript of Part I for printing. We record with appreciation the help rendered by the three conscientious workers.

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CONTENTS

A. Rahman

Social Goals and R & D Policy

Preamble

In the formulation and implementation of R&D Policy, social and cultural factors, which are often ignored as unimportant, are as significant as any of the purely technical factors. However, the linkage between the policy and these factors is neither causal nor limited to the contemporary period. The linkages go back in history and are interwoven in a manner which makes their full appreciation rather difficult.

It would be our endeavour, during the course of the present discussion, to highlight some of the significant features which emerge from the analysis of historical factors, the new horizons which have become visible as a result of the accumulation of scientific and technological knowledge and the new social and environmental awareness and aspiration. It may, however, be worthwhile to emphasise that while appreciating these new features we must bear in mind the differences in culture between one country and another and the varying degree of perception which people within a country may have.

It may also be worthwhile to briefly mention the conceptual framework within which the problem of social goals of R&D policy are examined. I had put it forward in a paper presented to the International Congress of History of Science in 1973 in Tokyo. The three basic elements of the framework are:

Science, in each historical period, had its own characteristics, and major thrusts in science could be linked to major changes in society. Agricultural revolution, for instance, gave birth to and developed those branches of science and technology which were connected with the agricultural practices — Astronomy for providing the calendar of seasons of sowing and harvesting and later on fixing the dates of festivals connected with these practices, geometry for measuring the land, arithmetic for counting the number of land holdings and computing the produce, weights and measures for determining the total quantity of agricultural produce. Agricultural technology, by and large, was based on utilising agricultural products, including wastes and forest products, and it was low energy technology, using animal or human power as a source of energy. The production system was built around small units to meet the demands of known consumer. In contrast to this, the Industrial Revolution helped in promoting technologies based on mineral resources, which were of high energy types and the production system was based on large scale units, the size of which went on increasing. Further, the production system was geared to supplying goods to unknown markets. Each of these periods was also characterised by the value system developed by science and this value system was a reflection of the values of society.

Within each period of development a definite pattern of development and an increasing degree of sophistication were noticed. For instance, from the evidence available so far the ancient River Valley Civilisations had accumulated considerable data and information through observation, but were not able to develop the tool of logical analysis and to postulate a consistent hypothesis. The Greeks, however, used logical analysis as a tool to develop theories and they were so dazzled by their discovery that they neglected observation as a basic element of developing scientific knowledge.

In each period and in different societies, political linkages of science and technology helped in understanding both the development of science and the possible future trends. In a society based on slavery, working with hands could not be promoted; hence science in that society could not but be non-experimental and speculative and could not interact with technology to develop it further. The latter could evolve only slowly and gradually as a result of accretion of experience of craftsmen. Further, as long as slave power was available, new sources of energy could not be developed.

Similarly, in a society based on exploitation of man by man and of one country by another, major resources of science and technology could not but be diverted towards this end. With this conceptual framework it may be worthwhile to have a look at new perception of problems, human requirement and certain political features of the current international scene.

New Perceptions

Social Perceptions : In the nineteenth and the early twentieth century, it was believed, as a result of rapid development of science and technology, that all problems facing society could easily be solved by developing suitable sophisticated technologies. When there was shortage of labour, or the cost of employing went up as a result of bargaining by organised labour, machines could be developed to do the work of man. When there was a shortage of raw materials either as a result of scarcity or as a result of the under-developed countries bargaining for them or withholding them for some reason or the other, then alternative raw materials could be developed or even synthesized to meet the shortages. When the cost of energy was going up as a result of exhaustion of resources or the increased costs, e.g. of coal, due to high cost of mining, increased wages and welfare to miners, then petroleum could be imported cheaply to serve as a basic material. One could go on multiplying examples. The point which needed to be emphasised here was that all these developments created an euphoria that technology and science as a part of technological developments were used increasingly for purposes of exploitation of less developed countries and weaker sections within the country and that this state of affairs could not continue as became evident from the movement of coloured people in USA and the price hike of petroleum by OPEC.

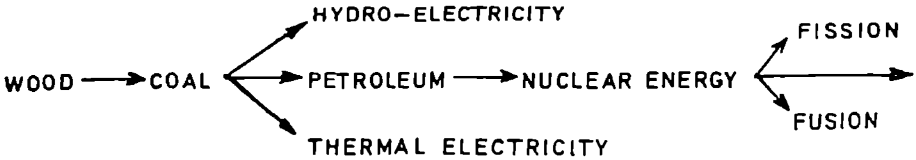
Secondly, increasing technological sophistication required resources in R & D which had to be borne by the society. In other words, resources from other areas had to be diverted to meet the R & D requirements to achieve technological refinements and sophistication, and to produce, what came to be called technological fixes. These resources had to be diverted from social benefit or welfare areas, and the diversion of funds led to considerable lopsided developments and finally aggravated the social situation.

Thirdly, each development in technology and its application in the production system created social reactions, such as retrenchment of workers, individual transportation as against social transport system, rate of accidents, health, and other series of reactions. Besides, technological changes also produced human problems. Each invention when applied required human adjustment. It was realised that both man and society did not have infinite capacity to absorb and adjust to rapid technological changes, and whatever capacity they had had, it was achieved only at a heavy cost.

These social perceptions led to two sharp trends. First was the attack on science by humanists in advanced countries which was viewed as a disruption to human values and societies and as an instrument of curtailment of man's freedom and opportunity. The second trend was the questioning of technological solutions in terms of their human, social and environmental consequences and the raising of the problem of application or otherwise of a technology based on these considerations. This led to the movement of technology assessment.

The result of these two developments was the end of the euphoria, and more sober and maturer views on technological developments and their applications emerged. This had also profound impact on R & D programmes, as could be seen from the changes in the investment pattern in different areas of research.

Technological Perceptions : In the era of technological euphoria it was believed that technological developments had an inevitable direction, starting from the simplest to the most complicated. For instance, the historical development of materials for the production of energy was considered as shown below :



However, the energy crisis, and the health and environmental hazards on the one hand, and the cost of production of energy on the other, have led to serious consideration of using "non-conventional" sources of energy. In other words, we are going back to those sources of energy which were extensively utilised before the Industrial Revolution. It must, however, be emphasised that in doing so we are using scientific and technical knowledge, accumulated over centuries, to make their utilisation more efficient and suited to the needs of contemporary society.

The other technological realisation which has affected seriously the ideas about contemporary technology is the realisation that the raw materials and the sources of energy on which it is based are finite. In other words, it is not possible to continue to use the resources on the scale on which these have been used, and are being used, for a long time. This fact has been very clearly understood by developing countries which have been the principal suppliers of raw materials so far. This dilemma has been brought out rather dramatically by the Club of Rome Study.

This realisation has diverted the attention of developing countries to raw materials and sources of energy which are renewable. In terms of scientific research, this has meant a new and added significance to biological research. In addition, it has also led to the development of technologies which utilise raw materials more efficiently and reduce wastes, and which are capable of utilising waste-products.

The other impact of these developments in the foreseeable future is likely to be the evolution of a more rational approach on the utilisation of non-renewable resources and their utilisation in basic production in preference to consumer industries or those industries which tend to satisfy personal needs of a few, e.g. the motor car.

Environmental Perceptions : Like the idea that natural resources were infinite or at least in abundance for a long time to come, the regenerative capacity of the environment was also taken for granted. It was thought that the forest resources could be utilised without seriously affecting the environment. This was surprising despite the knowledge of how the earlier societies had reduced once fertile land to desert through such thoughtless practices. Besides, it was also taken for granted that the atmosphere would not be seriously affected by the different types of discharges. The same notions prevailed regarding rivers and oceans. With the increase in industrial activity leading to greater and greater pollution of the air as well as waters and destruction of the fauna and flora, it was soon realised that environment was being affected seriously and irreversibly, and unless something was done immediately to check the trend the planet earth would become a poisonous bowl.

The indiscriminate use of insecticides and pesticides in agricultural farms has worsened the situation by causing serious and harmful effects on man and other living beings. The picture of such harmful effects was first dramatically described by Rachel Carson in her book, *Silent Spring*. The use of these materials on Vietnam War, which led to serious ecological effects, highlighted another dimension of the problem.

During the course of studying these problems and focussing attention on the consequences of the use of these materials, it became evident that the vested interests of the industry somehow managed to render ineffective any operational programme, and a serious thought had to be given to this dimension of the problem.

The impact of these realisations, slow to begin with and often negative in approach, was in two different directions. The first approach was aimed at maintaining the technologies as such, but controlling the pollution through adopting new methods and techniques of effluent control. Standards for the maximum permissible discharge were worked out. In doing so, it was soon realised that this led to substantial increase in costs. Besides, with the increasing quantities of effluents even the permissible limit was seriously affecting the environment, and in some cases like the generation of heat and heat discharges in the atmosphere it was not possible to have any worthwhile control. Secondly, therefore, different technologies were thought out to reduce these hazards. This, in turn, led to developing technologies based on biological materials.

Impact of the New Perceptions: The social impact of the technological evolution and environmental consequences of technologies was the reconsideration of the nature and value of these technologies and the exploration of alternative technologies which would avoid some of these consequences.

For the first time after the Industrial Revolution, the increasing use of mineral resources and fossil fuel was questioned and alternative renewable raw materials were considered seriously. This led to a new and greater emphasis on biology, which was different from the traditional lines of research in as much as it aimed at biological engineering. In other words, it led to the development of biological material for specific applications such as a fuel, a raw material, or a controller of pollution.

These developments are of immense consequence to science, and may lead to a shift from physico-chemical to biological technologies. In the latter, the knowledge of physics and chemistry is likely to be extensively utilised in developing biological materials. Extensive use of biological materials may also have a serious impact on production units, in terms of their size in particular. Since biological materials are bulky and occupy large space, they are expensive to transport. Under such conditions, the production units may be regrouped geographically for the purposes of processing raw materials at site where the material is available, and transporting the processed material to other areas for making the end-products. As an example, the production system suggested by the Regional Research Laboratory, Hyderabad, for the manufacture of fine chemicals, could be cited.

Aspirations

Throughout human history, the goals which societies have set before them have aimed at creating a society which provides equal opportunity to every human being to realise his or her capacities to the fullest possible extent and the social organisation based on equality of functioning. This dream has, however, never been fulfilled. The gap between one section of society and the other has gone on increasing. The same is true between one country and the other. This gap has created social and political tensions which have now reached a stage that unless something is done to change the situation drastically they may destroy the very fabric of society.

One major reason for the increase in social and political tensions is that over the last couple of centuries the spread of education, knowledge made available through science, the ideas of democracy and the technological possibilities all have created a new awareness amongst the people of the possibilities which are within their reach and which have been so far denied to them. Therefore, in the context of the present trends in society, unless they are forcibly reversed, the aspirations of people are likely to be continuously raised and the necessary resources and technologies developed to meet the requirements of the people. It will no longer be possible for the elite of the society to get away with the major portion of the resources of society and technologies developed for meeting their own needs.

Further, the aspirations of the people have been so raised by the dissemination of knowledge through mass media that the people hope and expect to have a quality of life which is in harmony with environment and provides them the necessary means to meet and develop their creative urges, leisure and resources to enjoy life.

This is a new dimension which is going to substantially change the R&D policy not only in areas of consumer goods, but also in nearly all the other areas of research. R&D programmes will also be influenced by this new dimension, and the planning of such programmes will depend upon the extent to which the R&D policy takes cognizance of the needs of the people and the manner in which it decides to fulfil them. Each country, in the context of its social goals, will have to take a decision as to how it wishes to go about them. The many options available for arriving at a decision are : provision of that pattern of life which can meet the barest minimum needs of the people; the continuation of the existing life pattern—starvation for most and luxury for few; consumption pattern based on meeting individual whims and fancies, leading to wastage of goods; consumption pattern meeting social needs with considerable restraint and discipline to provide as much for as many people as possible, if not for all; and finally the problem of meeting the needs of people, either by making people work for what they need or through aid.

Practical Implications

The new perceptions, both social and technological, the aspirations with its options and the accumulated knowledge of science and technological capabilities now available, were taken into account in shaping goals and policies and practical programmes to achieve the social and political objectives. These factors are all the more important in view of the tendency to think of problems as global and hence global solutions. It may, therefore, be worth emphasising that each of the perceptions and aspirations mentioned earlier and their interpretation differ from country to country.

These differences arise due to uneven social and political development in different parts of the world, economic development that different areas have achieved, the political and social systems which may have evolved, the level of scientific and technological development they have achieved and the potential they have generated and finally, the social and political will they have achieved.

These differences, it may be noticed, are operative not only between one geographical region and another but also between one country and another and even within a country. The latter is specially true for those countries which are spread over considerable land mass like USSR, USA, India, and China.

Secondly, in the application of science and technology to the solution of these problems.

the level of development reached in a country, the way the available knowledge has been utilised to become aware of the problems and their various facets and inter-relationships, and the resources available which can be generated in a given period of time, are of critical significance. This is particularly important for the underdeveloped countries which so far have been, on the basis of advice tendered to them by the advanced countries, following the road already traversed by the advanced countries and with no adverse consequences. Further, in the pursuit of social and political objectives, the developing countries had neglected the possible role which science and technology could play, and in using the available knowledge failed to explore an alternative path in the generation of technologies which could take into account the new awareness.

Thirdly, certain basic features of the international situation would require to be taken into account. The most important amongst them are : the existence of socialistic and capitalistic system, which offers two different ways of controlling resources and utilising them to meet social needs; the diversion of most of the resources to the development and production of weapons of destruction, instead of meeting the needs of people: and lastly, the existence of and the role of multinational corporations in generating and utilising technologies, on the one hand, and subverting those governments which obstruct their objectives or do not fall in line with them, on the other.

Any policy which does not take into account these factors is not likely to develop programmes which will be realistic and effective. Those countries which ignored these, did so at their cost.

Many of the underdeveloped countries have built up considerable monetary resources by virtue of their collective bargaining in the sale of raw materials. They, instead of working out a well defined policy for diverting these resources for social development, are only draining these resources for the purchase of arms, ammunition and other warfare materials. In doing so, they are on the one hand, supporting R & D programmes directly related to the production of armament and on the other, increasing the ratio of obsolescence of armament which they are purchasing. Further, they are also denying resources to the development of their R & D capabilities.

Multinational corporations as supranational institutions can very easily, as they often do, on many occasions, cut across social and political objectives of a country by supporting or undertaking those programmes which are contrary to these goals. Further, in view of the very considerable resources available to them they are in a position to take over, by offering very attractive terms, the cream of the scientific and technological talent of a country and occupy them in furthering their objectives or engage them in such activities as sales promotion and marginal management roles. They are also known to have their interests furthered by bringing pressures on countries to develop single commodity economy and to become the suppliers of raw materials to the corporation. In doing so, the entire economy and the political and economic freedom of the country get mortgaged to these corporations. Any effort to free the country from the strangle hold of the multinational corporations leads to the toppling of the government. Their history is also linked up with the spreading of large scale bribery and corruption leading to the disruption of the political process.

Having described some of the major factors which go, or ought to be taken into account, in the formulation of R & D policy it may be worthwhile to illustrate their operation in a country, in order to suggest the way these operate and how a preponderance of one or a set of factors affects the direction of programmes and the development of science and technology.

R & D Policy in India

British Period: A well defined policy for the growth of science and its utilisation for national development began with India achieving her independence. It may be worthwhile to briefly mention the major features of scientific and technological developments and the policies followed before independence.

Historical evidence is now accumulating about the development of science and technology in India in antiquity and the medieval period. As a result of the knowledge available it is possible to have an idea of the strong points and the weaknesses of these developments and to know why the process did not go further than it did.

With the conquest of India by the British, a process of de-development of the country commenced. Industries in India were disrupted and the country was forced to become the supplier of raw material for the British industries, on the one hand, and to serve as the favoured market for the British produce, on the other. In the wake of this disruption and import of products from Britain, any further development of Indian technology which had existed so far, became impossible.

In the field of science, the disruption was achieved through programmes of education and introduction of English as a medium of instruction. The education, in fact, was aimed more at producing clerks for the administration than to give training in vocations or in science and technology. The over-emphasis on English and the literature available in this language made inaccessible the earlier literature on these subjects in the classical and other languages of the country.

As a result of the twin processes, science and technology came to be associated, in the minds of the Indians, as a western phenomenon. Besides, Indians were repeatedly informed that their cultural tradition had been religious in nature and had not soiled by material pursuits. This calculated emphasis on the nature of Indian culture has an immense impact not only on the development of science and technology in India but also on the personality of Indian scientists.

However, despite the well defined policies, the pressures exerted on the government by the nationalistic forces and external factors, particularly those exerted by the needs of the war, World Wars I and II, led to a change in policies followed; a greater attention was given to the training of technicians and scientists, and some thought was given to the promotion of research to utilise local raw materials and to develop a few subsidiary industries. The submission of Holland Committee Report after World War I and Hill Report after World War II indicated the changes in the British policy. While the former report gave an idea as to how far and how grudgingly Britain was prepared to go under pressure and the latter report, when the political situation had made it evident that India would soon be free, clearly indicated that the attempt was to tie up India as much as possible with Britain.

While Britain was following a clear cut policy for science, the national movement as represented by the main political party, the Indian National Congress, was indifferent to science. In fact, the majority of the leaders was not only unsympathetic to the development of science and technology but were antagonistic towards it. They considered that the ideas of science were anti-religious, against the Indian tradition and technology, and were associated with British exploitation of India. One of the few leaders who did not agree with this type of thinking was Nehru. He realised the importance of science and technology and sought to make these as part of the culture of new India. Under his chairmanship, a National Planning Committee was established by the Congress. The Committee was to prepare the blueprint for the various aspects of development of India after independence. Nehru invited leading Indian scientists to be the members of this Committee. and various panels of the Committee participated in preparing an outline for the future development of India.

Nehru and Science in India : Nehru was one of the few, if not the only one, political leaders of the world in his time, who had an abiding faith in science and the role which technology could play in national resurgence. He went so far as to say that future belonged to those who cultivated science and befriended scientists. Consequently, when he assumed the reigns of free India, he established, for the first time in the world. a Department of Scientific Research and Natural Resources; further, in order to indicate its importance he assigned the portfolio to himself. A decade later, he reviewed, perhaps, for himself, the way science and technology developed and utilised for the development of the country; and finding lacunae he came forward to remedy the situation. The Parliament, at his initiative, passed a resolution in 1958, called the Science Policy Resolution, to further accelerate the process of utilisation of science and technology for national development and to involve scientists in the decision making machinery. This is the first and perhaps the only instance when the Parliament of a country passed a resolution of this nature.

In order to understand Nehru's involvement in the development of science and technology in India. the following steps taken by Nehru might be looked into :

(a) creating social consciousness amongst scientists by posing social problems before them and asking them to try to find answers. This he did in various meetings he addressed particularly at the annual session of the Indian Science Congress Association, which he made it a point to attend regularly; (b) making administrators conscious of the utility of science: (c) involving scientists in the decision making process by appointing them in various committees: (d) using scientific knowledge in the reforms he proposed to undertake, as for instance, in the use of metric system and the preparation of an Indian calendar: (e) giving support to science and technology. He spent a great deal of time and effort in creating a base for scientific and technical research against the opposition of industrialists, administrators and some of the partymen. As a result of his efforts a chain of research laboratories were established under CSIR, a number of agencies like Atomic Energy were established. Science & Technology Departments of the Universities were expanded, Institutes of Technology created and adequate resources were provided to meet these requirements. Whenever, under great financial difficulties, research institutions' grants were cut, Nehru went out of the way to restore them. He called the research institutes as temples of learning and wanted them to flourish fully; and (f) promoting scientific temper. Nehru knew that science could not flourish merely by creating an infrastructure in a society which was steeped with superstition: he, therefore, made considerable effort himself, and repeatedly pointed out to the scientists the need for the popularisation of scientific outlook amongst the people. He wanted to make science and technology as part of Indian culture. He thought this to be a critical factor in the development of science and technology in India.

As a result of the untiring efforts of Nehru, an institutionalised base for science and technology was laid in the country and it began to flourish considerably. Today it has the third largest scientific and technological manpower in the world. India is one of the seven countries of the world which are contributing most to scientific developments. In fact, it is on the threshold of a self-generating scientific and technological tradition.

Scientists and Society

It may be worthwhile, having pointed out the leadership provided to science by the political leaders of the country, to examine some of the specific characteristics of the scientists themselves. There are three features which I would like to refer in particular, namely the training of scientists, their aspirations and links.

The training imparted to the scientists was highly compartmentalised and with hardly any field work. The result of this training was that even though a large body of highly specialised scientists was available they could not be effectively employed to solve the problems facing the society. As a result of this type of training and psychology, a large number of scientists continued to work single-handedly on limited problems which, in the early stages they had started as Ph.D. scholars. This reduced the impact of R & D on national development.

In a society largely illiterate, education was the key to dissociate oneself from the illiteracy and supersititions, and for a comfortable life, and scientists were no exceptions to the rule. In fact, a survey of the origin of scientists showed that they came from peasantry or lower middle class background. These scientists coming from the lower echelons of the society thought that the study of science could improve their position and provide them with better opportunities. In other words, their aspirations were to be, through science and technology, part of the elite. Further, each one of them wanted to go overseas, either to become a part of the R & D establishment, or to return with a degree which would improve his position further in the employment market. Within their own ranks scientists had their hierarchy which reduced their effectivity further.

The links of the scientists, in the context of the Indian situation, depended upon the position they occupied in the hierarchy. The highest amongst them aspired to become Secretary to the Government of India and some were even successful in fulfilling their aspirations. Further, they had their links with political leaders who were invited to major scientific events to inaugurate or preside over. J.B.S. Haldane had comments on the bane of this trend amongst the scientists. They had their links with industrialists also. Besides the personal links, the institutional links were also there. Leading industrialists were on the top most decision-making machinery of the agencies and different laboratories.

In view of the nature of training, aspirations and links, the broad problems of science which needed repeated attention and the role which scientists could play in social transformation were lost sight of. Further, the gap between the people and the scientists grew and the problems facing the people continued to multiply. It was not surprising, therefore, that scientific activity became an end in itself, occupying itself with limited goals.

Social Goals of R & D

The preceding description gives a bird's eye-view of the development of science and technology, role of Nehru and the pre-occupation of scientists with their objectives. It would now be worthwhile to briefly describe the four phases of the goals of R & D in the country. These are :

(a) creation of infrastructure:
(b) import substitution and export promotion;
(c) attainment of self-reliance; and
(d) science for the people.

Infrastructure : The first phase of development of science and technology was the establishment of the R & D infrastructure. The blueprint for this was provided by the Hill Report. However, the rapid development of different branches of science and emergence of new areas like nuclear energy, electronics, space, etc. created the need to establish suitable agencies for developing these branches. Bhabha's letter to Nehru on the need for creating finest institutions in India comparable to those any where in the world, which led to the establishment of Tata Institute of Fundamental Research, clearly indicated the goals of this period. Under the same objectives, a chain of Institutes of Technology, on the model of MIT in USA, were created.

The three basic assumptions under which these institutions were created were : (a) the benefits from science and technology are well-known and hence, science and technology must be supported; (b) once the infrastructure is created, it will produce results for the benefit of society; and (c) science being international, the establishment created as a part of the infrastructure should work in areas which are under study in Western Europe and America in order to keep abreast of them and catch up with their development. As was to be known later that these assumptions were not valid despite the infrastructure, results were not coming forth to justify the hopes and the investment made. These questions were raised repeatedly and in the Parliament heated debates followed.

Two features of the Indian S&T manpower in this period are worth mentioning. First, those who came out of the advanced educational institutions, migrated to western Europe and USA to continue their scientific life there. Even those who remained and worked here, or those who returned after a prolonged stay abroad worked in areas of relevance to the advanced countries. In other words while technology was continuously being imported in the country, the R & D establishments were working in areas not relevant to the country. Secondly, by virtue of this the Indian scientists were isolated from the hopes and aspirations of the people and were part of the R & D establishments abroad. In other words, the Indian R & D establishments became more often extensions of R & D establishments overseas rather than Indian in character to meet the needs of society.

Import Substitution and Export Promotion : During the late fifties and early sixties, India was faced with severe crisis with regard to its foreign exchange, and the question of contribution of R & D institutions, established at considerable cost and on whose maintenance considerable money was being spent annually, was raised repeatedly and discussed in the Parliament. As a result of these questions and debates, a major shift in the thinking of the scientists became evident and was reflected in the R&D programmes. More and more scientists started talking about and working out research programmes aimed at import substitution or export promotion. In the former case, the programmes were aimed at substitution of raw materials and intermediates with those locally available and in the latter case backing up the export with R & D by improving the quality of the products.

The point which needed to be emphasised here was that it was the political and economic conditions and the social pressures generated by them, which led to the re-examination of the R & D infrastructure and its role, leading ultimately to the modification of its goal — from science and technology for itself comparable to any where in the world to science being utilised to meet specific economic requirements.

Self-reliance : The wars with Pakistan and China brought India face to face with the political reality that its requirements were subject to political blackmail. It was unable to get chemicals, equipment and machinery as it followed an independent policy. Besides, the scientists offered themselves to participate and contribute to the war-efforts; some of the laboratories produced materials or equipment urgently needed by the defence.

The major impact of this development was that the policy enunciated for science and technology was directed towards achieving self-reliance at the earliest. The clear cut expression of policy is now available in the document, "Approach to Science and Technology Plan", prepared by the National Committee on Science and Technology as a basis for the preparation of the fifth Five Year Plan.

Science for the People : It might also be mentioned that this period was also a period of intense political changes in the country, marked by the struggle for power between the more conservative and radical wings of the ruling political party, resulting in the radical transformation of the country. This political struggle had its reflection on science also, as reflected in the election manifestos of different political parties for the 1970 election.

As the political events sharpened the question, 'the role of science' came increasingly under attention: Science at what cost, for whom and for what purpose? This led to considerable debate on the nature and character of science and technology. It was initiated by a paper on "Alternative Technology" presented to One-Asia Assembly. The debate on the document, "Approach to Science & Technology Plan" raised some of these questions, though not very effectively.

The debate and the ideas generated by it led to a number of new experiments. CSIR adopted a backward district, Karim Nagar, to show what science and technology could do. The Indian Institute of Science started a project on the Application of Science & Technology to Rural Areas, and considerable thought and attention were given to the problems of rural technology. At the initiative of the Prime Minister, the Indian Science Congress Association devoted its 1976 session at Waltair exclusively to the problems of rural technology. CSIR started an active research programme to utilise natural products and agricultural waste.

The three phases of the R&D policy in India clearly reveal two things: First, the goals set for by society condition the R & D goals and secondly, the impetus for changed goals is not due to result of internal development of science, but due to the result of interaction with society, with the political leadership taking the initiative.

Conclusion

The links of science and technology with society have been briefly indicated to suggest that science and technology are part of the wider social movement, and its goals are the reflection of the wider objectives.

If the R & D policy is the reflection of social goals set by a society then the research programmes have to take into account these linkages. It is the task of the managers of R&D establishments to see that the harmony between the R & D policy and social goals is established and maintained constantly.

Scientific Community & Society

Character of Indian Science

Indian science faces an identity crisis. It has built no tradition of its own and has remained an alien graft. Two factors are mainly responsible for the character of Indian science.

(a) *Historical factor* : Modern science was introduced by colonial masters to serve certain imperial policies. Both in its language and in its idiom it remained foreign. Instead of viewing science as a force liberating the society from prejudices and superstitions, it was adopted as another arm of the colonial power. Society merely adjusted itself to accept science as another co-existing and competing dogma. Science became another occupation to be used for personal advancement and security.

(b) The other factor is inherent in the two aspects of science which are manifested in the practice of science in the West. Now, the two valid aspects of science are : (i) a technique to acquire new knowledge; and (ii) a means of organising and codifying existing knowledge and thereby making it a tool for application. While there has been an active debate in the West on the need to find suitable balance between these two aspects, alleging that within the last three decades Western science has become fragmented and irrelevant by an overwhelming preoccupation with the first aspect, the wave of this debate does not seem to have concerned the Indian scientists. Thus, Indian science having started with a historic handicap has further isolated itself by conveniently copying from the West a polarised practice of science. In these circumstances, Indian scientists have on the one hand justified revivalism and obscurantism while employing a vocabulary of science and on the other have converted the practice of science into an exercise in escapism.

Since scientists are trained in the universities and since most of the research comes from the universities, it would be worthwhile, at this stage, to examine the nature of the universities. The university system operates on a discipline-oriented basis and has become increasingly fragmented and purist. Society, on the other hand, is mission-oriented and demands application of knowledge in an inter-disciplinary style at the highest level of scholarship.

It is, therefore, no wonder that although there is a large number of scientists in India, no coherent scientific community has evolved. Consequently, the social significance of science has been lost sight of. The concept that science is many-sided social enterprise and a way of understanding and acting upon the world, has not found any true believers.

It is well known that great science cannot be generated without a great scientific community. Considering the amount of money spent in India, one has to concede that barring a few exceptions the standard of Indian science is indifferent and ordinary. It is not possible to improve scientific endeavour in India without cultivating a scientific culture and an Indian identity for science.

Science is Everybody's Business

Modern science must find its roots in the Indian milieu. It cannot do so by remaining aloof and alienated. The foremost task is to give Indian science a proper identity. For this, science must be demystified and freed from professionalism. It must find a place in the larger culture of the people. The accent of scientific endeavour must be on co-operative efforts rather than a fierce competition. There must be a period of some forced isolation so that Indian science discovers a national identity. By fostering inward-looking growth a spirit of self-confidence will be generated.

The issue of academic freedom and autonomy of science must be met and clarified. It is often forgotten that practice of science is largely done by people who are necessarily not more brilliant than people who practice other things. A historical analysis shows that 'normal science' is largely a problem-solving affair. Scientific research is not necessarily subjecting a theory to test, but, is most of the time using a theory to solve puzzles. This is the paradigm concept of the art of the soluble. While it is true that sometimes a revolution in science comes through a piece of research, it is naive to consider every research as an act of revolution. It is this romantic image of science which has made science a sacred cow and generated the foolish belief that you can never give enough to science and scientific research and also that money spent on the training of scientists and looking after their requirements will help in the economic growth. Further, there is ample historical evidence to show that every pure science started as an applied science. Thus, the criteria of choice of pure research have been always external to the fragmented discipline of science. What is disheartening is that the scientists in the Third World are accepting areas of research which, historically, have been generated from the needs of a technologically advanced nation and insisting that if their nation did not support their pursuits, conditions of scientific creativity would be impaired. This is a dangerous argument and leads only to an intellectual wasteland. Blessed may be the specialists, for they surely know what they are talking about; but the generalist knows why he should talk at all. Thus, the planning and organisation of science cannot be left alone to the specialists of narrow outlook, but should also be the business of specialists of broader outlook. After all, science or scientific community is embedded in the society as a whole. The practitioners of science cannot impose their style and their standards of value upon society, as what they claim as urgent is largely self-generated. They have little time or inclination to view what they do from a universe other than their own. Values are established from without a universe of discourse; means are established from within.

Implementing Science Policy

The concepts, which will guide the evaluation of an integrated science policy, have been discussed before. It is clear that in the developing world with urges to accelerate the process of development and modernisation, viewing science in isolation will be disastrous. Any policy of science must aim at allowing penetration of science in the mass culture, application of science for national development, and growing of a suitable scientific manpower. More than formulation of a policy, its implementation is vital. Very often we have a good policy but no will to implement the same.

Public policy touches science on three points, namely, (i) training of scientists; (ii) control of scientific institutions; and (iii) support of specific projects. These aspects will now be discussed.

(a) **Educational Strategy**

Science must be rescued from the value system of the university. The recent fusion of science with technology has generated the scientific revolution. The society should assimilate science at all levels. Teaching of science, therefore, cannot be only for those who are supposed to have aptitude for science. Science should become a compulsory subject for all school children. The plea that the teaching of science is expensive is unacceptable. Education of the young is incomplete without science. Moreover, teaching of science by drawing examples from the productive processes of life does not require all the plans which are considered mandatory when one tries to teach science to selected students within the confines of a classroom. Once science becomes everybody's business the dichotomy between science and non-science would be reduced. Further, the excessive professionalism of science has caused a harmful fragmentation of the university system. The incongruity between university and society must be removed. The kind of persons which a country needs to exploit scientific revolution may be categorised as : (i) as many top-ranking scientists as the country can throw up; (ii) a larger number of professionals to do supporting research, design and development; (iii) still a larger number to do the secondary technical jobs and take major responsibility in the human jobs; and (iv) politicians, interpreters, and administrators who know enough science to have a sense of what the scientists are talking about. These are the manpower specifications for the scientific revolution. If science remains an isolated concern of a few, there is no chance of training such diverse manpower.

It will be obvious that such a training for science must be done by making the programme relevant to the nation. Search for relevance can be made only through innovation and experimentation in the educational structure, in its flexibility, in the process of evaluation and in the methodology of teaching which integrates learning and doing in a continuous manner.

To meet the need for the generation of competence in the interface of science and society, the university should start new departments of science studies which will train scientifically literate humanists, analyse the development of science, assess technology and disseminate science *via* mass media.

The universities in the West, over the last three decades, have become highly discipline-oriented and hence, incongruent to the society which is mission-oriented. It is a sad spectacle to observe many Indian universities imitating this style of life. The western universities themselves will have to rechart their path and again become mission-oriented through their true mission of teaching undergraduate students. Indian universities must take care that in the pursuit of grants and facilities for research their true mission is not lost. One suggestion would be to make it honourable for teacher-scholars as well as the research-scholars to have valid roles in the university. It is through mission-oriented endeavour of teaching that true scholarship emerges. It is incorrect to claim that the teacher-scholar will be an inferior breed of man.

(b) **Scientific Institutions**

The Goverment has created a large number of national laboratories for mission-oriented research of national relevance. Some of these laboratories are also engaged in fundamental research. While the bulk of national fund goes for mission-oriented research it is a curious fact that the bulk of research output is prompted by curiosity-oriented research. A strategy must be developed whereby the existence of these national laboratories should influence the choice of research involvement in the universities. It should be possible to create suitable linkages between the universities and the national laboratories so that they do not work at cross purposes. It is not a matter of merely allowing Ph. D. research to be done in these laboratories. This Ph. D. research by style and operation, is an imitation of the university system. It neither compelled the university to change its outlook nor has fundamentally strengthened the mission of these laboratories.

(c) **Funding of Research**

Large funds have been distributed for various special projects to be carried out in the universities and national laboratories. But, an analysis of the titles of the papers produced and the background and performance of these scholars would seem to indicate that this money has only strengthened the *status quo* and has not served the basic purpose. Indeed they have largely undermined some bold and lonely effort in directing research towards national relevance and evolving a cadre who can display self-confidence in being engaged and committed to creative science.

The distribution of research grant should be critically examined. In future these grants should be placed at the disposal of the university if it is prepared to undertake the responsibility of furthering the cause of inter-disciplinary, time-bound, mission-oriented research.

(d) **Organisation of Science**

It has been already argued that few rare revolutionary discoveries of science are all not of science, and science cannot find roots in a traditional society merely by turning out more science graduates and purchasing more equipment. Similarly, all the hopes and aspirations a nation builds around science would never be fulfilled if the nation does not discover its own effective way of managing science and meeting the challenge posed by scientific revolutions. We are only beginning to see that the organisation of science would be uniquely different, and the national purpose must be to evolve a suitable organisation. The tendency to glorify science without appreciating the marvels of social organisation that make possible the effective use of that science is lopsided and will not help in the evolution of a suitable scientific organisation.

S & T and Industrial Development: The Case of Shangri-La

Economic Background : Planned Development

The primary premise is that the economy is a mixed one. Despite substantial and positive public sector programmes, the Government's overall strategy is to promote its economic objectives through the development of infrastructure services and the provision of incentives for the private sector. The overwhelming economic problem continues to be unemployment; thus, the predominant objective of the Plan is to increase employment opportunities. Total population is about 1 million.

Agricultural production and export are crucially important to the national economy. There is a continuing need for high level investment (including high level science and technology) in agricultural productivity to stimulate export of agricultural products and to help reduce the exent of the present reliance on the importation of food as well. The physical and technical constraints which face Shangri-La, however, mean that the unemployment problem cannot be solved through the development of agriculture. The underlying strategy of the development plan, then, is to look for the main increase in economic activity in the manufacturing sector. The Plan places the highest importance on encouraging the manufacture of products, and manufacturing processes, which are labour-intensive and which are export-oriented. Because of a comparative advantage in labour cost, Shangri-La will gain an export advantage in this way. Manufacturing must be export-oriented because manufacturing for local consumption alone will not provide the necessary employment opportunities. The general strategy for the decade envisages that employment will increase from 195,000 in 1975 to 325,000 in 1985, with one-third of that increase coming from increased employment opportunities in the manufacturing industry sector. Tables 1 to 3 indicate respectively the anticipated increases in employment by sector, changes in the relative proportions of sectoral contributions to GDP, and changes in the relative proportions of agricultural products and manufactured products in the external terms of trade.

Although the agricultural sector continues to be important, it is expected to provide only 25% of the anticipated increase in the employment opportunities. On the other hand, if the manufacturing sector develops as expected, it will provide 33% of the required increase in the employment opportunities, - for a partial reduction in the heavy reliance on the importation of manufactured goods for local use, and for a significant increase in the proportion of export earnings.

Table 1 — Anticipated Increases in Employment Opportunities by Major Sectors : 1975-85

Sector	1975 No.	1975 % of total	1985 No.	1985 % of total
Agriculture (including Livestock, Forestry and Fisheries)	76,100	40	109,000	34
Manufacturing (other than Agricultural Processing)	18,400	9	60,400	19
Construction, etc.	13,000	7	30,000	9
Transport, Comunications, Utilities	14,700	8	23,000	7
Trade	19,800	10	28,000	9
Services (Tourism, Education, Health,	32,100	16	50,000	15
General Government Administration	13,900	7	17,000	5
Others	7,000	3	8,000	> 2
Total	195,000	100	325,400	100

Table 2 — GDP Targets at Factor Cost 1975-85

Sector	1975 $ Million	1975 %GDP	1985 $Million	1985 %GDP
Agriculture	206	24	317	17
Mining	1	...	3	...
Manufacturing : Agricultural Processing	78	9	114	6
Other Industry	54	6	316	17
Construction & Works	51	6	133	7
Electricity, Water & Utilities	30	4	69	4
Transport & Communications	102	12	220	12
Trade	90	11	198	11
Services, etc.	186	22	347	19
Tourism	8	1	60	3
Government Administration	44	5	58	3
Total	850	100	1835	100

Table 3 — Changing Composition of Exports* 1975-80 (%)

Export Items	1975	Anticipated in 1980
Processed Agricultural Products	98	83
Other Manufactured Items	2	17

* In terms of value, total value of exports in 1975 was $ 365 million; anticipated value in 1980 will be $ 445 million.

The combination of the manufacturing sector with the transport, communications, construction and public utilities sector (i. e. activities whose bases rest more or less on the physical and engineering technology disciplines as against the agricultural and biological disciplines) is expected to provide more than 50% of the anticipated increase in employment and more than 50% of the anticipated increase in GDP. The manufacturing sector is expected to provide 17.2% of GDP in 1985 compared with 6.3% in 1975 whilst the combined technology based activities will grow from 27.8% of GDP in 1975 to 39.8% in 1985. Although the employment opportunities are increased, it is, nevertheless, anticipated that the additional employment generated in the manufacturing sector will be almost twice as productive as the additional employment generated in agricultural sector.

National Research and Development System

Neither the National Plan nor its underlying statement of policies and objectives, directly confronts the role of science and technology as instruments for the pursuit of developmental goals. Nevertheless, there is no question of the importance attached to science and technology by the Government and associated planning agencies. This concern can be measured by the provisions made at various points in the Plan for the expansion or initiation of research and survey programmes underlying public sector investments.

These provisions are of a capital kind and are in addition to the science and technology services provided in the recurrent budgets.

Physical Dimensions of R & D in Shangri-La

The scientific establishment is small, but it is fairly well concentrated. There is no wasteful dispersal through a range of small scale institutions. Moreover, the smallness of the country and, relatively, of the population provide favourable conditions for ready communication across the scientific community. Table 4 describes the scientific establishment in various ways. In general terms, the table indicates that between 1974 and 1976 total expenditures almost doubled whilst the number of full-time equivalent scientists and engineers has been fairly stable. In general, too, the table indicates that both the productive enterprise sector and the government sector perform as much research as they pay for it.

Although expenditures in both the government sector and the productive enterprise sector increased by approximately the same *absolute* amount ($ 2.5 million for productive enterprise and $ 2.8 million for government) the relative

Table 4 — R & D Expenditure by Source and Performance Sector : Current and Capital Expenditure during 1974 and 1976 ($ 000)

Performer	Source: Government 1974	Government 1976	Higher Education 1974	Higher Education 1976	Productive Enterprise 1974	Productive Enterprise 1976	Foreign Funds 1974	Foreign Funds 1976	Total Source 1974	Total Source 1976
Government	1,970	4,381	16	264	150	...		...	2,136	4,645
Higher Education	...	...	...	...	...	...			...	...
Productive Enterprise	...	...	...		576	6,008			576	6,008
Foreign Funds / Others	1	195	153	21	475	300			629	516
Total Performer	1,971	4,576	169	285	1,201	6,308			3,341	11,169
Full-time Equivalent Scientists/Engineers	43	48	10	7	40	36			93	91

rates of increase differ significantly in relation to the totals of expenditure and the components of expenditure. Thus, with 1974 = 100, the 1976 position was :

	Productive enterprise	Government	Higher education
Total	170	232	168
Current	171	280	180
Labour	150	310	160
Others	190	210	240
Capital	95	160	33

Assuming away inflation the greatest increase is in the labour cost component of the government sector. This reflects a threefold increase in the number of technicians employed in the government sector, as well as salary increases since 1974. Expenditure per full-time equivalent scientist/engineer changed in each of the sectors as shown in Table 4.

Distribution of the National R & D Effort

The national research and development effort is directed overwhelmingly to matters relating to agriculture and the processing of agricultural products (including fisheries, forests and livestock development). In both 1974 and 1976 almost 80% of all scientists and engineers were immediately involved in agricultural research. The remainder were divided roughly equally between the medical sciences and engineering technology, the social sciences and humanities, education and the arts. Much research in the social sciences and industrial technology was also oriented to the agricultural sector.

There are two main institutions conducting science and technology programmes in Shangri-La. These are the Ministry of Agriculture and the Shangri-La Crop Research Institute which represents almost the whole of the 'productive enterprise sector' included in the above tables. There are a number of research and development activities conducted in the government sector, e. g. in meteorology, fisheries, physical planning and surveys, some health research and considerable work of social and economic kind in the Planning Bureau and other agencies. Despite this diversity of interests in the government sector, in absolute terms the research and survey activities of the Agriculture Ministry constitute the major Government R & D effort.

The University is less than a decade old. Degree programmes have been initiated in agriculture, engineering and management, but a relatively small proportion of the enrolments is in the degree programmes. Most teaching is directed to diploma courses or to the conduct of short term specialist courses. There are some enthusiastic post-graduate programmes and these are pursued in close affiliation with overseas universities. Each School has a strong research interest and pursues programmes of strong social and economic relevance although the absolute investment in research is not high. The 'research budget' appears to be low in the sense of a coherently identifiable appropriation labelled research. The figures for both staff and expenditure for the higher education sector included in the above tables are, of course, attributions based on the application of a co-efficient to general university figures. It is not known what co-efficient has been used in deriving the above figures, but it would appear that it falls between 0.05 and 0.1 given that in 1976 the full-time academic staff was about 70 (plus 100 part-time) and that the annual budget was between $ 5 and 6 million.

No separately organised research units appear to exist for the conduct of health and medical research, either biological or social. The Health Ministry and the general medical services have access to the usual analytical and diagnostic laboratories but there are no 'research laboratories'. The Ministry's position appears to be that, because of the mode of organisation of the health care delivery system, the most relevant and profitable research programmes would be those based on the processing of clinical records. It is intended to build a research component into clinical practice in this way.

With the exception of a few individual engineering research programmes in the university, there is neither a separately identifiable programme directed towards manufacturing industry nor any separately incorporated organisation with the primary responsibility for secondary industrial research. An Industrial Standards Bureau has recently been established but is not yet fully operational. Its objectives relate to the development of industrial specifications and the testing of products and processes for conformity. The Bureau will serve consumer interests and mainly, it is intended to facilitate the foreign acceptance of exports manufactured in Mauritius. The Plan envisages that the Bureau 'might later carry out research for the improvement of local products'.

The simple conclusion is that although the agricultural sector is served by active and strong programmes and research organisations, there is no technology research and development capacity for the secondary sector at all.

A. RAHMAN

Planning of Scientific Research

What is Planning

Planning was anethema to the scientists for a long time. Scientists, brought up in the lore of pioneering tradition of science, thought it to be a curtailment of their freedom which was so vital for the creative activity. One possible reason for this could be its association with Soviet Union which had embarked upon utilising science and technology as an instrument of socialist revolution and reconstruction of the society. Since Soviet Union, according to some propagandists, was looked upon as an example of freedomless society and directorship and since planning was associated with it, it was generally believed that planning should be avoided for the growth of science. Even those societies which nurtured the idea of allowing total freedom to scientists to undertake research programmes of their own choice adopted various degrees and methods of planning of research to direct it into only those channels where their governments wanted.

Looking at planning theoretically it would appear to be an exercise in selecting a few from amongst several choices available for achieving a set of goals. Planning of scientific research requires a perspective of historical and social factors and economic and technological factors for taking a total view of the situation. This is particularly difficult because certain social factors cannot be quantified nor can they be ignored. In order to make the choices it is necessary to have the requisite information. This calls for a machinery for collecting information and continuously updating it. The information has to be stored in a manner, whereby it becomes cumulative and can easily be updated, retrieved and analysed. In the absence of uptodate information the decisions are often taken on past situations rather than the current, with considerable adverse effects.

The second requisite for planning is the analysis of the available data. The analysis of data is done to know the interaction of various factors, their linkages, how each one of them operates and the total effect of all of them put together. The analysis, however, cannot be carried out without working out the concepts and tools for analysis.

Planning also involves forecasting. This is an extremely difficult exercise in view of several imponderable factors which seriously affect the situation. Take for example, the Fifth Plan for chemical industries in India considered the general world trend for suggesting the plans of development of petroleum based chemical industries. However, before the document was published the OPEC came out with price-hike, thereby rendering the document valueless and making the planners to reopen the issue.

In addition to forecasting of trends and taking decisions on that basis, one has to predict the possible consequence of decisions taken to achieve the set objectives. For instance, the Atomic Energy Commission of India published a document which suggested the demand for energy in the country and the degree to which and the condition under which the commission could meet the demand. It also assumed a certain technological line of development. Taking these factors into consideration it proposed a scale of investment for the next 10 years. In justifying the approach, the lines of development and the scale of investment, it suggested a list of direct possible benefits and fall out in other areas of research and industry. The entire document, like any other document of this nature, was based on a series of assumptions and forecasts, any of which could go wrong, rendering the entire exercise untenable. In fact, many of the assumptions made had tended, since the publication of the document, to be incorrect. Not because there was anything fundamentally wrong with them, but because certain factors, such as health and environmental hazards or the cost factors, which were ignored or minimised earlier, came into greater prominence.

Further, it would also be necessary to know, for instance, if such a scale of investment was evolved for one area, what would be its impact on other areas of research, other branches of science and different technologies? In addition, what would be the scale of investment required in the developmental programmes of industry. These factors and other factors are required to be worked out in detail in order to develop a national science policy. As an exercise, one could study the impact of USA space policy — to send the man to the moon — not only on the development of science and technology in USA but also on the achievement of other objectives, e.g. removing of inequality, eradication of diseases, etc. The instances given are only to illustrate the complexity and the possible pitfalls. Both are part of the process. The point is not that we are likely to go, or have actually gone wrong, but the way with which we have tried to tackle the problems. After all, in the planning of scientific and technological research the first step is to shape the destiny of human society, and that is not an easy task. Only with time, experience and development of necessary conceptual framework and techniques would we be able to do better than at present. It is better to take the first step than to none-at-all.

Methods of Planning

Generally, two methods are being followed in the planning of research, viz. the aggregative and the centralised. In practice, in no country, the boundaries of the two are clearly demarcated. It is a mixture of both the methods which is followed, with a dominance of one over the other.

In the aggregative method, the plans from different research institutions are invited and depending upon the links of various research establishments, their heads and the scientists with the decision-makers and the fashion of the time, research allocations are made. In the centralised planning, as a result of dicussion amongst scientists at various levels, or taking into consideration the international trends and national needs, on the one hand and national capabilities and potential, on the other, certain priority areas are worked out, where major investment is to be made. The research establishments and scientists are then asked to submit proposals for research in these areas.

The Council of Scientific and Industrial Research in India is at the moment, passing through a transitional phase; that is, from aggregative planning to a central direction. Previously, it used to invite research projects from the laboratories. The laboratories, in turn used to ask divisional heads to submit their plans. These plans from the different divisions of the laboratories were put together, and with cushioning of possible cuts, were passed on to the CSIR Headquarters. The headquarters, in turn, take the plans of the laboratories as such and after adding to them any new projects or proposals for the establishment of new laboratories, would submit to the Planning Commission for grants. The Planning Commission, depending upon the availability of resources, would allocate funds to CSIR, which, in turn, would distribute them, depending upon the cut in demands, to the laboratories.

The first step, which it took as a departure from this method, was to invite specific projects and then to allocate resources on the basis of merit of these projects. It, then, went a step further to allocate special grants to well-identified, clear-cut, time-targeted projects in five specific areas — food, pharmaceuticals and drugs, energy, pesticides, and electronic materials and equipment. As the next step in this direction, areas of research were suggested by the CSIR Headquarters for giving major emphasis, and in this connection, it took upon itself the responsibility of bringing the laboratories together and form out areas of responsibility. Specific mention in this direction could be made of fermentation research, corrosion, utilisation of forest and agricultural products as raw materials for industries, etc. Mention may also be made of adopting a backward district and trying to use the technologies developed within CSIR institutions towards its development.

Dimensions of Planning

Having indicated briefly the meaning of planning and the methods which could be followed in putting it into practice, it may be worthwhile to illustrate by a few examples as to what it would mean in practice.

It may be worthwhile to take the political decision — "Food should be made available to all the people" — and examine in some details as to what it really involves, when it is to be translated into a set of research programmes.

General Decisions — It will involve a general understanding about the level at which the demand is to be met. The quantity of calories, proteins, minerals and vitamins a person requires per day for doing a particular type of work under a defined climate is now well known. Taking into consideration basic requirements, the quality will have to be decided. Having arrived at a general understanding of these two factors, the availability of food must be determined and gap estimated. Knowing the gap between its demand and supply a decision must be taken as to how to fill the gap, whether it is by increasing the efficiency of the existing agricultural practices or by increasing the acreage of land under food cultivation. However, if the latter decision is taken one must know whether it will be at the expense of forests or at the expense of a reduction in the acreage of cash crops.

A sociological study of land distribution amongst peasants may reveal uneconomic holdings and inadequate utilisation of land for the purposes of cultivation. Consequently, the objective of increasing food production to meet the gap can be met by social reform. This may involve better distribution or collectivisation of land. This involves considerable resources for motivating the people to accept any change in land distribution. Those who ignored it in the past had to pay a heavy price, as we know, by way of ruination of agriculture.

The availability of food can also be increased, without going into any of the abovementioned lines of approach, by cutting down the losses both at the production and the distribution sites. We know in India, under the existing conditions, about 20% of the grain and more of fruits and vegetables are lost due to pests, rodents, and harvesting, storage and distribution losses. Clear-cut decisions need to be taken on each of them; for instance, in the control of pests, the decision will involve the choice of pesticide, chemical or biological, for use, estimation of its optimal dosage and study of the impact of its use on the environment, fauna and flora and human health. In the development of storage structures, one has to decide about the materials and sizes to be used, the location of these structures and conditions under which storage has to be effected.

In taking decisions on the various alternatives posed, as exact and as latest information as possible has to be made available; this information has to be analysed and correlated with each other and other factors; forecasts have to be made as to possible results if one or the other line of action has to be taken. In addition, the technological level of the country in a given time and the availability of resources will have to be taken into account. Further, each solution has a degree of efficiency in a given set of social conditions. A highly efficient technological solution in USA cannot automatically become an efficient technological solution for rural India.

The latter type of approach requires a different type of expertise, i.e. in operational research, which is unfortunately least developed in the underdeveloped countries. These have social scientists and natural scientists, and each group carrying out sophisticated technological research in the area of their specialisation, most probably related to what is being done in the advanced countries, rather than coming together and using their specialisation in solving a set of problems. Planning requires not only the interaction of the two but their working together to find optimal solutions.

Research Decisions: Though the general decisions taken on the food front as indicated earlier may meet the country's food requirements for a short period, it will be desirable, after analysing the population trend and the quality of food to be provided, to build buffer stocks. This will involve the formulation of a major research programme for developing high-yielding and quick-growing varieties which are less susceptible to pests and less damaged during storage.

Such an approach will involve certain degree of capability in terms of science and technology, in terms of institutional infrastructures for research, scientific and technical manpower, and resources to carry out research and field trials. Unless these are developed it will be difficult for a country to fully develop this approach and gain from it the results which it expects to achieve. Those countries which did not build the necessary manpower and infrastructure even at the mercy of the so-called international experts did not make any break through which they were hoping to make. The manpower and infrastructure are vital even for knowing what is going on elsewhere and what is being imported by way of know-how, equipment and machinery.

The development of new varieties, high yielding varieties as they are called, demands researches in the area of water utilisation, fertilizer and insecticides besides agricultural research. The increased water requirement would entail survey of the water resources, development of water supply system by way of canals, tubewells, making of pumps and adequate resources of power, diesel or electricity to meet the requirement of the last mentioned items. The extensive use of sub-soil water would also require study of the inflow of water to these areas; otherwise after a few years the situation could be serious. Further, the extensive use of water for the new varieties would also require study of problem of drainage and salt and other contents of the soil. In the absence of these studies, waterlogging and increase of salt in soil surface may render the earlier gains not only ineffective but create serious agricultural and social problems.

The question of agricultural machinery assumes considerable importance in this context. Most of the agricultural machinery developed in Europe and America is high energy consuming and suited to large farms. If these conditions do not prevail, as for instance, where the size of the land holding is limited by social legislation the question of suitable machinery requires to be looked into.

The agriculture in Europe and America has now become a high energy consuming industry and two questions require to be seriously looked into: Can one sustain the level of agriculture on the existing basis of consumption of energy, particularly when the total energy input is more than what is obtained as an end product? If the answer is that all countries cannot do so then one has to think more seriously of a different type of agriculture than that developed at present in advanced countries, with a better input-output ratio.

The second problem would be of the sources and generation of energy to meet all these demands; from water-pumping to industries producing fertilisers and pesticides, as well as for running the agricultural machinery. A failure in any one of the areas may result in an overall failure.

The question of energy has posed a serious problem. The ancient agriculture was heavily dependent upon natural factors, with solar energy and animal and manpower as a major input, and the energy input and output ratio was favourable. If this is to be disturbed it has to be replaced by a viable system with favourable input-output ratio; otherwise it has to be artificially maintained and may not survive for long. This raises the problem of solar and biological sources of energy being developed and utilised more effectively. In the latter category is biogas and alcohol by the destruction of cellulosic material.

The point which is emphasised through the above example is that the entire problem is a system, one decision simultaneously involves complementary decisions in other areas and unless these are taken results in individual areas may be available but the result as a whole, which is hoped to be achieved, cannot be obtained. The task of planning is to take a total look, as much as is possible, and develop programmes which fit into the broad decision taken. Unfortunately, this cannot often be done due to the division of the social system into compartments of discrete responsibility as well as the division of the research system on the basis of subject specialization.

One of the major problems in the developing countries is the lack of persons who could have a systems approach to the problem. If we were to develop the systems approach and bring about an effective collaboration amongst scientists of different specializations and between institutions with divergent functions and government departments responsible for decision-making in India it would require considerable efforts. The result system in India is divided between the university system, the different agencies in the natural and social sciences and the decision making government departments. In the context of the problem discussed, one can list about 15-20 agencies and departments involved and the task of bringing them together to an agreed approach and a common place of work is, if anything, formidable.

In the context of the problems mentioned earlier, it may now be worthwhile to briefly describe how any agency, CSIR to be specific, has worked out an approach and machinery and developed the necessary techniques for the purpose.

Planning of Research — CSIR Model

General Features : In the evolution of planning of research, at the headquarters level, its history might be taken into account. Technically it was started in 1964, but it had various phases based on the appreciation or otherwise of its utility, acceptance or rejection by the scientists. This was important, as the acceptance by the scientists took time and the necessary machinery to be evolved besides taking time was also built up by trial and error method. The second point which required to be kept in mind was the stages of development of science policy in the country. These have been mentioned at some length in the paper on Social Goals and R & D Policy and hence it is not necessary to elaborate them here. Lastly, while CSIR was organising its effort and developing methods, techniques and models, the National Committee on Science & Technology (NCST) was formed and it prepared an approach document and the plan. The plan for CSIR became a part of the national plan. Besides, numerous directors of CSIR laboratories were appointed chairmen or members of various panels and they had effectively contributed to the formulation of the national plan.

Planning Machinery : In 1973, in the reorganisation of the CSIR headquarters, the previous Research Survey & Planning Division was reconstituted as the Planning, Coordination, Monitoring and Evaluation Dlvision and charged with the discrete responsibility of coordinating the plans of the laboratories, preparing CSIR Annual Plans and Fifth Five Year Plan.

The first phase of activity centered round the preparation of the Fifth Five Year Plan and for this purpose a dialogue with the laboratories was initiated and two sets of questionnaires were worked out; one for planning data for the preparation of the Fifth Five Year Plan and the second for monitoring the projects and their evaluation. The questionnaire designed for the purpose of getting information for the Fifth Plan clearly specified and asked for information on technical, economic as well as social dimensions of research, and the project leaders were requested to indicate the basis of priority for the specific programme.

The questionnaires for planning as well as for monitoring and evaluation of data were circulated to the laboratories and comments asked for and later discussed at the directors' conference and only then adopted for general use. Similarly, the data collected were analysed, with help of computer and the picture which emerged was circulated to the laboratories and discussed at the directors' conference. The purpose behind the procedure was twofold: to get the laboratory scientists involved and to motivate them; secondly, to take advantage of their problems and experience at the bench and laboratory level to be incorporated in the planning machinery and procedures.

The second phase of the development of the machinery was in two directions: first, formulation of a training programme for project leaders, administrative and finance personnel and store and purchase people in the planning of research for making them aware of various methods and techniques developed in their areas, with the specific objective of linking them up with the project planning at the laboratory level; secondly, by identifying people in each of the CSIR Laboratories who can be charged with and developed to handle planning, monitoring and evaluation work (PME). A series of seminars and courses were organized to equip them with the techniques available or which were developed in CSIR.

In the course of the work on PME it became evident that considerable work had to be done on methods and techniques, particularly in the area of choice of research problem, in working out priorities between one project and the other, between one area of specialisation and the other, one laboratory and the other, and on the question of resource allocation. Similar problems were faced with regard to monitoring and evaluation — whether it had to be from the angle of expenditure, resource utilisation, time, or objectives.

There is considerable literature available on each of the above areas. However, the efforts to apply the tools and techniques developed elsewhere were culture specific and suited to only a set of socio-economic conditions; these could not be applied in India. Consequently, a programme of research was organised in these areas at the Centre for the Study of Science, Technology and Development. The details have been provided to indicate the range of problems and the effort required if the planning has to be taken seriously and done effectively. Since there is no cut and dry formula for doing so, the steps to be taken have to be as specific as possible, so that while reviewing it the mistakes can be pinpointed and removed in subsequent effort.

Process of Working Out a Plan: The process could best be described through a diagram (Fig. 1).

In working out the plan, the advisory and executive machinery of each laboratory is fully taken into account. This comprises project leaders and director of the laboratory, on the one hand, and the Research Advisory Committee and Executive Committee of the laboratory, on the other. Consequently, the CSIR Headquarters (HQ) rarely, if ever, discusses the technical feasibility of a project, which is decided by the project leader, director and the Research Advisory Committee and the same

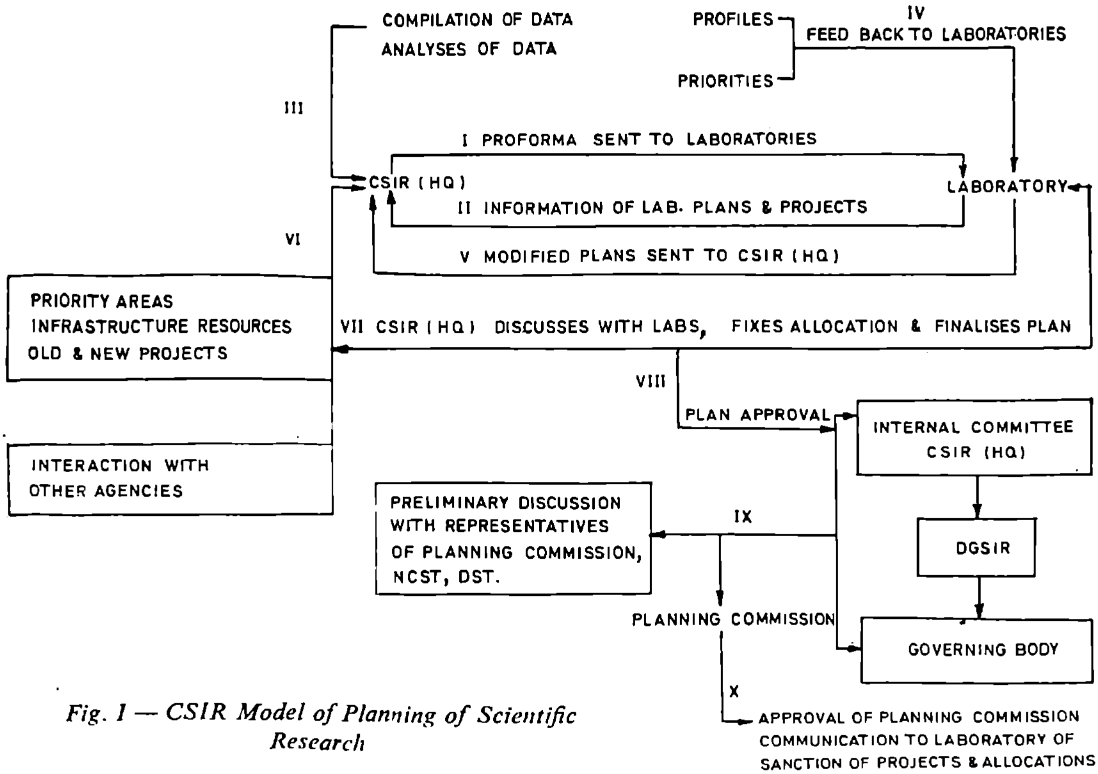


Fig. 1 — CSIR Model of Planning of Scientific Research

applies to allocation needed for a project, which again is decided by the project leader, director and the Executive Committee. The CSIR (HQ) generally concerns itself with the fixation of priority in the research programmes where the programmes are in consonance with national goals, and the manner in which each laboratory proposes to use its resources, or has utilized its resources; it also ensures coordination of activities of one laboratory with similar activities in other CSIR laboratories and the other R & D agencies. In addition, it suggests new areas where research capability can be built up.

The last mentioned point is particularly significant in view of the fact that in the planning process only those areas which have an established infrastructure claim for research funds at the expense of those areas which are not established and yet important, or for which institutional base has not been created.

Analysis: It may be desirable, having described the process, to give some idea, in detail, about the analysis of the data received from the laboratories.

To begin with, a broad analysis of the pattern of utilisation of resources of the laboratory is carried out. This covers expenditure on direct research, technical support, administrative and other support, number of projects, cost per project and number of manpower per project.

The projects received from the laboratory are categorised and analysed; some of the points of analysis are whether the projects are part of the country programme approved by UNDP, or National Committee on Science & Technology, inter-agency or inter-laboratory programmes. Their characteristics as to whether they are of exploratory, survey, pilot plant or developmental type are taken into account; further the time span and the resources required are also taken into account. A laboratory not having an adequate balance between different types of projects, time scale and resource input is required to have a fresher look at the projects again. The projects are also examined from the point of view of the objectives — social, economic, technological or scientific, which they wish to achieve under each of these broad areas; the objectives are further sub-divided into sub-objectives.

The success of the analysis depends upon the accuracy and compatibility of the data and the degree to which tools of analysis have been refined to suit to the conditions under which they require to be applied. In practice an open mind and flexibility in the method of data collection need to be adopted to avoid errors and to react to opportunities and possibilities. A rigid approach, without adequate feedback, can be disastrous to the entire process.

Areas for Research : Any effort at planning, without adequate support of a group charged with the responsibility of carrying out research may not be fruitful. Some of the areas of research are directly related to the planning process, such as project costing; preparation of a manual to help and to guide the project leaders and the laboratories; criteria for project selection, working out priorities and allocation of resources; and programming of project into phases and the links with regard to supply of materials and equipment, and work of other sub-groups.

Besides, in the above-mentioned areas, the environmental factors of a laboratory, its organisational capability, administrative sensitivity have also to be taken into account in arriving at decisions. A multi-disciplinary collaborative programme in a laboratory, with a rigid hierarchical structure and with divisional units working independently, may be difficult unless efforts are made to modify it effectively. Similarly, in a laboratory where elaborate rules and regulations are rigidly adhered to, the financial resources and inelastic administrative resources cannot be utilised in time, and time becomes a casualty, besides diverting the effort of project workers from research to obtaining of materials.

S.R. Valluri

Priorities in R & D Planning

The factors that influence the functioning of a research institute bear significantly upon its outputs. These factors need to be planned and organised as they differ vastly from one type of R & D institution to another, and no set principles and procedures are either available or even desirable.

The primary purpose of a scientific research institute is not the development of products but ideas that lead to a better understanding of phenomena and new technologies. The most important factor is the organisation of the structure and provision of a suitable climate for encouraging creativity and innovation. This is clearly dependent upon the varied mixes of freedom, coordination, group activity, motivations, communication, internal and external linkages, leadership, etc. Above all, R&D institutions deal with a highly vulnerable commodity —brainy people. It is the responsibility of the management to identify people with creative capability, nurture that capability, and manage them so that the intellectual capability of such persons is brought to bear upon problems of interest to the management.

Whether it is a planned economy or the one based on free enterprise, there are some broad aspects of management of the research institutions which are to be highlighted as they have a bearing on defining priorities in R & D planning. Research laboratories do not work in vacuum. Whether it is a private industry or a public sector undertaking, it is created for a specific purpose. This purpose defines its linkages with the relevant R & D institutions. These linkages, in turn, will define the charter and goals of the R & D institution and short-term and long-term research problems that are to be its concern.

It has been frequently suggested that if the R & D institution is directly associated with the user organisation or the ministry, greater clarity of purpose and better definition of goals will be achieved. Experience in India with the laboratories that belong to user ministries and those controlled by autonomous organisations such as CSIR would indicate that the problem is not so simple as that. The success to a great extent depends, in addition to the external linkages, on the manner in which the laboratory is internally organised. If the charter of the laboratory are far too broad, the laboratory will end up with the lack of clarity of purpose, lack of focus of its activities, and dissipation of its energies. It is in the interest of the organisation to define its objectives with some clarity in order that it will not have difficulties in defining its problem areas of interest. Experience also indicates that the external linkages, more often than not, tend to be elusive and the organisations which one is supposed to serve are not always clear as to what should be their short-term and long-term goals. The problem becomes even more critical if the laboratory is not intended for developmental and applied research work but for the growth of science. Our experience indicates that extensive dialogue with user organisations is essential in order to obtain a clear definition of the projects that are to be taken up. In NAL, we find that this has been greatly facilitated by the director of the laboratory being a member of the Board of Directors of the industry, and the director, Design & Development of the industry, in turn, being a member of the Executive Committee of the Laboratory which ultimately has to approve the research programmes from year to year. It was also found useful to have Scientific Advisory Committees for the various divisions of the laboratory which could interact with external organisations in order to obtain a better definition of R & D projects that are proposed to be taken up in the laboratory.

If the laboratory were to take up only those projects that are of direct and immediate relevance to user organisations, it would quickly tend to forget the long-term goals which are also its responsibility and transform itself to the equivalent of an inhouse R & D unit. The situation will not be entirely dissimilar to the case of a person who, instead of taking the interest from his saving account in a bank and using it for living, uses the capital itself and assumes that everything is all right. I tend to believe that it is of the highest importance that in addition to taking up projects of immediate relevance to user organisations, the laboratory directs some of its capabilities to take up R & D problems based upon forecasting future technological requirements and establishing a scientific base for them. Our experience indicates that this is perhaps one of the most important aspects of planning and defining of priorities in a laboratory created to operate in areas of high science and high technology. The work, which we did more than a decade ago, has been found to be of tremendous relevance now, and we expect that the work we are now doing will bear fruit in about ten years' time.

Having obtained clarity of purpose in regard to the goals and objectives and research projects to be taken up by the laboratory, the next important aspect is the one related to recruitment of manpower, its training and providing leadership in order that the trained manpower works on the problems that are of interest. Our exprience tends to indicate that even when trained manpower is available on the lower levels, without leadership at the senior levels it cannot be effectively utilised. A leader with good understanding of the scope and magnitude of R & D problems and the ability to make people work together is perhaps one of the most important assets of a research laboratory.

We have had in our country several instances, where, in the absence of trained leadership, the laboratories have suffered in spite of having capable people within the organisation. It is also our experience that where termination of the service of staff is not easily possible, the greatest discretion is needed in the recruitment of staff. While any organisation can live with a few incompetent people, excess of them can only end up in attracting more mediocre people to the organisation, whereas a first-rate scientist who is recruited today will continue to attract first rate scientists tomorrow and day after. A good leader has to have technical competence which commands respect, ability to get along with people, integrity and commitment to recruit the best for his organisation. A good leader aims at creating an organisation which gives importance to a sense of fairplay in rewards.

Scientific communities all over the world are extremely sensitive as to whom they report to, and it is impossible for a second-rate person to be accepted by a first rate group of scientists or engineers as their leader. Within the research laboratory the leadership has to tread a very careful path between the freedom of the individual scientists to inquire and necessity to coordinate his activity with that of the group towards a common cause. Most scientific discoveries have been made in a free atmosphere without the pressure of time and authority anxious for results, although the peer pressure from similar activity taking place elsewhere tends to be a strong motivation for bringing out the best in individuals. It is also true, by and large, that technological innovation of significance has resulted in group activities which would require some degree of coordination within and from outside the group.

It is sometimes alleged that coordination is a necessary evil imposed by bureaucracy and public financing. Is it necessarily an evil or does some dose of coordination have a positive influence on the activity and productivity of scientific work? Some published data in one of the many studies on scientists in organisations indicate that a combination of freedom and coordination in goal setting for scientists results in better performance of individuals. We find in our laboratory that when goals were set jointly by scientists and division chiefs and in turn, the division chiefs set the goals jointly with the head of the laboratory the performances were found to be the best, whereas in institutions where either the director or head of the division sets goals by imposition, the results were not found to be as good. R & D scientists and engineers have to interact with their chiefs, their colleagues and assistants. The need to involve them in the decision-making process related to their work has been generally recognised. This brings in some amount of administrative responsibility which, more often than not, is disliked by them. While technical workers want decision-making authority, they hate to take up the administrative responsibility associated with the task. This poses some difficult problems for the management. It would appear that where large organisations are concerned some amount of administrative responsibility of this type is unavoidable at intermediate levels also.

Where the R & D problem is not one of broad-based, forward-looking research, but is more specific, communication and group activity seem to play a fairly important role. Creative ideas are not the privilege of just one individual. Many good ideas can be shaped or crystallised by discussing the goals with the scientists. High quality research can be promoted by providing opportunities for scientists to stimulate each other. Communication is at its best in peer group culture and does not have limitations to group formation based on socio-cultural, caste, status and community considerations. Organised contacts with colleagues is a sure way of improving communication but one also faces problems and risks like the theft of ideas. The culture of informal communication could result in cohesive group activity and this is generally found to be missing in many of the R&D institutions, particularly in the developing countries, perhaps because there are not enough number of people who know enough about the subjects to hold such informal discussions.

It is desirable to note, in passing, that in addition to the above, it is also necessary to obtain an internal management structure at the working level which would enable an institution to bring out the best in its people. We have found, for example, that freedom within some broadly defined limits for scientists to pursue their ideas is greatly enhanced by project-wise planning of budget. This enables the management to decentralise R & D planning and its implementation to a much greater extent than is possible under central planning. This, combined with peer group discussions within the laboratory on research programmes and assessment of the progress by user organisations or their representatives periodically, was found particularly valuable in managing our laboratory.

S. R. VALLURI

Criteria for Choice in R & D

Irrespective of the political system a country has — whether it is a centrally planned, or a laissez-faire market, or a mixture of the two — a common fact in the functioning of the Governments nowadays is their tendency to control or exercise influence in the conduct of research and development (R & D), particularly in fields related to science and technology. The Soviet Union where centrally planned economy operates, released a paper on "Principal Trends in the Development of Science and Programme of Scientific and Technological Problems for 1966-70", which outlined the wide range of specific problems of interest to Soviet Union in Science, Mathematics and Technology among others. The President of United States has several Councils and Committees of eminent men whose responsibilities extend to recommending national policy for science and technology although a national policy for science and technology as such is yet to be defined in the United States. In India, the National Committee on Science and Technology evolved a Science and Technology Plan in 1974. Similar trends are noticed in many other countries also.

Except for a few anomalous situations such as those in the oil rich countries, it would appear that the standard of living and the state of development of people are closely related to the per capita amount of money invested in R & D and the per capita energy consumption.

It is a well known fact that the Governments all over the world are spending a considerable amount of money for scientific and technological research. This is because science and technology seem, at once, to offer to the Governments of the world a tool to eradicate hunger and poverty and offer opportunities for substantial increase in the standard of living of people.

Application of science and technology to solve a nation's problems seems to influence the very foundations of a nations socioeconomic structure. Inputs into science and technology seem to multiply and diversify material possibilities and offer a multitude of new opportunities hitherto unknown. It would, in fact, appear that, instead of necessity being the mother of invention, invention has become the mother of necessity. We should certainly avoid emulating the examples of conspicuous consumption that seem to determine the life styles in some of the countries of the world, but we should not fail to notice the benefits resulting from the application of science and technology which are unquestionable.

The implications of science and technology are particularly important and relevant to the developing nations. Their economies have been, by and large, based upon the export of raw materials and import of finished goods on the one hand and agriculture which at best barely succeeds in providing the minimum requirements of food, on the other. The result has been and continues to be depletion of the natural resources in the developing nations, continued dependence on imported knowhow for specific products and subsistence level of living for the people, although, intrinsically, they may have the wherewithal not only to satisfy the minimum necessities of life but even to aspire for a better and decent standard of living. The examples of developed countries have clearly shown that even for those who do not have plentiful natural resources, proper application of science and technology, with import of suitable raw materials, can substantially increase the standard of living of the people. There is, thus, little doubt that even for developing countries, with the growth of culture of science and the cultivation of scientific temper and with appropriate choice of research and development projects, much more can be achieved than what has been hitherto possible.

In determining the criteria of choice of the research and development projects, one can broadly identify three different levels. One is the definition of the political intent of a Government in terms of sectoral priorities; second is the follow up administrative decisions specifying the areas of primary R & D thrust; and third is the actual working level implementation where financial inputs are made for explicitly defined R & D projects in the industry, research and academic institutions to achieve some well-defined objectives. Generally speaking, the first and second levels which tend to overlap are made in the following perspectives:

(a) An assessment of agricultural, chemical, mineral, energy and manpower resources;
(b) an assessment of the funds available including foreign exchange for the exploitation of the resources;
(c) an assessment of the current standards of living of the people and the standards of living proposed to be obtained by the end of a certain period; and
(d) fixation of the R & D inputs based upon the sectoral priorities to be defined by the Government.

An important criterion for inputs into research and development should be clearly to maximise the benefits for the given inputs. The ratios of expenditure on fundamental and applied research to developmental research are different for different sectors. For some individual areas the typical proportions are given below (fundamental research : developmental research):

(i) Agriculture 9.7 : 1.0, (ii) Meteorology 2.0 : 1.0, (iii) Aeronautics and Missiles 1.0 : 5.6. (iv) Drugs and Medicines 1.9 : 1.0, (v) Electronics and Communication equipment 1.0 : 3.5.

It will, thus, be noted that for fields like aeronautics and missiles, electronics and communication, substantial amounts of funds are required for developmental research as compared to fields like agriculture. In developing countries which have serious food shortages (example : India), it would appear that inputs into agricultural research would maximise the benefits to a much greater extent than inputs into research in fields such as aeronautics and electronics. Also, the developing countries are faced with a serious problem, i.e. unemployment. Therefore, any R & D project whose results prima facie imply surplus of trained manpower or underemployment of people is clearly not a very good solution. There may be instances where it becomes unavoidable, but such projects should not become deliberate choices. To cite an example, it has been estimated that in order to meet the food needs by the end of this century, India would need about 250 million tons of food against the current production of about 115 million tons of food. Two models have been examined. In one, the energy subsidy is modest, requiring about 16 million tons of oil equivalent, with considerable dependence on human labour requiring fairly large area of land, of the order of 150 million hectares, whereas in the second model, energy subsidy is extensive, requiring about 70 million tons oil equivalent of energy, requiring much less land and even less human labour. For a country like India with an excess of unemployed and underemployed village population, the choice of R & D project leading to the second alternative will be clearly disastrous because it may increase food production, but there may not be people with enough money to buy ! The first choice, for most developing countries, seems to be R & D projects in Agriculture and agro-based industries and of course, projects leading to drastic population control.

While deciding the criteria of choice in R & D, it is also desirable to recapitulate the various types of research. Research is not any longer done simply to satisfy one's curiosity and improved knowledge of a natural phenomenon. Such research is a luxury which most nations, except the very rich, cannot quite afford. It is done since it has a bearing on all sectors of a country's activity, its Defence and Civilian economy. Pure research is a long-term undertaking unrelated to any immediate practical problems and designed to improve our knowledge of science and laws of nature. Directed research which is also called oriented basic research, is a long-term basic research which has been channelled into specific directions and is aimed at the solution of practical problems. Applied research is the direct servant of technology. It is designed to improve the existing products and processes or to develop new ones. Development is characterised as the process that uses technology in an innovative manner for producing a new product or evolving a new process of manufacture. Oriented basic research forms the borderline between the basic research and applied research and is generally carried out at institutions of higher learning, State-aided laboratories, independent research institutions, or in the inhouse R & D laboratories of big industrial organisations. Quite frequently, the research sponsored by some mission-oriented institutions has been phenomenon-oriented wherein the effort has been to obtain a basic understanding that is required to open up new fields of science out of which may result discoveries which overcome the existing technological limitations. Such investigations may tend to be expensive and perhaps beyond the limits of developing nations.

In defining the criteria of choice for R & D projects which developing nations may take up, the following points may be noted : In order to obtain a reasonably quick increase in the standard of living, many of these countries have tried to obtain imported knowhow and licensed production. While these have definitely offered goods for the people, they have nevertheless, by and large, remained isolated pockets in the countries without much of an impact on the country's economy. India, for example, is no exception to this rule. When one examines these, several aspects come into prominence. The first of course is the import of knowhow for a product, which need not necessarily be the import of knowledge to make similar products. To suitably graft imported knowhow, one has to have not only the culture of science in which the graft can take root, but also adequate preparation of suitably trained people who participate in the import of technology through the formation of R & D and design cells so that the next generation of products can be indigenously produced. One should closely examine the example of Japan in this context. It has imported knowhow for many products but so thoroughly absorbed it that they have been able to use it as a base for producing improved products.

For developing countries, it is virtually impossible to grow science in the multitude of areas in which it is being nurtured elsewhere. Science has to grow in the country so that in the culture of science, technology also can grow. The choice of the research areas has to be selective, bearing in mind the natural resources of the country, their essential requirements, and the input/output ratios to maximise the benefits in the shortest possible time. The support of science for the sake of science, to some extent, can be justified in the developing countries but the support must be directed to maximise benefits in the areas where the country has natural resources. For example, for a country like India which has a large cattle population, it would make considerable economic sense not to simply export raw leather but develop technologies which can produce exportable products. The value added cost would be significant. Additional employment potential created can be substantial.

For countries with a variety of exploitable natural resources, the choice of the areas to concentrate may tend to offer some problems.

In this connection, one may note with interest the examples of India and Brazil. In terms of natural resources and the state of the indigenous technology, the countries are comparable. Both the countries are also trying to increase the standards of living of their people. However, whereas India has decided to establish the R & D infrastructure in a very large number of areas, Brazil has decided to concentrate only in a few areas and make major investments in them. It would appear that in Brazil benefits can perhaps be obtained much quicker in those areas, whereas in India it might take a longer period of time for comparable benefits due to necessarily limited inputs. It would not be *a priori* easy to say which is a better alternative.

In converting the broad national goals into specific research areas, there are some very obvious difficulties which we all have experienced. If the Indian example is of any relevance, detailed dialogue between the national planners and the heads of research laboratories is needed in order to obtain a greater clarity of research programmes that are to be taken up.

Let me cite a personal experience in this connection. Sometime ago when one of our Ministers visited the Laboratory, I mentioned to him that a political decision is needed in order that the capability that is grown in a Laboratory like ours can be put to good use. The Minister who is, in a very real sense, a visionary, stated that political decisions are not made in vacuum but in a certain perspective. All that the politicians are capable of doing is to make a choice from a given set of alternatives, and it is the responsibility of the scientists and technologists to place before the political arm of the Government the various alternatives that are available, the pros and cons, the financial implications, etc. so that a political choice can be made. It is thus clear that the scientists and technologists have a dual role to play. In one, they have to make dispassionate and detached analysis of the several alternatives and their financial implications and place them before the Government for its choice. After the Government has made its choice, it will, in turn, become their responsibility to implement the political decision of the Government so that the objectives set forth by the Government can be achieved. When once the choice is made by the Government, the chosen objectives become the goals for the scientists and technologists.

The nature of the R & D projects that emanate from such objectives will cover a very wide spectrum. It will clearly be not possible to define criteria for their choice. Where the country faces very major problems, as for example controlling its runaway population growth or responding to critical energy needs, a multipronged attack may be needed in which crash programmes have to be launched, where simultaneously a large number of R & D projects are mounted to obtain a solution in the quickest possible period of time. In such cases the amount of money that is spent in the short-term may be significant because in the long-term perspective it can save the country from a catastrophy. Also there can be R & D projects with somewhat more limited objectives : import substitution of essential commodities and export promotion to increase the value-added cost of the raw materials, etc. The quantity of money to be invested, the choice of the projects and the *inter se* priorities will clearly have to be based upon a system analysis of the various alternatives, with a good bit of intuition playing an important role in the final choice.

In the final analysis, for developing countries whose economies have been characterised by export of raw materials and import of finished goods and essentially subsistence type of economy in agriculture, R & D projects leading to import substitution of crucial and expensive commodities, export promotion, R & D inputs into agriculture and agro-based industries, and better health and sanitation facilities are perhaps far more important than extensive inputs into areas in high science and high technology which are capital intensive and have long gestation periods and where competition from developed countries is very high. However, it is also equally true that if a developing nation aspires to become a developed nation and has the necessary intellectual and other resources available, it is essential that it pays attention to at least some areas of high science and high technology. It is to be noted that the choice may not necessarily be very clear cut, and a certain amount of arbitrariness may be more a rule than an exception in the ultimate choice.

LEON PERES

R & D Resource Allocation and the Planning Process

Throughout the various sessions of this Seminar, a number of terms have been used to describe aspects of R & D management and the related activities. We have talked about: the need to *integrate* R & D with the *planning process*; to *coordinate* at the institute and programme levels; to adopt *management* practices and *administrative* procedures to serve R & D. We have used all of these terms to describe ways of relating R & D activities to national and social goals. These terms are deceptively neutral in their appearance.

Resource allocation is also used in a neutral way. But its neutral appearance is equally deceptive. The deception is that each of the terms disguises a powerful political process. Resource allocation is of the essence of politics. An allocation decision confers benefits on one group (by transferring resources to it) whilst imposing costs on another (by way of a tax or by denying those same resources to a group anxious to pursue different purposes or programmes). No matter how sophisticated the decision apparatus or techniques used in the allocation processes may be, and no matter at what level the allocation is made, resource allocation is a political process. This political aspect is implicit in the notion that allocation decisions be used to persuade or direct scientists and science institutions to pursue *relevant* programmes.

I have been a little concerned, however, that scientists seem to be castigating themselves for being 'irrelevant'. They are urging one another to undergo a change in consciousness and so define their programmes or make allocation decisions in socially relevant ways. Techniques are being sought by which science can be bent to the social purposes. I have no quarrel with the overall aim of relating R & D activities to the social goals; indeed I fully support it. But I wonder whether science is exclusively at fault in the matter of relevance. The picture being drawn is one in which society is queueing up outside research laboratories with a long list of relevant demands; these demands are being arrogantly rejected by scientists who climb their ivory towers to escape the flood of relevant proposals so that they might pursue their own idle curiosity.

The fact, however, is that in most of the countries of the region, including my own, the society is not interested in science. It places no great demand on science and gives it very little attention other than, as Dr Valluri has remarked, including a formal statement of intent in a chapter of an official plan. It is also a fact that most R & D related innovatory proposals in the region have required the expenditure of enormous effort by scientists and laboratory directors: first, to identify likely individuals in the production units who would be sensitive to the need for change and responsive to an innovatory idea; second, to devote as much effort in persuading and then, training such people in the requirements of the particular innovation. Such 'likely' individuals are exceedingly scarce. The 'relevance' problem arises because, as Dr Vojdani has pointed out, such people are missing from most government agencies whose role is to give some precise definition to social goals, i.e. the mission-oriented departments of government. It is such groups that society relies on to translate its general social and economic aspirations into specific social goals. These rarely have the capacity (i.e. the people) to understand the relevance and the potential input that science can have for their missions. Thus they are often incapable of giving specific definition to social goals in terms to which scientists are capable of responding. This forces scientists themselves to reduce the general social goals to specific operational formulations. As mentioned already, it is likely that most innovations in the region have occurred because scientists have, in fact, been doing this. They have had to define social goals as well as the scientific programmes to serve them.

Scientists, then, should not feel guilty and have crises of identity and conscience about 'relevance'. The political and administrative systems have failed to produce a capacity in each of the mission departments (or productive enterprise units) that will enable each such body to give specificity to its particular band within the spectrum of national goals and then go on to define its operational goals in ways that can provide starting points for scientists.

In the absence of such definition should the scientist himself assume the role of turning general social goals into specific ones ? Some have done so and continue to be prime movers of important changes of a social and economic kind. Others might retreat to their own world of curiosity. Perhaps we should try to change the relative proportions by turning more scientists into salesmen for innovations, but I do not believe that scientists should be expected to assume the role alone. Scientists cannot be substituted for a political and administrative system that might itself be deficient. At best they can overcome some of these deficiencies, but they cannot and should not assume the whole responsibility. The scientist should certainly be an essential part of what Andrew Yauieb called the linkage between the R & D decision structure and the political and administrative decision-making process. But the scientist cannot perform the roles required at both ends of the chain.

It hardly needs to be emphasised that science must be integrated with the planning process. The emphasis on *Science*, however, implies that science is the weak link in the chain. It is science that has to be picked up, refashioned or moulded, bent and slotted into the planning process as if the planning process itself were perfect. Mr Haksar was certainly correct in saying that over time there has been an increasing acceptability of planning as a decision and allocation system. It is a way of producing specific goals from general social goals. With due respect, it seemed to me that he neglected to mention that, over the same period of time, the idea of planning has itself gone through significant changes. Critical aspects of planning are now seen to include : flexibility — the capacity to detect the need for change and to respond quickly to it; the need to embrace many decision centres in both the formulation and implementation stages; the need to disseminate knowledge and information widely through these centres; the need to see that appropriate 'values' are present and are observed at these various centres — e.g. concerns for social justice, equality, etc. — so that advice is given and actions taken in accordance with those values; and it is now seen to be necessary, again as Andrew Yauieb stressed, to allow for the participation of those whose lives are being planned.

Can we honestly say that our planning or decision-making systems display all of these characteristics as yet ? More specifically, are they capable of handling science and technology questions in ways that will serve the social role of science rather than hamper it? Can we be sure that, as we try to establish linkages between science and decision-making or integrate science with planning, that there are groups at both ends of the chain, and at the appropriate decision-making levels, capable of communicating effectively with one another? Unless this happens specific social goals will not be formulated in ways that will maximise the advantages to be gained from science and which would render the social role of science and scientist meaningful. Further more, if the linkages are not established clearly at the level of specific social goals, *external criteria* (i.e. external to science) will not be generated to guide the allocation of resources to science and technology. For after all, our general social goals are so general as to make any programme compatible with them. To generate criteria we must make social goals specific.

In the absence of external allocation criteria, expressed through linkages between science agencies and the mission and production agencies, we will continue to be preoccupied with *internal criteria.* Science Councils and Advisory bodies, where they exist, are generally very inward looking. They sit in judgement on the already responsible executions of research councils and other bodies. The formulation of issues is, again, very inner directed. We embark on endless searches for categories of basic science, applied science and development in a range of imaginative ways and search for magical proportions to guide the allocations between them. The same can be said for the percentages that, at one time or another, have been put forward as criteria for allocation — percentage of GNP; of sales; of turnover; of scientists to employed manpower; of expenditure per scientist and so on. We argue about the roles of the various performance sectors and the relative efficiency or effectiveness ratios. The mode of organisation of science is another favourite — should it be by discipline, multi-disciplinary, by task or project; and we argue about the balance between the various fields of science. But when it comes to our own interests we are again extraordinarily imaginative in finding ways to maximise the benefits and minimise the costs of *our* projects whilst doing the opposite for our competitors.

The inward looking process, the search for *internal criteria*, aggravates controversies within science and can lead to what Dr Khan described as a situation in which not just politicians but society in general is disillusioned or disenchanted with science. This is tragic enough in a society which is favourably disposed towards science. Where an anti-scientific temper is prevalent it can be disastrous. It is not so much the fact of controversy itself but its inward orientation and the absence of external criteria by which to resolve it that is potentially damaging. We only look inwards because there are no external criteria.

This then returns to the point of whether the scientists themselves should assume the task of formulating *external criteria.* But I have already expressed my doubts about the possibility and political morality of that. It would involve the scientist having not simply that sense of social responsibility which Prof. Rahman urges, but the skill, the political sensitivity, the wisdom or the arrogance that would let him conclude that he knows best what the specific formulations of society's goals should be. The socially motivated scientist must certainly be a part of the process, but he can only be a part. What he needs is the opportunity to enter into a process of mutual interaction and influence with those in the multiplicity of decision points that must necessarily exist in an effective political, administrative and planning system, whatever the nature of that system. There must be faults at the scientist end of the interaction system. I am much more certain that there are large gaps at the planning end. Very few mission departments or production units have the capacity to enter into communication with scientists to facilitate the process of formulating specific social purposes that can be the primary premises for the science organisations. Unless we are satisfied that the planning process has the capacity to 'receive' science, talk about integration is utopian. Scientists will turn away in despair if they cannot gain access to the political and administrative decision centres relevant to their fields of research. Even worse they might be turned away by those who lack understanding of the potential contributions of science.

I would conclude, then, that in considering how science should be brought to bear on social goals at the very least as much attention must be given to the administrative systems capacity to receive science as is given to the effort to bend science to the social purposes. Unless there are groups at both ends of the various communications or linkage chains capable of entering into dialogue with one another the notion of relevance is an empty one. The search for external criteria will fail and controversy about science and social goals will continue to be inwardly oriented.

The search for allocation criteria in social relevance, then, requires considerable change in the administrative decision centres in addition to any change that might be required in science. Such administrative change can also serve the needs of the planning process. This is because 'relevance' has two faces. There is no doubt that organized science ought to take relevant social values into account when deciding on programmes. But, at the same time, a scientific input is required in almost every aspect of government activity. A concern for science should itself be one of those values present and taken into account at each of that multiplicity of centres embraced within the planning process. This science value should be disseminated and protected along with other important social values throughout the political and administrative system. It is only in this combination of ways that socially relevant and acceptable criteria can be generated to guide resource allocation decisions in Research and Development.

G. S. SIDHU

Project Selection, and Programming, Monitoring & Evaluation of Research

In the topsy-turvy world we live in, it is seldom that one gets the priorities right, and being somewhat muddleheaded by nature, I am taking up first, what has been placed last, viz. *Evaluation*. Since one must also rationalise one's actions, I will justify my order of priorities by stating that evaluation permeates all stages of a project. Even project selection is essentially a pre-evaluation process.

R & D institutes are not homogeneous entities. The criteria, variables, and constraints of evaluation evolved in one institution and indeed even for different projects in the same institution will not, therefore, be applicable to other institutions or projects. As an example, I quote my institute where I have a strong group in Process Engineering and another in Molecular Biology. Projects in both cannot be evaluated in the same way because of the great difference of predictability in the work of the two groups — the first starting with reasonably established process knowhow data and evolving the basic engineering designs for commercial plants and the second charting unknown seas with a great deal of inherent certainty.

Project selection has already been adequately covered by other members of the faculty, and I will, therefore, restrict myself to a few points more relevant at the institute level.

A R & D institute should have two formal review mechanisms for candidate projects irrespective of the source of origin — a preliminary review which can be done by one or two specialists and if the project passes this review, then a more detailed review by a screening committee which should have, apart from technical specialists or professional scientists, one operations research (OR) expert and/or one management scientist. It is at this stage that the special technical skills of the scientific discipline need be combined with special skills of management scientists well-versed in the techniques of operations research, market research, system analysis, cost accounting and technical documentation.*

A favourable revision with or without modifications to the originally proposed project should trigger the preparation of a project profile which, depending upon the institute's capabilities/philosophy, could be a mathematical Project Score or a qualitative judgement leading to a management decision of taking the project on or rejecting it.

The criteria of choice can be based on economic, social, technical feasibilities and other considerations, e.g. scientific or technical need and merit, creation of natural capability. [These are discussed in detail in a paper by A. Wahid and A. Rahman in *J. sci. industr. Res.*, **35** (1976), 131-38.]

An institute has limited resources, and projects can generally be taken in only when some ongoing projects are completed or dropped. So criteria have also to be evolved for comparative evaluation. Because of the lead time required in acquiring new equipment and hiring new staff, an important criterion at the institute level is the available infrastructure and specialised manpower. Projects requiring major

* A R & D institute should create such a group if it does not have one; it should strengthen it, if it is subcritical in size. Such a group can be built around institute scientists who want to move into these specialised areas and strengthened through recruitment of professionals with appropriate specialist training and background. The group will be principally concerned with research planning, technical information, industrial liaison, and inhouse coordination.

capital equipment and/or new specialised staff should be foreseen 1-2 years ahead.

Once a project has passed the screening, a good R & D management must insist on the preparation of a detailed *written* Research Proposal. This is essential for effective planning and programming. The proposal should embody:

(a) the desired technical end objective,

(b) current state of technical development,

(c) the overall technical development project plan and its break up into subplans and the phasing of the project,

(d) the resource requirement and deployment: (i) manpower — highlighting key-personnel requirement, (ii) equipment, (iii) major consumables, and (iv) space,

(e) time required for completion: (i) date of initiation, (ii) expected dates of completion of subtasks, and (iii) expected date of completion of project,

(f) contingency planning — to foresee important likely bottlenecks and be ready with alternative solutions, and finally,

(g) the total cost and total time estimates. It is necessary to make three estimates on the basis of: (a) everything proceeding according to schedule, (b) optimistically going ahead of schedule, and (c) the 'worst case' estimate. Project overruns become less infrequent if the 'worst case' estimate is selected.

The project plan can then be depicted on a simple bar chart with a descriptive schedule of activities or it can be put on PERT/CPM Chart. Hybrid Research Planning diagrams can also be evolved. For major projects a PERT/CPM chart is preferable because it permits the assembly of individual tasks into a complete framework and shows the inter-dependence of subtasks. A realistic network plan should also, in the beginning itself, anticipate uncertainties and allow for some rework.

Now we come to the monitoring of an on-going project which is again another part of the total process of evaluation. There are four sets of questions that arise here:

(1) What is monitored?

(2) How is it monitored?

(3) Who does the monitoring? and

(4) When is the monitoring done?

The answers are: (1) The progress of the sub-tasks in the project and the project as a whole are monitored for deviations from the plan. (2) The monitoring system is dependent upon the way the project has been planned. (3) Sub-tasks are best monitored by the project leader sitting with the whole team; if each subtask has been clearly identified in writing and each team member understands his individual responsibility as well as the overall task, this review becomes very fruitful. The project as a whole is best monitored by a small committee—we have a Research Planning and Evaluation group with four permanent members and two to three invitees including the project leader. The Director is a member, but it is not necessary for him to sit on all project review meetings—which must also include a member of the OR group. (4) The periodicity of the reviews of subtasks may be once a week or once a fortnight. Frequency of total project monitoring may be one month or 2-3 months or on previously delineated review points; this programmed control is better than a nonprogrammed one — but it is better to begin with the latter. A *Built in controls* and a formal Management Information System will go a long way to ensure the smooth post-review, two-way flow of information: progress $\rightleftharpoons$ corrective action.

The purpose of monitoring is to identify causes of deviations from plan and delays and to effect midcourse corrections. The delays can be managerial or technical. The feedback leads to a revised plan where necessary and can also trigger a decision to stop a project and cut one's losses early enough.

A word about project costing is necessary here; scientists must learn the culture of thinking about their projects in budgetary terms, overcome their reluctance (sometimes aversion) in drawing time schedules, keep track of their time and time accounting, and record only *major inputs* and *not triviae*. Perhaps a Project Secretary common to a few projects could remove the drudgery involved; we are going to experiment with this system.

If a project has been sponsored, the client is there to keep the institute on its toes — frequent overruns on time and costs will get the institute a bad name and no more clients. If it is an inhouse project, it will be a good practice to name one of the senior scientists to play the client's role.

Finally, how does one evaluate the success of a project? A project is said to have been successfully completed if the end objectives have been realised in the planned time and within the allotted budget. I am referring only to projects with well defined and attainable objectives.

Evaluation criteria have been suggested and are used in some institutes which depend upon external impacts of the R & D project; e.g. has the project resulted in the production of goods? If so, has it saved Foreign Exchange? or How much is the financial turnover of the manufactured product? The difficulty arises as to what percentage of this should be ascribed to successful knowhow development. A good knowhow can be and sometimes is ruined by poor manufacturing — the reverse is also true — so how can one apportion credit? And there is also the question of time lag between R & D completion and production. So, to my mind, financial returns, except direct knowhow or design fees, are not the reliable criteria for evaluation.

At the institute level, the purpose of the final evaluation should be to find out the R & D effectiveness and use this as the basis for further planning and resource allocation. The evaluation must be forward looking and not a *post mortem*. It is important to understand the distinction between efficiency and effectiveness — *efficiency* has been defined as the utilisation of allocated resources to get maximum output from a given input; *effectiveness* is a measure of how well the work has been done and how closely has the result come to the expected/required goals. Let the management strive for effectiveness and the administration for efficiency; and let the overriding controls be professional controls rather than administrative controls; the former leads to "effectiveness" and the latter to mere "efficiency".

The President of India, Mr Fakhruddin Ali Ahmed, while addressing the annual convocation of the Indian Institute of Management, Calcutta, on 16th May, 1976 said, "Nothing was more dangerous than an *efficient* manager with the wrong priorities." So let the R & D institute management first determine the right priorities and then strive for "effectiveness" in achieving its goals.

Information for Decision Making

Type of Information

It has been pointed out in the paper on Planning of Scientific Research that information is the basic requirement of all the processes of planning and decision making. It would be desirable to go into some detail as to the nature of information required at different levels, its flow and utilisation for different purposes.

Basically, two types of information are required, viz. scientific and technical information and socio-economic information.

Scientific and Technical Information

This type of information is essential for knowing the thinking in a particular field of specialisation and the current researches under way. Previously, every research worker used to go through the literature in his field of specialisation and used to keep a record of the literature for future reference. This is being done even now. However, with the increase in the quantum of literature and the need to go beyond one's field of specialisation, it is not possible to cope up with the developments; specialised groups and agencies have been built up to do the work. Documentationists are now a group of professional workers and an essential part of the technical infrastructure of a research institution. They, depending upon the resources provided to them, use from manually operated reference card system to punch cards as well as computer system for the storage and retrieval of the technical literature. In order to be effective, they have to be a part of the national and international network.

Besides the technical literature, a researcher also requires to know what work is being done and who is doing it and where is he working. This information is required for avoiding duplication of research and for pooling the resources of manpower to speedily complete the work. In addition, in a problem requiring multidisciplinary approach, or in the translations of research results from laboratory level to the developmental level it is necessary to know the total number of experts available so that they can be brought together to complete the work. In any research system, even though there are many professional documentationists besides each worker doing his own reading and maintaining bibliographic cards, much of the information is obtained and utilised through personal discussions. This may be within a laboratory or outside. In the latter case, seminars and symposia play a vital role. In the former case every research institution appears to have "gate-keepers" who are store-house of information and to whom one goes, besides going to specialists in an area, for information which they are able to give or to suggest to the seeker as to where the information might be sought. The free and easy flow of information is only possible when the atmosphere of the laboratory is conducive to it.

Socio-economic Information

Any research project which is of applied nature requires socio-economic information besides technical information. The range of information in this area is indeed very wide; it covers information about raw materials, their availability and costs, about the existing technical processes, their efficiency and productivity, and about cost of products; in the case of new process it covers information on the capacity of the process to compete with the existing ones, readiness of industrialists to adopt the process, investment it would require, the design and engineering capacity available in the country to fabricate the equipment and machinery to put the process into operation. In the case of a product, additional information would be required, such as the possible behaviour in the market against established products and, in some cases, the health and environmental hazards that the product may have.

All the technical and socio-economic factors should be carefully examined while selecting a research problem because in the absence of information on these aspects it would not be possible to know whether such a problem has already been solved, or that developments in another field have rendered the approach adopted irrelevant. Similarly, lack of socio-economic data may show that the process is not workable though technically feasible.

Levels of Information

Information is required at three levels, viz. laboratory, agency and national. In some cases, it is required at international level also.

Looking at the problems of information at the laboratory, agency and the national levels for the purposes of deciding about the feasibility or otherwise of a research project to be undertaken it may be noticed that due to the difference in the decision each of the levels requires information suited to the purpose for which it is required. The concern at the laboratory level is the techno-economic feasibility of the project; at the agency level the problem is criteria of selection of projects on the basis of possibilities of their success, costs they would involve and the time they would take in relation to other projects received from other laboratories covering different fields of specialisation. In tackling the problems the agency has to have information about the capabilities available within a laboratory and within the constraints of the availability of resources. At the national level the nature of information is different, since it looks at major areas of thrust, competing demands of the agencies, and the investment required. These have to be correlated with national needs and demands, the overall position of the economy and the needs of different developments, for example, between agriculture and industry and within the industry, say, between coal and petroleum. It has also to take into account the regional differences and the need to develop them.

At the national level certain other dimensions become evident. This can be illustrated by one example — Manpower needs. Every developing country is faced with a shortage of manpower as well as unemployment of those who have been trained. To avoid such a situation the university system must know the possible areas of employment and the relative opportunities which may be available to the persons they train. Of course, universities will deny that their purpose is to produce for the market, but it is difficult to ignore the market phenomena. Any projections for the manpower requirement is subject to many uncertainties, since it takes time to train persons, and the situation may undergo a major change in the meantime. Consequently, it is very desirable to have the most uptodate information so that adequate projections can be made. Further, the information shall be over a period so that the trend can be worked out and projections corrected accordingly. This information need can be worked out at a national level.

Collection of Information

In any country there are a number of agencies which collect and publish the information. There is, however, a problem of comparability of information and often much of the exercise is rendered infructuous since the data in the same item from two different sources do not tally. Further, the information may often be available at a gross level, say, import of chemicals, but not on specific item on which the research project is to be mounted. In such cases the laboratory has to build the machinery for the collection of data. It may be found that a number of laboratories are engaged in the collection of techno-economic data in some detail, and in that case, a grid may be developed either to pool the data or a Central Referal System may be developed. In the latter case, instead of centralised storage of information, the Central Referal System can direct the enquirer as to where the information is. In India, at the moment, a national system of socio-technical information is being built up, called NISSAT (National Information System on Science and Technology) in which a particular national laboratory, like CFTRI, NAL, NCL, CDRI, CLRI, etc., becomes the base for the collection of information in the areas of food, aeronautics, chemicals, drugs, leather respectively and becomes a branch information centre of the national system.

The other factors which require consideration are the possible relevancy of data to be collected, time taken to collect the data, the method of storage and the speed with which it can be retrieved. Further, it requires to be stored in such a way that additional data can be added without difficulty.

The methods of storage are manual, based on cards, semiautomatic like punch cards and the automatic like computers. Depending upon the total units of information, and the resources available, these methods can serve a useful purpose by themselves or in combination. Each one of them has certain advantages and disadvantages. If efficiency of utilisation and costs are taken into consideration then the automatic may not be as useful as it is thought out to be. Further, the computerised system may also affect the question of criticality of information when being collected, its possible distortion in programming and hence in retrieval.

In this context, it may be stressed that information has become an industry and a very expensive one at that, with changing capacity and fast changing equipment brought out by numerous manufacturers. It is, therefore, necessary to be careful and not to get carried away by the propaganda of the manufacturers. With experience and criticality of judgement it is possible to use simple methods and machines with a high degree of efficiency and very good results.

Information Flow

The flow of information from the research worker to a laboratory, an agency, or an international organisation is vital for the development and utilisation of science and technology. However, it requires a machinery as well as adequate fitters to sift out what is not likely to be required at the next level.

Since all the information is not printed and easily available a suitable machinery which sifts out information from printed materials and documents and collects that information which is normally not printed, is necessary. Further, in order not to clog the channels of information and not to waste time and effort at different levels of information, sifting at different levels will be necessary to pass on only the relevant information to the next stage.

For any information flow for its effective utilisation, a two-way flow, from the research workers' level to national level and vice-versa, is necessary. One way traffic in the flow of information is, besides other reasons, not good even for developing adequate and comparable data.

Some Problems

It may not appear to be so, when one is dealing with limits of information, that every framework of information collection has a conceptual framework as well as elements of control. Consequently, it is desirable that the theoretical framework is thought out in detail.

The second problem in this area is also critical. How does one make qualitative judgements on the basis of quantitative data ?

How can services be built when demand is small, or how demand can be increased when services are limited, if not nonexistent, as is the case in the developing countries ? Further, how the services can be developed if the nature of demand is not spelt out ?

These and a number of other problems face the decision makers. Besides, there is also the pressure of international informational industry on the indigenous information system. In addition, in view of the capacities built up by the advanced countries, the necessary information is available to them on the basis of which they are able to control or direct the development of developing countries to their own advantage.

Conclusion

The only point which could be stressed in the context of what has been said is that INFORMATION IS POWER.

G. S. Sidhu

Creativity, Environment and Leadership

Let me begin by drawing your attention to the theme of this Seminar. It is "Management of R & D Institutions". A research institute does not function in a vacuum. It exists in a given external environment and the forces and pressures of this external environment provide it with opportunities and also act as constraints. The discussions in the Seminar so far have essentially been centred round the important external environmental factors. Let me now shift the emphasis to the central theme and move closer to the relatively more finite internal environment of a R & D institute, and its management.

Any institute has limited resources. The essence of good management lies in allocating these resources to make the best use of the opportunities offered by the external environment and in overcoming the constraints enjoined by it. R & D institutes in the countries represented here are, by and large, institutes set up by benevolent Governments with tasks well or ill-defined, or not defined at all. So the first duty of the institutes' management is to define its objectives consistent with any charter that it has received from the Government. These objectives may be centred around one or more of the following broad function types : Service, Research, Development, Design & Engineering.

Both the external and internal environment strongly influence this process of setting the institutional objectives. An institute has many formal and informal linkages with its external environment; these are (i) with its own headquarters which may be an apex organisation like the Council of Scientific and Industrial Research in India; (ii) with a user ministry, or (iii) with the top management of the industry to which the R & D institute is captive. The institute has also to react with various decision making bodies of the Government directly or through and on behalf of its headquarters. It must naturally have or strive to build strong linkages with the user/potential user industries. Linkages with other R & D institutions will also exist and are important.

The headquarter-institution linkage provides many opportunities and places several constraints; it provides an opportunity by way of providing financial resources and a constraint by directing how the money is to be spent. A good management at the headquarters will put only minimum constraints, that is, it will not permit the institute to hire staff from the money allocated for the purchase of equipment, but it will allow the institute to have its own method of financial control within the institute's annual budget. The headquarters can help/direct the institute to relate its research planning to the national economic/ technological plans. The headquarters are better suited for collection, storage, and dissemination of information on Government policies and directives, national needs, international relations, inter-agency collaboration, status reports on industry, etc.; it can maximise inter-laboratory coordination and impose constraints in dilution and duplication of efforts, but it should keep aloof from detailed planning and execution of R & D projects and the day-to-day administration of the institute.

The internal environment of the institute is determined by its organisational structure as reflected in its decision making processes. These decision making processes relate to personnel policies, finance and budgetary control, research planning, programming and evaluation.

I have deliberately put personnel policy first because it is perhaps the most important and yet the weakest link in the managerial network of many R & D institutes. In earlier discussions on R & D management, the question most often asked was : "Can R & D be planned and managed?" I will not answer it, because, except for a few diehards, no one asks this question now. It has, however, been supplanted by a much more pertinent and discerning question, viz., "Is the management of a R & D institute in any way different from that of any other organised activity? e.g., the activity of a sophisticated production organisation." The answer to this question essentially lies in the difference in the requirements of human resources in a R & D institute and those in a production organisation.

The techniques and tools of R & D management are basically not different from general precepts of management elsewhere and consist of organisation, direction and control, but it is the way in which direction is given and control exercised that sets R & D management apart. The major resource in R & D is not finance, or equipment and other facilities, but is the institute's human resource which, at one end of the spectrum, consists of scientists with a high level of training and specialisation and at the other end, semi-skilled house-keeping staff and in between, skilled staff, technicians, each belonging to a different subculture, and gives rise to many conflictive situations; a possible answer to this conflictive situation lies in (a) reducing supporting staff by changing over the methods of business administration, (b) separating activities like large pilot plants in order not to engage a large labour force, and (c) offering the same service conditions to all categories of staff. In the same institution you cannot have the Brahmins (the scientists) and non-Brahmins (other staff).

Let me outline some other conflictive situations. Conflict can be caused by the difference between the goals of the institution and those of individual scientists. Scientists often join well-equipped R & D institutes with high hopes of pursuing their own research ambitions and are disillusioned when confronted with a mission-oriented, institution's time-targeted, narrowly defined, project oriented goals.

In the case of new entrants, this conflictive situation can be avoided by explaining to them, at the time of selection, as to what the institute expects of them and what they can expect from the institute. The problem is more difficult in R & D institutes (1) which are changing over to mission-oriented research, or (2) being already devoted to mission-oriented research are changing over from divisional organisation to project organisation. This involves change from a hierarchical to a collegiate or participative management, and conflictive situations can arise mostly at the senior level of division heads who may feel that they are losing their academic freedom and hierarchical privileges. The solution may lie in an approach which should aim at involving the scientists concerned in the process of change from the discussion stage onwards. If the job of preparing the reorganisation report can be entrusted to some reputed external management consultants, the acceptance by the staff becomes easier.

In any good institute, there are bound to be a few people with a proven record or potential for open ended, long range research of a high calibre. When they are allowed more 'academic' freedom — this freedom is limited for others — conflict arises. Open discussion between the senior scientists can resolve this conflict, if it can be brought out that the development work, which is being done by other scientists, is of no less importance and perhaps is of greater importance and the credit and kudos of seeing one's work fructifying in an industrial project can be as rewarding as the reputation for first rate academic work. In such situations the management should guard against the tendency of some academically oriented scientists to assume the guardianship of this freedom and its misuse.

I have just mentioned collegiate management. How does it differ from conventional hierarchical management? Briefly, the former is an open system and the latter a closed system. In the collegiate management the decisions are arrived at by discussion and implemented in a cooperative manner; in hierarchical management decisions are taken at specified levels of authority and passed down for implementation. Therefore, the collegiate system, through its participative approach, engenders a high degree of commitment to institutional goals and trust in management; the ensuing team spirit generates many new ideas, and skill utilisation is maximised; more cooperation results in better achievement. May be this is an idealised picture, but it is worthwhile striving for and is attainable to a fair degree.

The topic allotted to me is Creativity, Environment and Leadership Development. I have dealt with Environment first, because creativity is partly a function of environment — or is it? Creativity is perhaps inborn but environment does help it to flourish. Let me concede that idea generation is not dependent on environment; if necessity is the mother of invention, adversity, rather than a comfortable environment, may help generate more new ideas. Coming to the microenvironment of a R & D institute, the person who has generated an idea may just keep it to himself for more than one reason — he may be low down in the hierarchy, be shy of communicating the idea for fear of ridicule, or may have no channel of communication. The same idea may, perhaps, occur to a senior scientist who may keep it to himself if he has become disinterested, cynical or apathetic — it is in such situations that a conducive environment fostered by a collegiate management helps in creative output.

To sum up, a creative environment promotes a feeling of belonging; in the members of the staff it fosters open communications; problems are thus ventilated, conflictive situations minimised and team spirit built up.

I feel hesitant to speak on this topic, viz. Leadership Development. I do not think there is any ready-made prescription for leadership development, just as there is none for R & D management — in fact more so. The Director's own management style can however contribute to leadership development. Is the Director a "Driver" or a "Persuader"? — if he is of the former type, the chances of leadership development in his institute are dim. Does he trust his younger colleagues with increasing responsibilities? Is he ready to write off an occasional mistake/wrong decision as the price of leadership development? or Having delegated responsibility does he continuously look over the shoulders of the young scientist with the nagging fear that he may go wrong? Does he feel that he has to attend all important external meetings personally? or Is he prepared to risk sending younger scientists to represent the institute? When taking an important visitor round the institute, does he let his scientists explain their work? or Does he regard this as the Director's duty or prerogative? To conclude, decentralisation and collegiate management are the prerequisites of leadership development, and if I were asked to define only one criterion for judging the success of an institute and its director, I would ask the director. "If you were to retire *today* how many of your colleagues are fit to succeed you immediately?" If he has not developed leadership of this quality he is a failure.

Some Basic Concepts of Technology Assessment

The growing consciousness of the peculiar nature of technical advance has led, over the last two decades, to a demand that some means of foreseeing the overall impacts of technology be developed. By "peculiar nature" I mean the unexpected, unanticipated, destructive consequences of technological change — pollution, resource depletion, and a widening of the economic gap between the developed and the developing countries. The effects may be said to be 'peculiar' because technology is commonly understood to be goal-oriented behaviour *par excellence.* This gap between goals and actual achievement takes the form, as Georges Gurvitch[1] points out, of "a striking disjunction between, on the one hand, social structures and their non-technical cultural works, and, on the other side, techniques. Unfettered technical knowledge escapes domination and control." Naturally various political groupings fear such loss of control and seek to guard against the potential threat that technical change offers. This has taken various forms depending on national socio-economic conditions and traditions and in this paper I can do no more than outline some of the basic principles and concepts of this movement.

Perhaps the simplest way of defining technology assessment (TA) is to present a number of definitional statements by three American spokesmen who, each in his own fashion, played an important role in seeing that technology assessment became institutionalised in the United States.[2]

According to Emilio Daddario[3] technology assessment supplies the need of "...identifying the potentials of applied research and technology and promoting ways and means to accomplish their transfer into practical use, and identifying the undesirable by-products and side-effects of such applied research and technology in advance of their crystallisation, and informing the public of their potential danger in order that appropriate steps may be taken to eliminate or minimise them."

Richard Carpenter of the U.S. Library of Congress argues[4] that :

"T.A. is the process of taking a purposeful look at the consequences of technological change. It includes the primary cost-benefit analysis of short-term localised market phase economics, but particularly goes beyond there to identify affected parties and unanticipated impacts in as broad and long-range fashion as is possible. It is neutral and objective, seeking to enrich the information for management decision. Technology assessment is a tool for the renewal of our basic decision-making institutions — the democratic political process and the free market economy."

Carpenter's explicit linking of TA with the political *status quo* is a significant attitude to which we will return later.

Joe Coates[5] enlarges upon the concern of Daddario and Carpenter with the secondary or tertiary impacts (Table 1)[6] of technology, seeing TA as "......the systematic study of the effects on society that may occur when a technology is introduced, extended or modified, with special emphasis on the impacts that are unintended, indirect and delayed.

...Should anticipate and evaluate the impacts of a new technology on all sectors of society...(but most so far) is a long history of partial assessments, generally limited to impacts on the economy, and more recently, the environment.

...emphasises the secondary or tertiary effects of new technology rather than the primary (intended) effects, because :

Table 1 — Mapping of Societal Consequences

Direct and indirect consequences of the automobile in USA

1st order	People have a means of travelling rapidly, easily, cheaply, and privately, door-to-door.
2nd order	People patronise stores at a greater distance from their homes. These are generally bigger stores that have large clienteles.
3rd order	Residents of a community do not meet so often and therefore do not know each other so well.
4th order	Strangers to each other, community members find it difficult to unite to deal with common problems. Individuals find themselves increasingly isolated and alienated from their neighbours.
5th order	Isolated from their neighbours, members of a family depend more on each other for satisfaction of most of their psychological needs.
6th order	When spouses are unable to meet psychological demands that each makes on the other, frustration occurs. This may lead to divorce.

(i) In the long run, the unintended and indirect effects may be the most significant, (ii) undesirable secondary consequences often are unnecessary and may be prevented by proper planning, (iii) first order impacts usually are subject to extensive study in the planning stage... (since they are)...the primary goal of the effort (and)...are generally explicitly planned for, and sorted out in the individual plan. Technology assessment focusses on the question of what *else* may happen when technology is introduced."

It can be seen from these quotations that proponents of TA have in mind something broader, more holistic in character than the multitude of institutional devices that have served for the last 100 years or more as 'controllers' of the impacts of technology, e.g. U.K. Alkali Inspectorate, anti-pollution and factory safety legislation, etc. These are seen to be relatively narrow in outlook and not sufficient for dealing with contemporary rates of technical change. They tend to be "disaster reacting"[7] rather than forward looking and preventative. I would argue that TA differs from traditional control mechanisms in that it seeks to be :

(a) forward looking, i.e. preventative

(b) holistic, attempting to perceive systematic relationships

(c) able to evaluate and compare alternative technologies and goals.

Doubtless, the majority of my listeners would not disagree with the aims of TA[8], for certainly technological change does, all too often, bring to light serious deficiences in our ability to plan effectively. Unfortunately, however, the best manner by which TA can be made is by no means universally agreed. There is no generally accepted method for determining whether the overall impact of a technology is beneficial or deleterious. The more optimistic practitioners believe that the widely recognised need for TA "will act as a trigger which begets a new form of social calculus for combining different forms of benefit and disbenefit into an objective function which allows decisions to be objectively assessed."[9]

Personally, I am not convinced that such a positivistic achievement is likely or even necessary. In any case the present polyglot methodology does provide information about the impacts of technology sufficient to allow existing societal methods of resolving controversies to get to grips with the implications of such impacts.

Some practitioners do, however, stress that despite their inability to provide combinatorial techniques which can adequately deal with costs and benefits..."verbal processes are considerably enhanced in their efficiency by the use of non-verbal technique. In other words the language of mathematics and other disciplines buttresses the assessment process when conventional language is insufficient to handle the multiple parameters in a typical TA."[10]

TA is essentially a multi- and inter-disciplinary team operation. It requires not only the requisite scientific and technological skills, but also sociologists, economists, political scientists and lawyers. Further, the team's leader should ideally, have an *inter*-disciplinary approach. For example, in their study on the British bread industry the Technology Assessment Consumerism Centre[11] had ten members whose backgrounds included nutritional science, biology, biochemistry, chemistry, systems analysis, marketing, law and engineering. Several members had also passed through the Liberal Studies in Science Post-graduate School and might be considered to have received an inter-disciplinary training in addition to their specialist degree.

We do not have time to exhaustively discuss and criticise the wide range of techniques that have been used in TAs; I would refer to the specialised literature in the field.[12] A typical TA methodology is the use of a check-list of steps and tasks which face the assessment team. The one I wish to bring to your attention was devised by the Mitre Corporation.[13]

This list has to be seen as a formal guide — a check-list — the steps of which are mostly followed in an iterative fashion and not necessarily in sequence, hopefully utilising all the analytic talents commanded by the assessment group.

Many aspects of the TA process will be familiar to those of you who have been concerned with R & D planning, cost-benefit analysis, operations research, research allocation, technological forecasting, etc. The wide range of techniques that have been utilised can be seen from the following list culled from an analysis of thirteen representative TAs by Medford.[14]

Computer input-output simulation models
Matrix techniques
Systems analysis
Standard statistical research
Modelling
Cost-benefit analysis
Multi-dimensional research
Extensive staff interaction
Trend projection
Behavioural science experiments
Content analysis
Citizen behavioural studies
Historical surveys
Multi-disciplinary research
Historical analogy
Group consensus
Survey review
Engineering analysis
Bayesian statistical mathematical models
Econometric models
Operations research
Problem-initiated policy analysis

Most TAs seek to incorporate some kind of cost-benefit element into their methodology.[15] This is, as I have already mentioned, a problematic element, for, we have yet to answer satisfactorily the question of "how to combine benefits and disbenefits for comparative trade-off purposes when some may be expressed in monetary terms and others in decrements or increments of personal and/or societal utility which are not expressible in monetary terms?"[16]

Gobor Strasser's[17] framework for TA (see Fig. 1) embodies such a cost-benefit analysis element. The diagram cannot show a time axis; obviously, we should not focus just on the present; we should include discounted future costs and benefits.

Such a framework has a certain didactic utility despite the above mentioned weaknesses. It serves to focus our attention on 'side effects', 'social costs',[18] and 'externalities' (see Table 2).[19] The identification of those costs of enterprises that are borne by third parties and/or the community as a whole (i.e. social costs) is an important task of technology assessment. I am sure in many cases even our present limited analytical tools would demonstrate clearly that many industrial products and processes are only profitable because the producers do not have to absorb all the costs themselves.

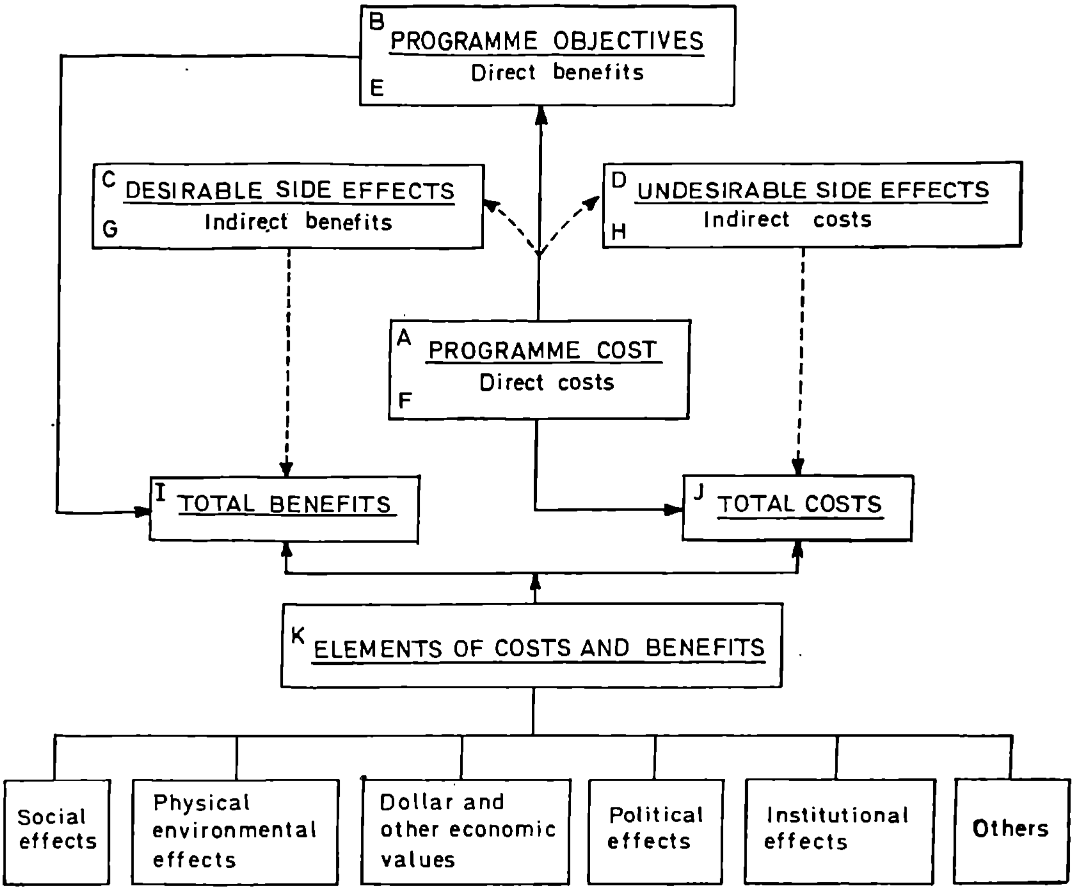


Fig. 1 — Framework for Technology Assessment

Such technology assessments pose something of a challenge as Strasser[20] sees it "to achieve an equitable balance amongst internal and external costs and benefits without causing unacceptable disruptions in our economic, social and political systems in the process."

The TA movement has been criticised in certain quarters on the grounds that it is part of an attempt to "deideologise" social science, and replace political struggle by "social engineering."[21] Certainly Carpenter's definition that I read out at the start of this talk, "TA... ......is neutral and objective.........a tool for the renewal of four basic decision-making institutions — the democratic political process and free market economy", seems to support such a view.

It is my belief that step 3 in the Mitre List (Table 3) of major steps in making technology assessment "Develop State-of-Society Assumptions" is of fundamental importance, yet it remains still at a primitive level of conceptualisation in the vast bulk of TA studies. There are several competing theories of social structure that might provide the basis for producing a more rigorous theoretical framework within

Table 2—Sample of Social Costs
(e.g. those arising from urban development)

INSULTS TO PHYSICAL ENVIRONMENT	
Air pollution	Relation urban, physical pathologics to public health
Water pollution	Problems of chemicals in food
Water shortage	Environment and cancer
Urban noise	Radiation, fall-out and human health
Urban congestion	Depletion and destruction of our resources
Highway & traffic problems	Depletion of energy resources
Improper physical design of cities	Soil erosion, soil depletion and deforestation
Urban population explosions	Wastes of all forms in urban life and their local expressions
Improperly designed environments in cities, factories, schools, farms	Idle and neglected physical resources currently needed
Relation of current agricultural practice to health	
INSULTS TO SOCIAL ENVIRONMENT	
Over centralised and uncoordinated public services.	
Impairments of the human factors in production.	
Improper displacements of human personnel by new developments in science and technology.	
Difficulties in finding employment for workers with limited skills.	
Idle but needed human resources.	
Disorganisation and poor health conditions in the work environment.	
Sources of the discontent and dissatisfaction expressed by students in the area.	
Mental ill-health in local area.	
Rise in the use of drugs and stimulants amongst youth.	
Political disorganisation in urban areas.	
Other types of social disorganisation in urban areas.	
The relationship of imbalances in the skill and educational requirements for employees, as community inputs, to welfare transfer payments as community outputs.	
Morbid social relations and social attitudes associated to some degree with contemporary urban society, e.g. crime, murder, robbery, rape, etc.	

Table 3 — Seven Major Steps in Making Technology Assessment

	DEFINE THE ASSESSMENT TASK
Step 1	Discuss relevant issues and any major problems. Establish scope (breadth and depth) of inquiry. Develop project ground rules.
	DESCRIBE RELEVANT TECHNOLOGIES
Step 2	Describe major technology being assessed. Describe other technologies supporting the major technology. Describe technologies competitive to the major and supporting technologies.
	DEVELOP STATE-OF-SOCIETY ASSUMPTIONS
Step 3	Identify and describe major non-technological factors influencing the application of the relevant technologies.
	IDENTIFY IMPACT AREAS
Step 4	Ascertain those societal characteristics that will be most influenced by the application of the assessed technology.
	MAKE PRELIMINARY IMPACT ANALYSIS
Step 5	Trace and integrate the process by which the assessed technology makes its societal influence felt.
	IDENTIFY POSSIBLE ACTION OPTIONS
Step 6	Develop and analyse various programmes for obtaining maximum public advantage from the assessed technologies.
	COMPLETE IMPACT ANALYSIS
Step 7	Analyse the degree to which each action option would alter the specific societal impacts of the assessed technology discussed in Step 5.

which to situate the question of a scientific analysis of the problems and consequences of technological innovation.

In an endeavour to overcome this weakness in TA conception I recently indicated[22] how the concepts of "mode of production" and "social formation" might be utilised.

The Concepts of Social Formation, Base (Economic Foundation) and Superstructure[23]

In his well-known Preface to "A Contribution to the Critique of Political Economy" Marx writes[24],

'...the guiding principle of my studies can be ummarised as follows. In the social production ›f their existence, men inevitably enter into de- inite relations, which are independent of their vill, namely relations of production appropriate o a given stage in the development of their ma- erial forces of production. The totality of these elations of production constitutes the economic tructure of society, the real foundation, on vhich arises a legal and political superstructure ınd to which correspond definite forms of social onsciousness. The mode of production of naterial life conditions the general process of ocial, political and intellectual life...".

I have attempted to summarise this concept n Fig. 2. This does not pretend to be more

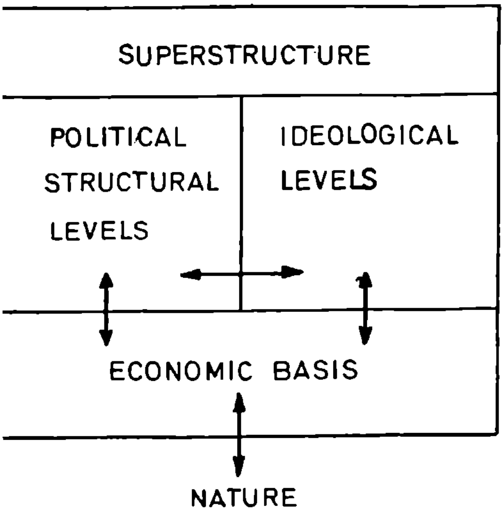


Fig. 2 — A Social Formation

han a pedagogic device, a simplified model of vhat is actually "... a complex structure of ocial relations, a unity of economic, ideologi- al, and, in certain cases, political structural evels in which the role of the economy is deter- ninant... Determinant in the sense that the onditions of existence of the dominant rela- ions of production assign to each of the levels certain form of effectivity and modes of ntervention with respect to the other levels".[25]

Thus, many of the peculiar features of the superstructure of the social formation in Brit- ain such as, for example, police, trade unions and 'work ethic', can only be understood from the standpoint of the social division of labour into the capitalist and non-capitalist workers.

Within the confines of a single paper, I am unable to present a historical analysis of this concept, and the vicissitudes of the vari- ous interpretations that have been formulated over the years.[26] I am, therefore, forced to confine myself to demonstrating that the con- cept enables us to deal more or less intelli- gently with the sort of problems that TA is concerned with.

If the practitioners of TA agree about any- thing it is that "Technology and public policy are inextricably intermeshed in our society".[27] Such a view is correct as far as it goes, but from the point of view of further analysis we cannot ignore such questions as: How and why such a situation arises, and what is the structure of the relationship, and how is it developing? It is just such questions that Marx and Engels' theories can help us to answer. We need to start from what they termed "the real pro- cess of production"[28]. This is to be found in "economic basis" (Fig. 2) and it is to a further breakdown of this 'basis' or 'mode of production' that I will now turn.

Modes of Production

Hindess and Hirst define a mode of produc- tion as an "articulated combination of *relations* (my emphasis) and *forces of production*"[29]:

(a) By social "*relations of production*" I mean the relationships that people form in the process of production, exchange and distri- bution of their material wealth. It is obvious that man cannot produce the necessities of life as an isolated individual but has somehow to unite and join with others. The basic nature of such relations vary according to whether the ownership of the *means of production* is com- munalistic or private. The relations of production can be communalistic in the sense of being based on collaboration and mutual help, or they can be private, based on domination and subjugation.

(b) The "*productive forces*" have a two-fold structure: (i) the means of production, and (ii) the human forces, people equipped with knowhow and experience to use these 'means' productively. Rosenthal and Yudin[30] to my mind, put their finger on the essence when they argue that "The productive forces express the attitude of men to the objects and forces of nature used for the production of material wealth."

(c) Here perhaps I should speak at greater length about the means of production. By *means of production* I am referring to: (i) Objects of production which are raw materials, things or elements of nature processed by production activities; (ii) instruments of production, means of labour whereby man is able to act productively on the above mentioned objects. Such 'instruments' range from primitive tools to complicated machines and apparatus; (iii) energy harnessed so as to facilitate productive activities; (iv) productive milieu or organisation, workshops, factories, etc.; and (v) finally science. The position of science in the 'basis' is controversial, for it is generally regarded as part of the superstructure. However, there seems little doubt that present day production is inconceivable without the rapid utilisation of scientific knowledge. That is what R & D is all about, bringing scientific method and understanding to the production process. For this reason many people have argued that science is becoming a *direct productive force* in society.[31] Thus science itself is changing and carries superstructure and basic features, and I would add in passing that this situation is placing science under great stress and strain[32] — it is a contradictory situation. It also raises the question of the current relationship between technology and science, how do the two differ, etc. Unfortunately, this cannot be done satisfactorily in a definitional/philosophical manner; it has to be tackled in a historical fashion on the basis of a study of the development of the productive forces within various modes of production.[33] However, since we are discussing technology assessment we ought at least to *briefly* examine the concept of technology and its relations to the various concepts under discussion.

Technology and Modes of Production

A typical definition of technology is given by the Mc-Graw Hill Encyclopedia of Science and Technology "...the systematic use of industrial processes, tools and techniques for the accomplishment of specific planned functions." This may appear similar to the productive forces concept but note how the human element is only implicitly referred to whereas the human element is an integral and explicit component of the productive forces concept. Thus what is generally referred to as technology in most discussions of technology assessment is subsumed in the means of production. I am not at all happy about this but for the moment we have to leave it there.

The essence of what I have said so far about modes of production is summarised in Fig. 3. This also indicates the chief *contradiction points* within the mode of production, and it is in consciously thinking about these that I believe we progress beyond the pragmatic "check everything you can think of approach" which permiates most TA.

Let me first explain my views on "contradiction points". I start first from the view that nothing is static and that everything is part of a process of change. Further that such change is not to be regarded mechanically, i.e. as though it occurs just because something external, from outside impinges or 'impacts' on to the subject. That this subject has also an inner source of change, of self-development. That this development may be contradictory, a result of opposed forces of development within the

SUPERSTRUCTURE
STATE
POLITICAL
IDEOLOGICAL LEVELS
*

A. SOCIAL RELATION OF PRODUCTION
*
B. PRODUCTIVE FORCES
(i) MAN (as a productive being)
*
(ii) MEANS OF PRODUCTION
(a) Objects of production
(b) Instruments of production
(c) Energy
(d) Production milieu
(e) Science?

* Major contradiction points

Fig. 3 — Elements of a Mode of Production

ubject. Let me give an example: the social elations of production. In Fig. 3 these appear s an *element* of the mode of production. Howver, this element, social relation of production, ; an abstract concept of a particular process ıvolving social classes, people in struggle and ɔllaboration within the economic base of ɔciety. It defines a specific mode of appropriaon of surplus labour and a corresponding ɔecific form of social distribution of means of roduction. So that, say, in a capitalistic mode production the capitalist class, defined by eir ownership and control of the means of oduction, is able to appropriate a certain nount of the surplus labour of the working ass, in turn defined by their ownership of pernal labour power but *non-ownership* of means production. In so far as these two classes ve divergent objective interests then their reionship is contradictory. At any given historical moment the exact structure and form of the relations of production depends on balance of class forces within it. It is this dialectic which provides the self-development element.

The particular states of the relations of production need to be taken into account in TA. Suppose we are considering, in a capitalistic mode of production, the potential impacts of a change from coal generated power to oil generated power, could this be done sensibly without a consideration of the balance of class forces? I think not. We would need to examine such questions as : Are the mine workers well organised? Do they see the move from coal to oil as a threat? Do they possess the means to oppose the change? and so on. In Fig. 3 the contradiction point between 'social relation of production' and 'productive forces' illustrates just such a situation. As a matter of fact this is the major contradiction, for there is a historical tendency for the forces of production to increase and come into conflict with the vested class interests of the social relations of production. Any technology assessment, say, of automation (a *logical* outcome of current technical and scientific trends within the forces of production), has to take this into account. With reference to this I would say that automation is impossible within the context of *private* relations of production.

TA and the Mode of Production

From Fig. 3 we can see the major 'contradiction points' and these ought to form an important part of any TA programme.

Suppose for example, we are going to assess a change in pest control technology, e.g. introduce a chemical control programme where previously only traditional cultural methods of control had been employed, we would need to consider the following steps :

(a) The effect on the various elements of means of production. This requires a detailed breakdown of the agricultural means of production and non-agricultural supporting elements. This is akin to the Mitre step — describe relevant technologies. However, it would also examine the particular milieu of production and the state of scientific knowledge. Examine the impact on and interrelations with the object of production, in this case crops and their agro-ecosystem and so forth.

(b) We would need to examine the implications of the change on the human factor in the productive forces. This involves several levels:

(i) A biological/health aspect, (ii) a technique/skill educational aspect, (iii) a cultural/alienation aspect — 'conditions of work', and (iv) economic/degree of exploitation and so on.

So far we have merely considered the potential implications for the productive forces.

(c) Would this change in pest control methods affect the social relations of production, e.g. could they increase the domination of the employing class over their employees, say, by reducing the required numbers of workers ?

(d) What impact would the new control chemicals have on the environment (natural world) ?

(e) To what extent are the new control methods and their potential impacts going to lead to superstructural changes? For example, changes in legislation, implications for national plans. Perhaps they have ideological implications? Remember how in the USA the sorts of environmental impact highlighted in Rachel Carson's *'Silent Spring'* led to the stimulation of conservationalist views.

I think I have said enough to indicate the kind of conceptual framework for TA, that is possible utilising the mode of production concept. What I have been arguing for is a restructuring (or rather a more explicit structuring) of our ideas regarding "the state of society assumptions" and "intermeshedness" of technology and public policy. I do not envisage any new analytic techniques, although my approach may call some into question, e.g. the scientificity of cost-benefit analysis within antagonistic/contradictory relations of production.

Social Formation and Modes of Production

As I indicated earlier, a social formation approximates to the traditional, but ideological concept of society; the structure of its economic level is not quite the same as "mode of production". Generally speaking social formations contain a predominant mode of production within their economic base, but they may also contain elements of other modes of production side by side. Such elements are economically subordinate but they may have important political and ideological implications within the superstructure. Thus one might find capitalistic and pre-capitalistic modes of production and even elements of a socialistic (state) mode co-existing. Such situations are particularly frequent in the developing countries. For this reason our TA framework cannot be built on the assumption that the mode of production is exactly equivalent to the social formation's economic base. We require a sophisticated overall analysis of the social formation of a particular country[34] within which to situate our TA. That is why it would be dangerous to transfer, for example, a TA of the green revolution technology made in the context of country X to country Y. If the structure of their social formations differed then what might have brought enhanced unity to country X could bring division and troubles to country Y.

Another point to be borne in mind is that social formation of any state is not static : that as Hindess and Hirst point out,[35] "the economic, political and ideological conditions of existence of the mode of production are secured, modified or transformed as a result of the outcomes of specific class struggles conducted under particular conditions of the economic, political and ideological levels of the social formation. That the particular *structure* of economic, political and ideological conditions in the social formation determines the possible outcomes of the class struggles conducted under such conditions". Such a structure is termed by Hindess and Hirst the *conjuncture*. Social formations move from one conjuncture to another (in everyday language it is analogous — although conceptually deeper — to major changes in the "political/economic climate"). Such movement is the outcome of class struggle, involving the modification or the transformation of existing social relations, and the specific outcomes of class struggles conducted under such conditions. Hindess and Hirst go on to argue that at certain conjunctures — which they term *"transitional conjunctures"*[36] (equivalent to 'revolutionary situations') — a possible outcome is "the transformation of the dominant relations of production", e.g. a change from capitalist to socialist relations. I mention all this in order to make clear that a rational scientific TA ought to be related to concrete analysis of the conjuncture, and the various societal transformations and displacements that are made possible by its structure. According to such a view there can be no *permanently* correct technology assessment. Thus a particular assessment of say Green Revolution technology could be negated by a certain conjunctural change.

Technology Assessment in Various Parts of the World

Unfortunately there is no time to describe the various forms that TA has taken in different countries. Perhaps the most comprehensive survey is to be found in *Technology Assessment in a Dynamic Environment* edited by Cetron and Bartocha.[37] This contains articles describing the situation in USA, Britain, USSR, Sweden, Israel, Japan, France, Germany and elsewhere in Europe. I have already outlined some of the major tendencies.[22] I would just point out that the United States still remains the chief centre of activity in this field and TA type activities have been institutionalised there under the National Environmental Policy Act[38] and the Office of Technology Assessment.[39]

All the evidence indicates that national and international institutional structures concerned with TA are beginning to emerge.[40] TA now has its own professional organisation — the International Society for Technology Assessment (ISTA), its own journal, *Technology Assessment* (with one or two others projected); it has been the subject of several major international conferences. TA is found to be practised by many organisations : governmental, international business organisations and universities. It seems to have gone beyond the stage of a fad. One notes, however, that less developed countries are conspicuous by their absence from TA studies. I am aware of the interest here in India — perhaps India will be the first developing nation to institutionalise her own TA capacity. The question of whether the UNO should have an Office of Technology Assessment (OTA) to encourage TA in developing countries is now being raised. In a special report to the UNO, Medford has argued that "... an unwelcome asymmetry is beginning to grow in TA, whereby it is becoming a subject predominately for the richer developed countries, it is time for the United Nations to consider taking a clearer role as the supporter of an explicit TA activity. The interest certainly exists in the developing countries but like the smaller developed countries they often feel that they have not got the depth of analytically skilled talent to spare on TA..." It seems that a strong case could be made either for a central UN technology assessment facility or better still, regional TA centres to furnish assessments for member-countries. Without such facilities being made available is there not a danger that backwardness in assessment of total impacts of technology will lead developing countries into situations in which they can be more easily exploited or manipulated by developed countries and multinational corporations?

Notes and References

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2. The technology assessment movement began in the United States in the mid 1960's, and the term 'technology assessment' was first used in a report

issued by the U.S. Congress Sub-committee on Science, Research and Development in 1966. Kiefer attributes the term to Philip Yeager, counsel to the committee.

3. Daddario, E. House of Representatives Bill, 1967.
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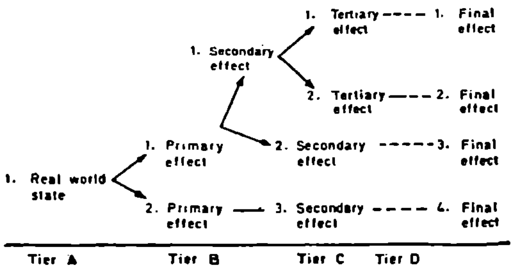
5. Coates, J. *The Futurist*, Dec. 1971, pp. 225-236.
6. Bereano *et al.* introduce the term "effects chain" which is a graphic display of all the effects flowing from a single starting point. The building of such chains is said to help the assessor "to comprehend the complex inter-relations stemming from indirect and multiple causality, (and) a means of suggesting causal relationships which were not originally perceived."



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16. Medford, op. cit.
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20. Strasser, op. cit.
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    "There are two basic respects in which policy-analytic methods in general are currently flawed and in need of refinement. The first is the tendency to reduce the various dimensions of a problem to terms that mis-state their underlying structure and ignore the structural features that give them their total character; the second is the almost universal tendency to focus on end results while largely ignoring questions of process", p. 625.
    A valuable critical discussion of technological determinism from a marxist view can be found in Zeorikine, A.A., 'Technical progress and society' in *The Evolution of Science*, Metraux, G.S. and Crouzet, F. (ed.). 1963, pp. 322-339.
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28. Marx, K. and Engels, F. *The German Ideology*, Lawrence and Wishart, London, 1965, p. 50. "This conception of history depends on our ability to expound the real process of production, starting out from the material production of life itself and to comprehend the form of intercourse connected with this and created by this mode of production (viz. civil society in its various stages), as the basis of all history; and to show it in its action as State, to explain all the different theoretical products and forms of consciousness, religion, philosophy, ethics, etc. etc., and trace their origins and growth from that basis; by which means, of course the whole thing can be depicted in its totality (and therefore, too, the reciprocal action of these various sides on one another)."
29. Hindess and Hirst, op. cit., p. 12.
30. Rosenthal, M. and Yudin, P. *A Dictionary of Philosophy*, Moscow, 1967, p. 363.
31. Marx's formula that science has become a direct force of production is found in his *Grundrisse : Foundations of the Critique of Political Economy* (Rough Draft), 1973, p. 706. "The development of fixed capital indicates to what degree general social knowledge has become a *direct force of production*, and what degree, hence, the conditions of the process of social life itself have come under the control of the general intellect and been transformed in accordance with it." *See also* Bernal, J. D. on "Science as a Productive force" in *Science in History*, 1969, p. 1248; "......science is becoming in recent times what techniques has always been, an indispensable part of the productive forces of society."
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34. Of course the analyst's task is not complete here, for the relation of a particular national formation to the international, socio-economic structures has to be studied — indeed in certain senses national social formations are products of the imperialist global economy which developed in the latter half of the 19th century, which situation is now complicated further by development of the socialist state economies, etc. Having said this it is by no means a simple task to say exactly how such analyses ought to be made, see for example, the UN document, "World Plan of Action for the Application of Science and Technology to Development."
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Harry Rothman

Development and the Demise of Naive Optimism about Technology Transfer

This article does not pretend to be an exhaustive or detailed statement about the state-of-the-art of technology transfer (hereafter TT). Its aim is to stimulate discussion and study of problems of TT and technology assessment (detailed notes on this are provided separately, Rothman, 1976).

Definitions of Technology Transfer

"Technology transfer is the process by which science and technology are diffused throughout human activity. Wherever systematic rational knowledge developed by one group or institution is embodied in a way of doing things by other institutions or groups we have transfer. This can be either transfer from more basic scientific knowledge into technology, or adaptation of an existing technology to new use. Technology transfer differs from ordinary scientific information transfer in the fact that to be really transferred it must be embodied in an actual operation of some kind." (Brooks)

"The transfer of technology must then mean the utilization of our existing technique in an instance where it has not previously been used." (Gruber and Marquis).

"When scientific or technological information generated and/or used in one context is re-evaluated and/or implemented in a different context, the process is called technology transfer" (Bar-Zakay in Davidson *et al.*)

"Technology transfer can be viewed as the generalized process of information transfer between science, technology and actual utilization."

"Technology transfer may be defined as the process by which a technology is applied to a purpose other than the one for which it was originally intended." (Doscher in Davidson *et al.*)

"Technology transfer is the process by which science and technology developed by one group or organisation for its specific purpose becomes adopted or adapted and applied by another group or organisation often, but not necessarily, for different purposes." (Welles in Davidson *et al.*)

"Technology transfer is a matter of either the unplanned percolation, or the planned transmission, of ideas, technical routines, or information from research (scientific and technological) to manufacturing industry and so into commercial exploitation and eventual use." (Burns)

Technology transfer "...is many things to many people but some of the less complicated definitions are: the multilateral flow of information and techniques across the boundaries of the sciences, technology and the practical world; transferring research results to operations; accelerating the application of research and exploratory development results to industrial application; science and technology transfer to the would be user at the earliest practicable date and in a language he can understand; the process of matching solutions in the form of existing science and engineering knowledge to problems in commerce or public programs... getting knowledge out of the academic area and into the hands of those who apply it". (Cetron in Davidson *et al.*)

All these definitions implicitly contain the view of the social neutrality of knowledge, an ideological and philosophically idealist position since they make no specific reference to the socio-economic structures and relations within which the processes they purport to define take place. Vaitsos's views might be discussed in this connection.

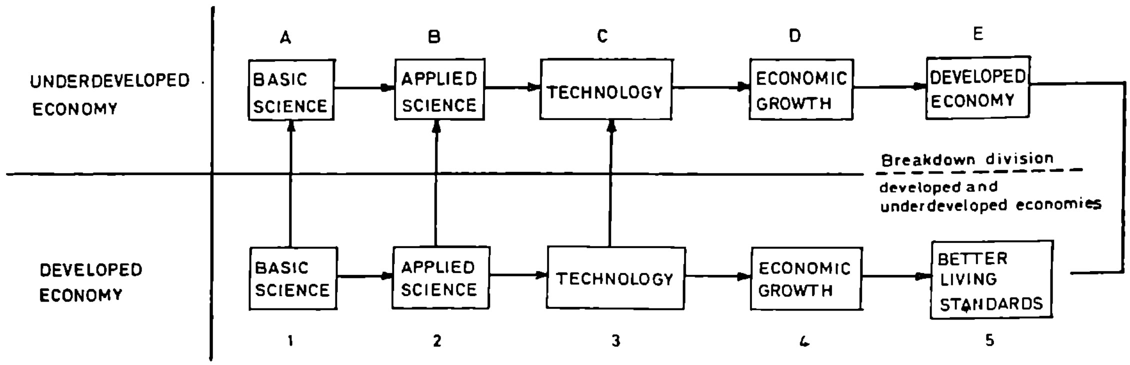

Fig. 1 — A Naive Optimistic Model of Science, Technology and Development

"The literature that evaluates issues related to the process of know-how importation by developing countries generally identifies the subject under the heading of 'technology transfer'. Terminology, although an inadequate index, is often illuminating to the extent that the concepts it represents have been adequately analysed and understood. The term 'transfer' indicates here the existence of a very limited comprehension of the market for technology. In commercial or economic terms we do not talk about the 'transfer' of copper or cotton, or television sets. We refer instead to the sale (or purchase) of these commodities. Similarly, in the case of factors of production, meaningful analysis has been undertaken by distinguishing and evaluating the characteristics of foreign direct investment, portfolio investments, international indebtedness, worker migration, the brain drain, etc. The term 'transfer' could represent a rather loose usage of the word; or it could be an indication of insufficient knowledge of the phenomena involved; or it could even fall within what Myrdal called 'diplomacy by terminology'..... we thus prefer the term *technology commercialisation.....*"

Recent Reviews

An idea of the sorts of research being done under the name of technology transfer (TT) can be gathered from the works of Gruber and Marquis (1969), Cooper (1973), Davidson *et al.* (1974), and Bradbury *et al.* (1976).

The Naive Optimistic Model of Science, Technology and Development

This view, prevalent in the early 1960s, is illustrated in Fig. 1. Essentially it combines a linear model of technological innovation with certain assumptions about the nature of underdevelopment and technology transfer. Research and experience have drastically modified this model, showing it to be wrong in many respects. An analysis of the various elements and relationships of the model will serve to highlight, as a basis for discussion, contemporary concepts and problems of TT.

Technological Innovation Process

In our model (Fig. 1) the steps (1) Basic Science→(2) Applied Science→(3) Technology illustrate the linear model of innovation much favoured by scientists who tended to assume a *science-push* model (Blackett). Economists, on the other hand, if they considered technology at all, often favoured a *demand-pull* model.

Current research (Langrish *et al.*, SPRU) shows that innovation is best regarded as "essentially a *coupling activity*, linking together some kind of need with some kind of technical possibility. On the one hand, it involves recognition of a potential market for a new product or process, on the other, it involves technical knowledge". (Macioti)

The chief role of basic science is said to be "a *supportive* one, that is not in producing the initial idea for innovation but in assisting the process by which an idea is converted into a marketable product or process". (Johnston)

Much research is thus concerned with ways in which centres of basic science (in UK — the universities) can cooperate with industry so as to enhance this function. These are summarised in Table 1.

In the Soviet Union and the socialist countries a somewhat different hypothesis of the relationship between science and industry predominates. Termed the *scientific and techno-*

Table 1 — Ways of Collaboration Between Universities and Industry*

1. PERSONNEL ASSISTANCE FROM INDUSTRY WITH UNIVERSITY ACTIVITIES

Lectures by industrialists at universities
Industrialists serving on university and faculty committees etc.
Industrial advice on, and provision of problems for, research
University staff and students visiting industry
Industrial advice on curricula
Use of industrial laboratories for higher degree work
Secondment of industrial staff to work at universities
Technical advice or assistance
Use of equipment or facilities in industry
Instrument development

2. USE OF UNIVERSITY STAFF AND FACILITIES

Industry using more consultants
Industry sponsoring research at universities
Provisions of special advisory or consultancy services
Secondment of university staff to work in industry
Refresher or retraining courses
Industry sponsoring students and also providing suitable training
An increase in multidisciplinary projects
Use of facilities or equipment at universities by industry

3. JOINT ACTIVITIES

Joint research programme with work at university and in industry
Interchange of staff
Joint supervision of students
Local 'science-based' industry developing from university departments
Joint meetings or colloquia
Joint appointments

4. POSITIVE ROLE OF 'THIRD PARTIES'

Industrial Liaison Centres run by universities
Science Research Council Schemes for improving contacts :
(a) Co-operative Awards in Pure Science (CAPS)
(b) Industrial studentships and fellowships
(c) Awards for science, industry and school teaching (ASSIST)
(d) 'Instant' awards (grants to students with industrial experience)
(e) Graduate schools
(f) Support for collaborative research grants
Research Associations translate research into technology for smaller firms and feedback to universities
Ministry of Technology Industrial Units
University Grants Committee 'pump-priming' support for schemes of assistance to industry
Professional institutions encourage joint activities and influence curricula by professional requirements
Min. Tech. industrial liaison officers encourage university-industry links

5. FINANCIAL (OR SIMILAR) SUPPORT FROM INDUSTRY FOR UNIVERSITY ACTIVITIES

Grants for research without a fixed timescale or agreed programme
Grants for studentships, fellowships, etc.
Loans or gifts of equipment
Endowment of a chair or university post

*Based on U.K.'s experience.
C.B.I., "Scientific Research in British Universities" — submission to the Science Sub-Committee of the Parliamentary Select Committee on Science and Technology, Nov. 5, 1975.

Table 2 — Characteristic Barriers to Innovation *

(Universities, Research Institutes, Industrial R&D Laboratories)

1. LABORATORY BARRIERS
 - Conflicting motivations on the part of professional personnel
 - Inadequate communications with the user community (state and local governments)
 - Lack of initiative in approaching industry
 - Limited money (in particular, the relative lack of developer/producer funding)

2. DEVELOPER/PRODUCER BARRIERS
 - Informational
   - Lack of university advisory participation
   - Lack of R&D synthesis
 - Technological
   - Appropriate reliability
   - Technology turnover rate
 - Legal
   - Patent
   - Anti-trust
   - Non-standard purchase conditions
 - Managerial
   - Lack of familiarity with market
   - Personnel retraining
   - Established competition
   - Pricing considerations
 - Institutional
   - Nature of firm-size, stability, outlook, existing distribution channels, R & D orientation, organisational structure
   - Competition with existing customers
 - Financial
   - Accounting considerations
   - Need for venture and investment capital
   - Basis for investment decision

3. MARKETING/DISTRIBUTION CHANNEL BARRIERS
 - Disaggregation of market
 - Lack of product definition
 - Lack of test markets
 - Lack of standard specifications
 - Lack of product acceptance testing procedures
 - Cost of sales
 - Inadequate distribution channels
 - Occasional requirement for leasing capability
 - Lack of needed and related product lines
 - Product life cycle

4. STATE GOVERNMENT USER BARRIERS
 - Informational
   - Flood of information which is uninterpreted and not user oriented
   - Dissemination of information is irregular and unsystematic
   - Sources of technology in many cases are unknown (technology disaggregation)
 - Institutional
   - State agencies are fragmented
   - Budget and planning procedure
 - Political
   - Conflict between short and long range objectives
   - Intergovernmental restraint
 - Climate
   - 2nd and 3rd order consequences
 - Economic
   - Cost of technology
   - Labour intensity
   - Resource allocation
   - Pricing practices of developer/producer
 - Legal
   - Federal grant-in-aid process freezes technology
   - Local codes inhibit statewide programmes
   - No State checkoff on R & D
 - Technological
   - Lack of inhouse technology and systems analysis capability
   - No R & D effort *per se*
   - Lack of operational performance criteria
   - Lack of trained operating personnel
   - Lack of technology assessment and forecasting capability
   - Lack of product acceptance testing capability

5. STATE BARRIERS TO LOCAL GOVERNMENTS
 - Constitutional
   - Lack of Home Rule authority
   - Appointment of some local officials by the State
   - Police powers reside with the State
 - Legislative
   - State governs taxing authority
   - State governs bonding authority
   - Certain legislative and policy making powers are withheld by the State
 - Administrative
   - Regional cooperation must be approved by State legislature

Contd.

Table 2 — Contd.

Policy and programme standards are set at the State level (health, police, education, sanitation, etc.)
Some personnel qualifications are set by the State
Grants-in-aid
Shared revenue

6. LOCAL USER BLOCKAGES

Informational
- Limited science and technology information available
- Information available is often not user oriented
- Information dissemination is irregular and unsystematic

Institutional
- Compacts
- Non-innovative climate
- Geographical dispersion

Political
- Conflict between short and long range objectives
- Intergovernmental restraint
- Political climate
- 2nd and 3rd order consequences
- Marketing practices of developer/producer
- Review process for Federal funds

Economic
- Cost of technology
- Labour intensity
- Resource allocation
- Pricing practices of developer/producers

Legal
- Ordinances
- Codes
- Enforcement
- Decentralised control
- Regulation
- Review process for Federal funds

Technological
- Lack of inhouse technology and systems analysis capability
- No R & D effort *per se*
- Lack of operational performance criteria
- Lack of trained operating personnel
- Lack of technology assessment and forecasting capability
- Lack of product acceptance testing capability

7. PUBLIC BARRIERS
- Lack of recognition of opportunities for innovation
- Inadequate understanding of technological benefits and/or consequences
- Political impact of public positions

Federal Government Barriers
- R & D priority setting
- Inadequate information dissemination
- Grant-in-aid process

8. CHARACTERISTIC STIMULI FOR INNOVATION

Behavioural
- Crises (local, regional, national, or international)
- Focus and articulation of needs provided by media
- Perceived attitude of electorate
- Entreprenurial efforts (in research, development, industry, or other)
- Moral convictions of governmental leadership
- Pressures from special interest groups
- Desire for specific improvements by citizens
- Desire for change from existing patterns and trends
- Image enhancement efforts by industry
- Desire for personal recognition

Economic
- Profit motive
- Availability of venture capital for new enterprises
- Availability of excess capital in established firms
- Competition
- Stimulation resulting from loss of share of market
- Tax-assisted investment opportunity
- Unique combinations of resources (mergers, acquisitions, contract spin-off opportunities, special contract provisions, etc.)
- Existence of available pools of specialised talents
- Technological opportunity
- Technological obsolescence
- Need for job satisfaction and work-force stability

Legal
- Statutory and/or regulatory constraints
- Legal/economic framework (tax structure, accounting techniques, etc.)

* Cetron, M. J., "Technology Transfer : Where we stand Today" in *Technology Transfer* by Davidson *et al.* (Noordhoff, London), 1974.

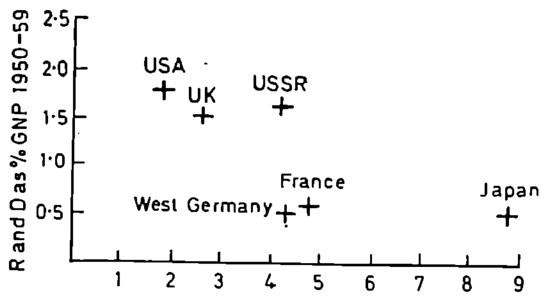

Fig. 2 — Correlation between R & D Expenditure and National Growth Rate

logical revolution it argues that science has now become "an immediate force of production" (Fig. 2) (Rothman 1976, pp. 38-40; Richta).

Technological Innovation and Economic Growth

In our model (Fig. 1) the steps (3) Technology→(4) Economic Growth, lead to the assumption that the more a country spends on R & D the more economic growth it can generate.

Technological innovation can be a spur to economic growth but their relationship is complex (Schmookler; Freeman). For example, the correlation between R & D expenditure and national growth rates is not strong (Fig. 2) ".....in this area it is extremely difficult to distinguish cause and effect; is it innovation which causes growth, or growth which causes innovation?" (Hill and Samuel & Co.)

There has been much research to identify barriers and stimuli to the innovation process. Their findings have been summarised by Cetron (Table 2).

Economic Growth and the "Quality of Life"

Step(4) Economic Growth→(5) Better Living Standards, i.e. it improves that mysterious phenomenon, the 'quality of life'. In the developed countries the opinion that with economic growth life necessarily gets better is regarded as naive on several counts.

There exists a philosophical-sociological school who regards technology as inherently *oppressive*. One stand believes the machine will control man. In the past "technique belonged to a civilization and was merely a single element among a host of non-technical activities... (Whereas) today technique has taken over the whole of civilization" (Ellul).

The Frankfurt School of social philosophers (Marcuse; Habermas) argue that liberal political practice is being replaced by a *technocratic strategy* based on *instrumental reason* which integrally relates politics and science as a means for obtaining more efficient control by ruling elites (Schroyer; Gorz). Thus, they argue that advances in technology are leading to reductions, not increases, in human freedom (Reich; Roszak).

Other stands are: *Environmentalist Movement* concerned at the growing environmental impact of technological change (Carson; Commoner; Rothman 1972; Ecologist); *Consumerist Movement* concerned at the reduction in quality of many products and services and the manner in which change is foisted upon the public by industry (Packard; Nader).

Such concerns have prepared the ground for the rise of the TA movement: the passing of the National Environmental Policy Act (NEPA 1969), with its demand for *environmental impact statements* for major federal technology projects, and the establishment of the Office of Technology Assessment (OTA 1973). This is discussed elsewhere (Rothman 1976).

At a more utopian level we note the emergence of the *Alternative Technology* movement (Dickson) which postulates and seeks an alternative — different way of life which is able to develop and survive with less damaging technologies. In this context Robin Clark of Biotechnic Research and Development (BRAD) distinguishes between a *hard* technology society (contemporary industrial society) and a *soft* technology society (Table 3).

The Hudson Institute stands out against such critics who are considered "modern Lud-

Table 3 — Some Utopian Characteristics of Soft Technology

	'Hard' technology society	*'Soft' technology society*
1	ecologically unsound	ecologically sound
2	large energy input	small energy input
3	high pollution rate	low or no pollution rate
4	non-reversible use of materials and energy sources	reversible materials and energy sources only
5	functional for limited time only	functional for all time
6	mass production	craft industry
7	high specialisation	low specialisation
8	nuclear family	communal units
9	city emphasis	village emphasis
10	alienation from nature	integration with nature
11	consensus politics	democratic politics
12	technical boundaries set by wealth	technical boundaries set by nature
13	world-wide trade	local bartering
14	destructive of local culture	compatible with local culture
15	technology liable to misuse	safeguards against misuse
16	highly destructive to other species	dependent on well-being of other species
17	innovation regulated by profit and war	innovation regulated by need
18	growth-oriented economy	steady-state economy
19	capital intensive	labour intensive
20	alienates young and old	integrates young and old
21	general efficiency increases with size	general efficiency increases with smallness
22	centralist	decentralist
23	operating modes too complicated for general comprehension	operating modes understandable by all
24	technological accidents frequent and serious	technological accidents few and unimportant
25	singular solutions to technical and social problems	diverse solutions to technical and social problems
26	agricultural emphasis on mono-culture	agricultural emphasis on diversity
27	quantity criteria highly valued	quality criteria highly valued
28	food production specialised industry	food production shared by all
29	work undertaken primarily for income	work undertaken primarily for satisfaction
30	small units totally dependent on others	small units self-sufficient
31	science and technology alienated from culture	science and technology integrated with culture
32	science and technology performed by specialist elites	science and technology performed by all
33	strong work/leisure distinction	weak or non-existent work/leisure distinction
34	high unemployment	(concept not valid)
35	technical goals valid for only a small proportion of the globe for a finite time	technical goals valid 'for all men for all time'

dities" and present glowing world futures of an "Americanisation of the whole world" (Kahn and Bruce-Briggs).

Development and Underdevelopment

According to this model (Fig. 1) the underdeveloped economy is a proto stage, or retarded stage, of the developed economy; the technical innovation—economic growth process steps (A $\rightarrow$ D) are essentially the same as steps (1 $\rightarrow$ 4) in the developed economy and, further, if they could be sufficiently stimulated the underdeveloped economy could "take-off" and grow into a developed economy. It is a simplistic version of the "theories of stages of growth" school (Rostow; Aron).

Other schools of economic thought reject such a view claiming that underdevelopment is a historically unique form of economic organisation. Marxists argue that "it is capitalism, both world and national, which produced underdevelopment in the past and which still generates underdevelopment in the present" (Frank; also Szentes). Support for this view also comes from non-Marxist theoreticians (Prebisch; Myrdal).

Technology Transfer from Developed to Developing Economies

Technological innovation and economic growth according to the model in Fig. 1 can be stimulated by a series of transfers of scientific knowledge and technical knowhow $1 \rightarrow A$, $2 \rightarrow B$ and $3 \rightarrow C$. Sufficient stimulation will enable the economy to become "developed". This in practice does not occur and these transfer processes have been accused of maintaining and generating underdevelopment in certain circumstances.

Science in Developing Countries

The model assumes that the social function of science in developing countries is the same as that in developed countries. Such a view is increasingly questioned and theories of the *marginalisation of science* and *technological dependence* are counterposed (Herrera). Cooper's summary of these arguments is reproduced below (Cooper).

"(i) The Latin American countries have experienced import-substituting industrialization. The process of industrialization has been heavily influenced by the fact that income distribution is skewed in favour of the urban middle and upper classes, who therefore dominate consumer goods markets. Generally speaking, the elite consumers demand the same kinds of goods as consumers in the industrialized countries. The technologies required to manufacture these goods are in existence already and many of them are owned by enterprises in the industrialized countries. The new enterprises which have grown up in Latin America have, naturally enough, made use of these technologies. Sometimes the new enterprises were set up through direct investment by the technology owners, but even when they are independent of foreign capital, they frequently purchase foreign technology through licence agreements or other contractual methods. Consequently, foreign technology has tended to be a substitute for technologies that might have been developed by local scientific research and development. Even in those rare cases where local laboratories have successfully developed the types of technology which local enterprises might want, there is a strong tendency to use a foreign version of the technology instead — usually on the grounds that it is more likely to work. This is one reason why the local scientific system is cut off from production. The argument is often extended so as to explain why engineering is both underdeveloped and underutilised in many countries.

(ii) Similar arguments apply to other types of industrial sectors, such as those producing inputs for agriculture, or the capital goods sector itself.

(iii) Finally, those large parts of the economy where the remnants of pre-capitalist organization persist (for example, subsistence agriculture and rural craft industries), generate very little demand for local scientific inputs. Part of the reason is that these sectors are simply not organised in a way which is favourable to technological advance; the other part (it is argued) is that the economy as a whole works so that these sectors are deprived of resources, particularly investible resources, which go preferentially to the 'modern' sectors owned by the middle class industrialists in the cities.

The result is that the scientific institutions are alienated from production activities or 'marginalized' because there is no demand for locally developed technologies from the productive sectors. Consequently science in underdeveloped countries is largely a *consumption* item whereas in industrialized countries it is an investment item. Furthermore, the lack of pressures on science from the local economy means that the main determinants of research orientation are the individual decisions of research workers; and these research workers take their lead from the international orientations of research. The scientific communities in the underdeveloped countries are outposts of advanced country science, with very limited

Table 4 — External Public Debt Outstanding of the Developing Countries and Cumulative Inputed Capital Value of Skilled Migration to Selected Developed Countries as at end of 1972*

Region of origin	External public debt outstanding (end 1972)	Cumulative inputed capital value of skilled migration (to end 1972)[1]	Col. (1) less Col. (2)	Col. (2) as per cent of Col. (1)
	(1)	(2)	(3)	(4)
		US $ million		
Africa	16,248	3,089	13,159	19
Asia	43,244	33,108	10,136	77
Western Hemisphere[2]	29,576	8,545	21,031	29
Total	89,068	44,742[3]	44,326	50

*International Bank for Reconstruction and Development, *Annual Report*, 1974, Statistical Annex., p. 83, table 4A; and chapter II, appendix Table 16.

[1] Accumulated annual figures for gross flows to the United States (from 1961), Canada (from 1963), and the United Kingdom (from 1964).

[2] Includes Latin America and the West Indies.

[3] Does not include value of migration from "other developing" regions.

links with the economic and social realities which surround them. There is no conspiracy or individual bad faith about this : it is simply the way the system works."

One aspect of the "frustration of science" in developing countries is the brain-drain of qualified scientists and engineers (QSEs) from the underdeveloped countries to the developed. This is contrary to our model's assumption and can be regarded as a "reverse transfer of technology" (UNCTAD 1975). This is the subject of much critical examination.

A considerable amount of the aid provided by developed countries is "wiped-out" by this unacknowledged aid from the developing to the developed countries. This is clearly shown in Table 4.

The question of controlling the brain drain is raised. Suggestions include : (a) Improving conditions in home countries — what would this entail? (b) Banning the emmigration of QSEs — A "Berlin Wall"? (c) A migration tax to be levied by developing countries.

Another question to be examined is : if and when QSEs return to their home country to what extent are they able to bring back — transfer — knowledge and experience appropriate to the local needs?

Transferring Technology

Marginalisation of science can prevent the link A/B→C operating. Does this really matter if we can transfer technology from developed countries, i.e. link 3→B? Experience shows that because of the technological dependence problem this transfer often fails to bring the benefits hoped for.

Research into the causes of such failures has concentrated on four areas : (a) Transfer "channels" and their functioning; (b) technical base; (c) the effects of multinational corporations; and (d) "Inappropriate" technological transfers.

Transfer Channels and their Functioning

There are many channels by which technology transfer takes place between a developed and a developing country (3→C) (Table 5). People are the most effective and efficient transfer channels in the long term — so called

Table 5 — Channels of Technology Transfer*

1. Multinational corporations, internal personnel transfer or the acquisition of a foreign subsidiary.
2. Foreign student exchange programme.
3. Foreign aid programmes (economic).
4. Foreign aid programs (military).
5. Selling end items (with maintenance manuals, blueprints, etc.).
6. Industrial shows, exhibits and trade fairs.
7. Selling components (avionics packages, propulsion plants, etc.).
8. Technical meetings.
9. Patents.
10. Open literature.
11. Production licensing.
12. Immigration/emigration (the brain drain and reverse).
13. Technical literature.

*Cetron in Davidson.

"transfer-on-the-hoof". "Transfer is a process of agents, not agencies; of the movement of people among establishments, rather than the routing of information through communication systems". (Burns)

The factors which affect the nature, rate and direction of technology transfer are ennumerated by Cetron (1974) as: "1. National policies, laws and regulations: (a) Taxes and tax credits, (b) Tariffs, (c) Non-tariff barriers, (d) Standard requirements, (e) Immigration, and (f) Trade union restrictions. 2. Corporate policies. 3. Market demand. 4. Scientific 'base' of the nation or industry. 5. Chance. 6. Level of R & D effort. 7. Education. 8. Gatekeepers. 9. Availability of translations. 10. Individual personalities and roles. 11. Availability of venture capital."

You might care to rank these in order of importance on the basis of your own experiences.

Appropriate Technical Base

Technology transfer is not simply transfer of *information*; it requires also a receptive environment, i.e. if an appropriate industrial technical-scientific infrastructure does not exist, transfer fails. Prerequisites of such a base are:

(i) QSEs and an education geared to producing them and (ii) an ability to train management and operating personnel who will be able to adjust, run and maintain the new technology.

The Japanese have also been most successful with respect to providing adequate technical base for transfer. Japan remains a unique example of a capitalistic economy overcoming technological dependence by policies "designed to create a complementary relationship between the important foreign technologies and skills, and 'learning-by-doing' by local technologists" (Cooper). To what extent are Japan's experiences applicable to developing countries?

The distribution of QSEs between the various sections of industry within a country is important. Are there optimum distributions to be sought? In UK, for example, 85% of government R & D is concentrated in a limited number of 'high technology' areas but this practice has contributed "only slightly" via industrial production to the GNP (Pavitt).

The scope of the technical base varies from industry to industry and between companies. A recent report (Johnston) classifies companies into 3 kinds:

(a) Companies which are aware of a need to extend their resources and have the capability of doing it.

(b) Companies which may wish to extend their resources but do not know how to achieve this.

(c) Companies which have no awareness of the possibilities of, or interest in, extending their resources beyond available inhouse.

Companies in the category (a) are best able to transfer knowledge into their organisations; they can formulate their needs and identify appropriate information sources and innovatively adopt new technology into their organisation.

Companies in the category (c) generally characterised by very few QSEs are unable to see the necessity for changes.

Research associations and technical advisory services are seen as means to improve such weaknesses. Such services need to be active and entrepreneurial — seeking out and establishing links with firms and not being content for firms, particularly category C, to come to them. UK's experience with research associations shows that it is ironically, category A — the firms already possessing the most advanced technological base — which are able to make the most use of such facilities (Johnston).

Licensing Agreements, Multinational Corporations (MNCs) and TT

These are two of the most important channels. Particularly since one of the consequences of technological dependence is negative balance of payments. The manner in which one views the results produced via these channels depends on one's economic and political situation.

The applicability of product cycle theory to the technology transfer process between developed and developing economies has been heavily criticised (Cooper). In practice technology transfer can often be seen to be a "commercialization of technology" whereby MNCs seek quasi-monopolistic advantages in developing countries, where they are often able to obtain relatively high rates of return compared to the costs of making their technology available.

The means used by MNCs to maintain control in their relations with developing countries have been scrutinised (Langdon); they include : restrictions on production via marketing and export agreements; maintenance of control from abroad, often by manning key posts by their own nationals; bribery; "clever" accountancy in which profits are hidden as "costs".

The costs of such activities to developing countries can be high (Table 6). The bargaining position of MNCs is often stronger than that of the recipient. There is growing interest in means to increase the bargaining power of the latter. Suggested means (OECD) include :

(i) Increased information on the costing and accounting of technology transfer; (ii) information on alternative sources of technology; (iii) increased cooperation between developing countries themselves; (iv) strong administrative controls over transfer deals, e.g. controlled industrial strategies and nationalisation which is very much dependent on political and economic interests of ruling class; and (v) international codes of business conduct for TT. What should such a code contain and under what conditions would it be effective?

An alternative opinion is provided by an American study, "there is no question that the multinational corporations have exerted a powerful influence within the countries where they operate for upgrading the quality ofmana-

Table 6 — Types of Costs Incurred by Developing Countries for the Transfer of Technology*

(i) For the right to use patents, licences, knowhow and trade marks ;
(ii) for technical knowledge and knowhow at the pre-investment and operational stages;
(iii) for price increases in intra-company sales;
(iv) for profits capitalised in the acquisition of shares in 'receiving' company;
(v) for some part of the profit of fully foreign-owned subsidiaries which have no special provisions to pay for technology transfers from the price;
(vi) for overpricing of capital goods and equipment;
(vii) continued import of spare parts (maintenance of imports);
(viii) import of raw materials and intermediates, curiously sometimes more costly than finished product;
(ix) repetitive visits of foreign experts and technicians;
(x) supply of reconditioned machinery as new.

(These items emerged from seminar discussion)
*UNCTAD, "Technology Transfer", Report TD/106, Nov. 10, 1972.

gement and technical performance." (US AID 1972).

The role of patents in the TT process in Latin America has been studied by Vaitsos (1973, 1975). He claims that they have had a predominantly negative effect, "devoid of significant benefits" for developing economies; acting as "import permits" which enable MNCs to achieve monopoly privileges, which in turn, exacerbate technological dependence by restricting the possibilities of indigenous technological advance by initiation and adaptation. Vaitsos's work raises the question of what value patents have for developing countries?

Appropriate Technology

Technological dependence encourages the transfer of inappropriate technology to developing countries. "Inappropriateness" can be taken to refer to:

(i) inappropriate production technology which being capital intensive may create unemployment by destroying the economic viability of labour intensive industries;

(ii) inappropriate products, generally held to be western-type consumer goods for a relatively small elite of high-income consumers. Such products which do not represent the true needs of the mass of the population, divert resources, both human and material, and generally require capital intensive production methods.

Inappropriate technologies are imported for two major reasons: 1. Developed countries produce technologies for their own needs in the first place. For reasons of efficiency and/or profit they innovate for economies of scale and reduction of labour costs, i.e. become increasingly capital intensive. 2. Importing countries find it difficult to assess appropriateness, partly because it is an intrinsically difficult task requiring certain kinds of technical infrastructure, and partly because of conflicting interests.

The general concepts of appropriate technology, or as it used to be termed intermediate technology, are familiar. In certain respects it can be seen as a subset of "alternative technology". Its essential aspects are (Stewart):

(a) low capital cost per work place; (b) low capital cost per unit of output; (c) low capital cost per machine; (d) simplicity: (i) manufacture, (ii) in operation, (iii) maintenance and repair, (iv) organisation; (e) non-modern sector; (f) rural-sector; (g) small-scale; (h) use of local inputs; and (i) self-help.

According to Schumacher, an intermediate technology enables the poor to help themselves "by making available to them a technology that recognises the economic boundaries and limitations of poverty." Such an emphasis is not new since it formed part of Mahatma Gandhi's political strategy.

Further, successive Indian Five Year Plans have discussed the matter, particularly with respect to small-scale industries; however, successes seem to have been limited (Chandrakar). It will be interesting to hear what success the *Appropriate Technology Cell* is now having in profoundly influencing national development policies.

Technology Policy and Technology Assessment

The vicious circle of underdevelopment is rarely broken and the transition (D) Economic growth →(E) Developed economy of our model fails to occur. Can the various constraints that we have mentioned be overcome? With respect to the specific role of technology transfer, we might seek to apply a policy of banning the import of all technologies which are not considered appropriate to the task of developing the economy. Such an approach requires a special political determination not normally associated with capitalistic market economies.

Further, there remains the problem of deciding the appropriateness of a technology — appropriate for what and for whom? It is precisely in this area that TA could play a valuable role within developing countries. It is not to be confused with traditional technical evaluation, for it attempts to consider also the potential impact of a technology on the social, economic and environmental sectors.

"What gives a new, special meaning to technology assessment is perhaps the fact that this art of evaluation represents the effort to grip 'technology' as an object of direct policy control at the government level" (OECD).

Details of the TA are given elsewhere (Rothman 1976) — technology assessment is "the systematic identification, analysis and evaluation of the full range of social impacts, both beneficial and detrimental, which may result from the introduction of a new technology or changes in the application and utilisation of existing technology." Technology assessment is best conceived of as an input to the decision-making process enabling decision makers to consider the possible consequences of several different courses of action. It is intended to illuminate the possible technology policy options available, and great emphasis is placed on the impact of technologies on the social, cultural, political, economic and environmental systems and processes of society.

National development plans and science policies ought to be formulated on the basis of democratic discussion with the widest possible participation. This will tap and encourage new sources of creativity and presumably ensure that policies are more widely understood and accepted. Technology Assessment methodology *could* enable such discussions to be more easily and usefully held (Gibbons and Voyer; *Issues in Canadian Science Policy*).

As far as a technology policy is concerned "core actors" include QSEs in R & D laboratories. They could be encouraged to participate in technology assessments within their own laboratories. These need not be massive and expensive exercises. Rather they could be intensive discussion groups concerned to identify the potential impact on specific criteria of technologies with which they are familiar.

Assessment of the Potential Impact of Technology

In a paper entitled 'The Potential Impact of a Technology Transfer on UN Objectives: An Exercise in Technology Assessment Appreciation', a group of experts tried to critically examine the kinds of thinking which might be applied to the selection of suitable subjects for technology assessment. For the purpose of their exercise, they have taken United Nations Organisation (UN) as a specific example, as everyone is familiar with the goals and constraints of UN (see Appendices 1, 2 and 3 for details). Some of the salient points discussed in the paper are summarised in the succeeding paragraphs.

Each technology could be assessed using a relevance technique based on the deliberations of special committees of QSEs who develop the appropriate parameters of the technology's impact and quantify these in order to rank the technologies in order of 'cogency' (Medford).

They might also suggest solutions and possible research programmes. The committee system is preferred to the Delphi questionnaire method of analysis since, in general, consensus is reached quicker and more efficiently, especially if aided by secretarial help, taped proceedings and proper chairmanship. Under such optimal conditions a 3-day meeting should be sufficient for consensus to be reached (Medford).

Unlike most methods of technology assessment which assume that only second or higher order impacts (i.e. unplanned or unintentional consequences) yield disbenefits, this system provides a 'look out' function over fields which have net first order disbenefits.

The goal of the technology assessment is to provide three major impact statements:

(a) Politico-economic impact statement (PEIS) — specifically related to national plans (where appropriate).

(b) Socio-cultural impact statement (SCIS).

(c) Environmental Impact Statement (EIS).

These areas are assumed to be independent and the impacts can, therefore, be weighted.

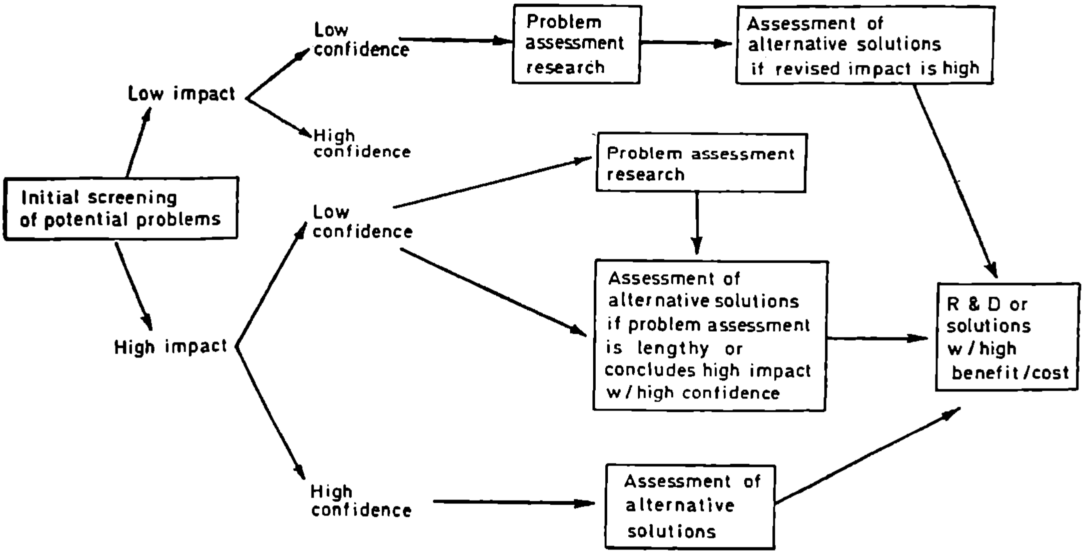

Fig. 3 — Rationale for Determination of Research Programme Strategies

Thus the impact of technologies can be, for example: 0 - no impact; 1 - might eventually be impact; 2 - will have considerable impact; ∞ - certain overwhelming impact.

These will be scored positive or negative depending on whether the impact is beneficial (+ve) or detrimental (−ve). A statement of the time elapsing before the impact becomes perceptible and the rate of change of impact with time will also be given along with a statement of the investigators who are confident of their assessment. Low confidence means that further problem assessment is necessary. High confidence infers that technology assessment can be used as the basis for public policy making (Fig. 3).

Some examples of indicators used in the assessment of impact are :

A. Who or what is affected : Individual—Institutions/organisations—Human artefacts—Biological environment—Physical environment.

B. Elements of quality of life affected : Health — Economic security — Political freedom—Cultural system of religion—Disposable time — Environment : aesthetic; biological.

C. What are the broad characteristics of the problem : Severity — How intense ? Scope—How extensive ? Persistence — How long ? Correctability—How reversible? Frequency — How often ? Geographical distribution — Where ?

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Appendix 1

Key U. N. Goals

1. Maintenance of peace and security;
2. Prevention of widening economic and social gulfs between rich and poor countries;
3. Reduction of conflict between national interests when the introduction of new technologies and processes is likely to exacerbate disagreements;
4. Preservation of parts of the Earth's system, which are presently beyond national jurisdiction, from actions (technological in nature) and uses which might be detrimental to the common interests of mankind;
5. Surveillance of technological benefits and disbenefits imposed upon individuals and sectors of society bereft of customary means of redress within the compass of national systems;
6. Mitigation of natural and man-made disasters through anticipatory planning (for the use of ameliorating technology) on an international scale.

If the technology assessment process is to have meaning for the UN, it must give early warning of technologies which enhance or are detrimental to these six actions, thereby helping UN to approach its goals.

This exercise hopes to demonstrate that a careful selection of technologies to be assessed can be made, in the light of the *a priori* anticipation of their impact upon the above six actions (plus any others inadvertently missed), and that subsequent assessment exercises under the auspices of the UN—with appropriate control over the quality of assessments produced—will prosper UN's attempts to meet avowed objectives.

Appendix 2

Basic Methodology of Selection

The methodology presented relies upon a relevance technique. An examination of existing relevance techniques (Cetron & Ralph, Jantsch & Medford) shows that assessors do not normally bother to examine fields that, in their closed societies, do not yield first order benefits. Indeed, most of the existing technology assessments are based upon the implicit understanding that only second and higher order impacts of technology are likely to be disbenefits. Conversely, a relevance method which suits UN's unique requirements must facilitate a "lookout" function over fields which *may* have net first order *disbenefits*.

Whereas a parochial assessor would keep surveillance over net detrimental impacts, on the understanding that the society to which he belongs would not countenance the continuance of the disruptive technology, a UN assessor *must* always be on the *qui vive* for situations where collective disbenefits might prevail. Such situations arise when (say) military technology reaches a state which could trigger political instability and war, or when high attainment of technological potential by a few Member-States allows them to instigate applications which solely benefit the instigators and bring overriding disbenefit to all other parties. Naturally, not all possible fields for assessment by the UN fall into the category of 'net detrimental impact'. In fact the contrary is hoped for. Nevertheless, because both net beneficial and detrimental impacts must be considered it has been necessary to construct a new relevance for UN's purposes. This new relevance technique depends upon the relevance function shown in Fig. 4 which has skew symmetry through the origin of "good" and "bad". The properties of the UN *asymmetric* relevance functions shown graphically are constrained to be as follows :

1. The UN will not achieve its objectives, or keep attached supporters, if it does not continue to emphasise the six actions listed in Appendix 1.

2. The analytic form of the function (considered below in greater detail) assumes that the six actions listed are *technically* independent and that the pursuit of any action individually, without regard to the others, will in the extreme of infinite effort ultimately achieve UN's goals.

3. However, the weighting to be attached to the importance of each of the six actions (see below) will acknowledge that, other things being equal, some actions are more important than others.

4. The function will also predicate that the ultimate result of UN actions, in the presence of exogenous impacts, will have an asymptotic outcome; either complete harmony, peace, and security for all members (the desired goal) or the opposite.

5. The function will have positive and negative marginal returns to all enhancements or frustrations of the six actions, in accordance with the more usual theory of utility functions as used by economists.

One analytically convenient function which satisfies all the above requirements and which may be used to convert *a priori* subjective opinions into a measure of the likely impacts of technology upon UN objectives is as follows :

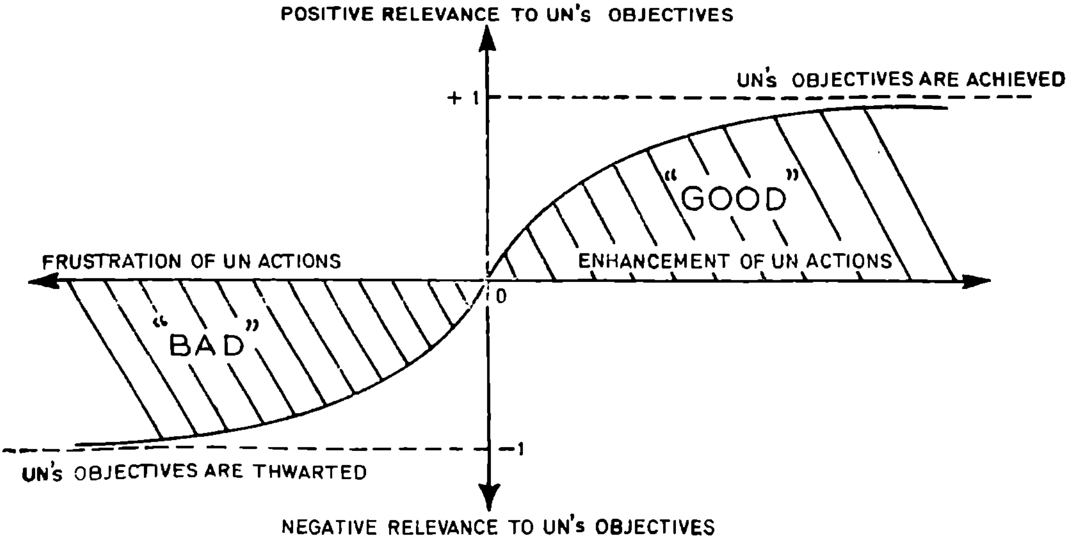


Fig. 4 — Requirements of a UN Relevance Function for Examination of its Technologic Assessment Needs

Total likely impact upon progress

$$=P=1-2\left[1+\exp.\left(\sum_1^6 w_r \cdot x_r\right)\right]^{-1}$$

Note that this function is skew symmetrical about $x_r=0$,

where

x_r is a measure of the impact of the technology, or process, upon the rth of the six actions carried out by UN

and

x_r is scored according to a modified form of de l'Estoile's scoring, used in a conventional French relevance system [see Medford (1973)] but in reversed form so that higher numbers signify larger expected impact

i.e.

$x_r=0$ if there is no impact on the rth action

$x_r=1$ if there might eventually be an impact on the rth action

$x_r=2$ if it is thought that there will be considerable impact on the rth action

$x_r=\infty$ if it is absolutely certain that there will be an overwhelming impact on the rth action. All scores are counted negative or positive according to whether the impact is detrimental or beneficial

and

w_r is the weight of importance attached to the rth action by the UN. For illustrative purposes a weighting, made after some reflection, is as follows:

$w_1=0.5$ for any action impinging upon the maintenance of peace and security

$w_2=0.15$ for any action impinging upon the prevention of widening economic and social gulfs between rich and poor countries

$w_3=0.1$ for any action impinging upon the reduction of conflict between national interests

$w_4=0.1$ for any action impinging upon preservation of parts of the earth outside national jurisdiction

$w_5=0.075$ for any action impinging upon individuals and sectors of society bereft of customary means of redress within the compass of national systems

$w_6=0.075$ for any action impinging upon the mitigation of natural or man-made disasters.

In the exercise one will, of course, be free to substitute whatever weighting one believes is appropriate.

Another property that makes the above relevance function attractive for UN use is that it easily allows dynamic effects, such as changes in technology (and impacts) with time, to be taken into account. That is, the function may be used to focus attention upon the total impact of technology *and* the rate of inception of total impact;

i.e. the introduction of time into the measurement of relevance is not complicated because of the form of the derivative of the function:

$$\frac{dP}{dt}=1/2(1-P^2)\sum_1^6 w_r \cdot \frac{dx}{dt}r$$

and a division of the expected impact score x_r by the time estimated for it to become perceptible (say) T_r will conveniently approximate to the terms representing the derivatives of the individual impacts $\frac{dx}{dt}r$.

Application of the Methodology of Selection

The premise on which the use of a relevance, or objective function is based, is that its use will simplify a complex decision-making process by sensibly coordinating the many subjective, qualitative or partly quantified, opinions of the available experts.

It is envisaged that the above relevance function will be used by a group of experts, who will represent most of the diverse interests of UN's members and UN's staff.

They should be able to arrive at a consensus about the values to be attributed to the following:

—the weights to be attached to the importance of each of the six (or more) important UN actions, i.e. all values w_1 to w_6;

—the impacts of the technologies under discussion upon the actions, i.e. x_1 to x_6;

—the times T_1 to T_6, which must elapse before these impacts become perceptible.

After the relevance function has been quantified, two results are obtained:

(i) the numerical value of the total likely impact of the technology upon UN progress, P, and whether this impact is positive or negative; and (ii) the numerical value of the rate of change of impact with time $\frac{dP}{dt}$.

Quite obviously these values have *prime* importance because, to re-emphasise, they measure the impact of the technological field upon UN actions, its rate of change, and whether these impacts are detrimental (negative values) or beneficial (positive values).

Fields under consideration, as likely candidates for technology assessment, can then be ranked in descending order of cogency. For example, one way of measuring cogency (although not the only way) would be to multiply the two numerical values together, allowing

TOPIC SUGGESTED FOR TA : Offshore Mining of Minerals beyond National Jurisdiction

EXHIBIT No. 1	r	Best estimate of the impact on the rth action x_r (see footnote)	Weight of importance attached to rth action : w_r	Product $x_r.w_r$	Anticipated time for x_r to be perceived: T_r years	Rates of inception : $\frac{w_r.x_r}{T_r} = w_r.\frac{dx_r}{dt}$
Maintenance of peace and security	1	—1	0.5	—0.5	20	—0.025
Prevention of widening economic & social gulf between rich and poor countries	2	—2	0.15	—0.3	10	—0.03
Reduction of conflict between national interests	3	—2	0.1	—0.2	10	—0.02
Preservation of parts of the Earth's system outside national jurisdiction	4	—2	0.1	—0.2	5	—0.04
Surveillance of technological benefits & disbenefits imposed upon individuals & sectors	5	0	0.075	0	0	0
Mitigation of natural and man-made disasters	6	—1	0.075	—0.075	5	—0.015
			1.000	—1.275		—0.13

Likely total impact $= P = 1-2\left[1 + \exp.\left(\sum_{1}^{6} w_r.x_r\right)\right]^{-1} = -0.56$

Likely rate of inception of total impact $= \frac{dP}{dt} = \frac{1}{2}(1-P^2).\sum_{1}^{6} w_r.\frac{dx_r}{dt} = -0.045$

PRODUCT = +0.025

Note : The impacts x_r must be counted positively and negatively for "good" and "bad" impacts respectively, according to the scale : $x=0$ for no impact; $x=\pm 1$ if there might eventually be an impact; $x=\pm 2$ if there is likely to be considerable impact; $x=\pm\infty$ if there is certain to be a massive impact.

for the normal algebra of signs, and count the highest product as representing the greatest cogency. An interesting point here is that a product of two opposite signs will yield a negative score and therefore low cogency, which is as it should be because the practical significance is that the *initial* trend of the impact is away from the ultimate direction of the impact. (This method of scoring is by the rate of perception of the square of the impact and is more sensitive than scoring by magnitude of impact or rate of perception of impact).

To illustrate the application of the basic methodology Exhibits 1 and 2 are presented. Each exhibit represents the quantification, for the purposes of demonstration only, of the

TOPIC SUGGESTED FOR TA : Laser Technology for Separation of Fissile Isotopes

EXHIBIT No. 2	r	Best estimate of the impact on the rth action x_r (see footnote)	Weight of importance attached to rth action : w_r	Product $x_r.w_r$	Anticipated time for x_r to be perceived: T_r years	Rates of inception : $\frac{w_r.x_r}{T_r} = w_r.\frac{dx_r}{dt}$
Maintenance of peace and security	1	—2	0.5	—1.0	10	—0.1
Prevention of widening economic & social gulf between rich and poor countries	2	+2	0.15	—0.3	10	+0.03
Reduction of conflict between national interests	3	—2	0.1	—0.2	10	—0.02
Preservation of parts of the Earth's system outside national jurisdiction	4	0	0.1	0	0	0
Surveillance of technological benefits & disbenefits imposed upon individuals & sectors	5	—1	0.075	—0.075	5	—0.015
Mitigation of natural and man-made disasters	6	0	0.075	0	0	0
			1.000	—0.975		—0.105

Likely total impact $= P = 1-2\left[1 + \exp.\left(\sum_1^6 w_r.x_r\right)\right]^{-1} = -0.45$

Likely rate of inception of total impact $= \frac{dP}{dt} = \frac{1}{2}(1-P^2).\sum_1^6 w_r.\frac{dx_r}{dt} = -0.042$

PRODUCT = +0.019

Note : The impacts x_r must be counted positively and negatively for "good" and "bad" impacts respectively, according to the scale : $x=0$ for no impact; $x=\pm 1$ if there might eventually be an impact; $x=\pm 2$ if there is likely to be considerable impact; $x=\pm\infty$ if there is certain to be a massive impact.

re evance of a potential TA of a specific field to UN activities.

Exhibit 1 is for offshore mining of minerals beyond areas of national jurisdiction, with the possibility of pollution, exacerbation of national conflicts, likely substitution of importations of minerals from developing countries, and the possibility of man-made disasters.

Exhibit 2 is for a new technology of frequency tunable lasers which could lead to new methods for the separation of fissile isotopes, without the customary large scale plant, consequent enormous capital investment, and the possibility of manufacturing weapon grade isotopes with easier protection from surveillance.

The relevance and cogency scores derived from these exhibits are shown below:

Technological Field	Relevance Scores		Cogency Score
	P	$\frac{dP}{dt}$	$P.\frac{dP}{dt}$
Offshore Mining	−0.56	−0.045	+0.025
Separation of Isotopes with tunable lasers	−0.045	−0.042	+0.019

From the above it is seen that, using this method of relevance, one would conclude that a technology assessment of offshore mining of minerals beyond national jurisdiction, is of more importance to the UN than an assessment of a new laser technology for the operation of fissile isotopes.

Appendix 3

Scenario for a U.N. Technology Assessment of (a) Pheromone research (b) Acupuncture

In this appendix two brief outlines of technology assessments will be made : One of pheromone research and the other of acupuncture techniques.

The scenario merely sets out to outline the most basic elements of the technologies and suggest how and why an organisation such as the UN might care to conduct assessments of these technologies.

An assessment of pheromones might be categorised as an exploratory technology assessment because their synthesis and use have not presently occurred. By comparison an assessment of acupuncture is neatly categorisable as a technology assessment of a possible technology transfer.

(a) *Technology Assessment on Pheromones*

Pheromones are chemical substances concerned with coordination of individuals *within a population*. Pheromones are secreted by animals to the outside and if picked up by another individual of the same species cause that individual to respond in a particular manner. They were first described in insects, and appear to be widespread in that order being known to be concerned with the coordination of individuals, often in sexual behaviour and in regulating the behaviour and physiology of social and subsocial insects. *Insect* pheromones have a potential in pest control and bee keeping. It has been postulated that similarly acting substances may be widespread in mammals, including man There is indeed a search for human pheromones, but so far none has been isolated.

Since many of the widely known examples of pheromones are concerned with sexual behaviour there is some keen interest in the applications of derived, or synthesised pheromones. When chemical companies find acceptable uses of pheromones, there follows the possibility of unacceptable usage. Except that here "(un) acceptable" may be rather ambiguous words. Use of pheromones by another person may generate motivation and trigger behaviour which is very acceptable to one's self *at the time* ; but it is certain to be seen, retrospectively, *not to have been* acceptable. The illicit use and manufacture of drugs has already created major social problems, e.g. LSD. The illicit use of pheromones might be a major problem. There is also the potential use the authorities might make of such substances to control the sexual libidos of a population.

Naturally technology assessment of pheromones will require more than ordinary effort put into the description of the background biological science and potential technology of their use. And this will require much caution and finesse in building up the necessary data base. However, a wide seeking of information from companies practising pharmaceutical research will probably yield dividends if carried out in a confidential manner by an assessment team containing a biochemist. Similarly a careful literature search by the team for biological information will allow a compendium to be made of all that is presently published about pheromones. With industrial intelligence from pharmaceutical companies and an understanding of the biological background an imaginative technological forecast can be then made of the possible uses and abuses which might be made of pheromones. The forecast can be considerably assisted by the use of precursor extrapolation, i.e. looking at the present rate of growth in use of those pharmaceutical products and noting expected advantages of the possible pheromone substitutes. Naturally, some new functions for pharmaceuticals might also arise, which can only be conceivably fulfilled by pheromone products, and these will be of special significance and should be especially examined for primary and secondary impacts.

A positive consequence might well be that the UN has prewarning of dangerous substances — derived from ethical pheromone chemistry — which should be under international control.

(b) *Technology Assessment on Acupuncture Techniques*

It has been said by Cetron (1973) that technology transfer is many things to many people; the multilateral flow of information and techniques across the boundaries of the sciences, technology and the practical world; transferring research results to operations; accelerating the application of research and exploratory development results to industrial applications; science and technology transfer to the would-be user at the earliest possible date and in a language that he can understand; the process of matching solutions in the form of existing science and engineering knowledge to problems in commerce and public programmes. And most of these people believe that technology transfer predominantly goes from developed countries to the developing countries or from westernised countries to the eastern countries. Since no systematic assessment has been carried out to examine the benefits and likely impacts of transferring acupuncture techniques, for anaesthesia or curing disease; from China — where the science of inserting needles along several body meridians (acupuncture) originated in ancient times — to other countries an assessment by the UN of this subject might beneficially disprove the latter contention.

Melzack (1973) believes that the potential benefits of acupuncture, particularly for surgery in the elderly patient, are very great: and that it is almost certain that acupuncture results could stimulate research which will provide valuable clues about pain mechanisms generally. Added to this commendation from a psychologist who has studied and contributed to the theory of pain mechanisms there are many other authenticated accounts about the efficacy of acupuncture. Thus a description of the science and bioengineering technology of acupuncture can begin with some very formidable evidence already available for a data base. And if a Chinese expert in the field can be recruited to the team of technology assessors one can imagine a very thorough description of acupuncture and its supporting technology (for example electrical stimulation of the acupuncture needles) emerging.

Naturally the assessment would also concern itself with validated reactions of patients to the acupuncture and answering Melzack's question as to why acupuncture is not used routinely on all patients. Furthermore, the assessment would not leave out of consideration why the specificity theory of pain — as taught in Western medical schools — does not explain how acupuncture works or why, indeed, Western theories would cast doubt upon the major features of analgesia by acupuncture. The traditional Chinese explanation of the analgesic properties of acupuncture could be compared with the explanation in terms of hypnosis and the blocking of neural signals to the brain. Then a quasi-statistical comparison could be made between the efficacy of acupuncture and pharmacological anaesthetics and their respective side effects. For example, simple statistics which could be compared are: duration and persistence times of the analgesic effect, time for analgesic effect to occur after the initiation of the process, effects of these analgesic processes upon blood loss and shock to patients, relative costs (including training of anaesthetists) etc. If these comparisons were not unfavourable to acupuncture, then the impacts upon general surgical and medical practices of transferring acupuncture techniques to westernised countries could be examined. What would be the effects of the transfer on the economics of medicine? Would there be any social advantages or disadvantages — like reducing the supply and availability of pharmacological drugs, which can be abused? Would international advantages accrue through the Chinese being able to exchange their knowhow for other commodities? Would the pervasiveness of an acupuncture technology encourage do-it-yourself acupuncture with unpleasant consequences?

Policy options — like selectively introducing a centre of excellence in the practice of acupuncture to a western country — could be formulated and these could be compared. Altogether an assessment which would almost certainly do no harm to anybody and perhaps do a great deal of good to many. The only negative consequence of such a UN TA could be that acupuncture emerged as a charlatan's tool but the probability of this is virtually zero. The positive consequences of such a TA are that, under the auspices of the UN, assessors will be looking at something of very probable benefit to mankind; be demonstrating that effective cooperation between east and west, developed and developing countries, is a dual and not a one-sided bargain.

Peter Vas-Zoltan

International Science Cooperation

It is easy to understand that science is the most mobile and dynamic element of the productive forces. Its development depends directly on the formation of international relations. The process of science becoming public property occurs in three ways : First, there are scientific results which can be controlled by the man of the street, without understanding their essence — e.g. we can watch the cosmonauts on the TV, we can admire them, but we do not know anything about the scientific background. Secondly, we may read in the newspapers that Mr Watson has received the Nobel Prize for the invention of the DNA (desoxy-ribo-nucleic-acid) but even among scholars there are only few who fully understand the problem. Thirdly, a new washing powder, or a ball-point pen, is used by everybody, but nobody considers their scientific origin. As science in the industrially developed countries becomes more and more a productive force, i.e. a decisive factor of economic development, governments and enterprises take on to organise actively the exchange of information and the optimalisation of the production of scientific knowledge.

This activity does not depend on the desire of a government or a business company — collaboration is objectively unavoidable. There are good reasons for it :

— it follows from the substance of some disciplines, e.g. geology, oceanography, meteorology, astronomy, space-research, linguistics and so on;

— there are some very expensive technological development tasks : e.g. a 300 Giga electronvolt capacity synorophasotron generally can be built only by means of international cooperation;

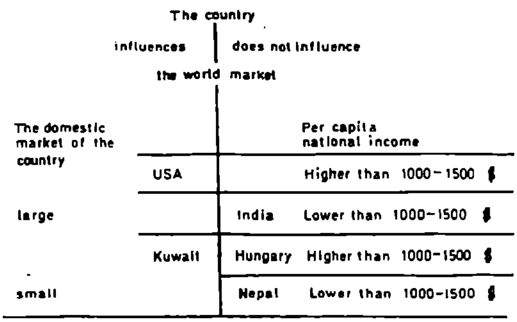
— economical planning of big telecommunication and transport systems can be accomplished only by the collaboration of several countries; and finally

— the standardisation of products which absolutely cannot be efficient without international collaboration.

All these factors, taken as a whole, throw light on the final reason of international cooperation, and this reason is of a fundamentally economic character. To prove this essentially economic reason, we have to start with the scientific investigation of production structure. The structure of production changes time and time again. Each product consists of two parts : intellectual and material. In the long-range process of production the required volume of work per unit of product decreases. Parallelly with this decrease in the socially required volume of work per unit of product, the intellectual percentage grows. That means, the part of scientific and technical achievements grows and gains ever more importance in the production process.

The national capacity of production in the majority of countries is very limited. There are only two countries which have enough intellectual and material capacity to develop their economy : the Soviet Union and the United States. For other countries there exists only one way to develop economically and scientifically : International cooperation. They are in a quandary — the question is whether we have to join international division of labour or not. Answering this question in the negative would only lead to prolonged backwardness.

Naturally the question is posed in another way in the different categories of countries. Generally, we speak about developed and developing countries, but in this case we need more categories. The criteria for marking these countries imply several elements. First the state of the economic development of the country — briefly : can it influence the world market movements or does it depend on them ? Is it obliged to adapt itself to them ? Second, the size of the domestic market which is of crucial importance from the point of view of profitable production. Does it enable mass production — that means, less expensive — of goods. Third, the level of per capita national income, or GNP, which is, among other things, the indicator of consumption capacity. In a relatively developed country this index must exceed at least US $1000. To illustrate the above schematically :



Level of per capita National Income

This is one starting point in deciding on the participation in the international division of labour. Of course there still follows an entire process of decision making. I do not want to allude to the problems of priorities, to the criteria of choice, to the allocation of resources — these topics were subjects of other conferences. Presuming that all decisions were already taken concerning the main goals of scientific research — both the strategic and tactical ones — we still face the dilemma : what can we do with our resources, and what must we buy, receive, exchange from abroad ? In this aspect there are four categories for parameters of decision making :

1. General geographic, climatic, demographic data, the level of employment, population density, etc.

2. General economic factors and parameters of economic policy. Is the country rich or poor in energy resources, raw materials, minerals ? The level of the infrastructure of the country; the transport facilities; the share of foreign trade in the production of the national income.

3. General scientific and technological parameters : which are the traditions, if any ? What are the qualification standards of manpower, especially of the scientific staff ? The organisation level of the scientific establishment.

4. Special scientific and technological parameters of the country in question : in which scientific respect is the country self-sufficient ? Where is the biggest insufficiency in the scientific establishment ? Is the scientific and technical apparatus suitable for international scientific cooperation ?

Having answered all these questions — although the replies will be manifold on an international scale — we have to decide what system we want to obtain from the international scientific division of labour and what can we afford in exchange for it. In other words : we have the criteria to select the priorities for international collaboration. In other words, we have solved the problem of *what* and now we have to face the second question : *how* ? To acquire foreign experiences, to learn foreign skills, to attain the knowledge of operation used abroad, there exists several ways.

With full knowledge of the actual demands we have to make the choice simultaneously among the partners and among the methods of collaboration. Concerning the partners, the traditional political links serve as general reference points, but it is possible that an emerging sound scientific contact develops into further political liaisons. This is important because the second question is put as follows : where is it possible to satisfy the actual demand by resources available ? This question implies not only the fact which country does research in question well but another aspect, too. Where can I receive the results of research from? Which country, which research institute, which enterprise will be inclined to place at our disposal the needed results? At the same time we must consider by what conditions and through which channels would the transfer of a piece of scientific or technological knowledge be satisfactory and do these conditions meet the partner's requests?

Practically, the methods of collaboration are elaborated on a large scale, although the forms of cooperation grow all the time richer.

In the field of international scientific cooperation we distinguish two types of cooperation: the first is the case when we can receive the needed knowledge free of charge, or through a non-equivalent change. Such is international aid, technical assistance — I shall come back to this topic later on.

The second type of cooperation is the equivalent or formally equivalent exchange of scientific experiences. This problem will be expounded now.

Then there exists also a third type of international scientific relations, the *non-cooperative* contacts between countries, e.g. brain drain.

The large network of international scientific and technological collaboration consists of two kinds of groups: the bilateral and the multilateral type of contacts. In the framework of the bi- and multilateral contacts we make usually another distinction which concerns the level of cooperation. This may be governmental or non-governmental, which is a legal, sometimes political and in most cases practical method of solution. I do not want to deal with it in detail. I would like to touch only upon the essence of the following legal distinction: the higher the hierarchic level of the convention of scientific and technological cooperation, the more general the content of these conventions; and vice-versa: the lower the level of the convention, the more actual problems are involved in it. To put it briefly, in the governmental agreements there are recorded the principles of cooperation, in the ministerial conventions the methods and the biggest tasks of collaboration, and at the enterprise or university or research institute level there are set the actual research goals and obligations. I do not want to state that the level of cooperation is of no importance, but this is more the duty of lawyers or politicians, than that of science management.

As you have noticed, I am alternating the expressions: convention agreement, contract, treaty and so on. May be it derives from my poor knowledge of English, but I consider these expressions synonyms, although I know that there are protocol-rules defining for which cases they must be used. Moreover, I want to stress that these conventions, contracts, etc. are denominated in several ways. There are agreements on cultural, scientific, technological cooperation, there are plans for research cooperation according to which name of the treaty the parties agree, but this is of no significance. The main point of these conventions is the actual content.

For us, researchers of science management, or research managers, the only matter of interest is the following: what can we include in these conventions. The simplest programme of a scientific or technological bilateral convention is the exchange of information. Partners send letters, publications, books, abstracts to one another. This is the lowest degree of an adjusted scientific contact. More developed phase seems to be an exchange programme of scholars, specialists or researchers. This kind of convention contains a programme for mutual study tours for a fixed length of time. A more developed kind of this exchange programme can provide for certain research themes or for fixed diciplines. The highest degree of contractual scientific or technological contacts is a convention on common research tasks. The latter can be made in three ways: First, the two institutes retain their own research strategies, work separately, but share the research results. Secondly, the research plan is intellectually integrated, but the research work is separated in the two institutes. Thirdly, they launch a common research project within one international team of one institute.

What is the aim of bilateral cooperation? It can generally be stated that the aim is the rational division of labour and the concentration of forces in the interest of better and more rapidly attainable scientific results. But there are other goals, too, if we regard the various levels of research work and individual disciplines. In fundamental research the aim is the control of the own research efforts or simply to gain methodological experiences. In applied research the aim is to obtain a scientific basis for technology. The social sciences attempt to bring about through international cooperation a lively information exchange and to obtain the most up-to-date methods. Besides, international cooperation in the field of social sciences and humanities is a special forum of the international class-struggle.

But there exists another sort of bilateral scientific cooperation as well, certain foreign trade agreements, the purchase of licences and knowhow. It is not compulsory for each country to do research in all disciplines; they may buy the results of such research from abroad, if this result is licensed. I would like to remind you of the fact, that the Curies — although they have been rewarded with the Nobel Prize — had never licensed their invention. This fact shows that it is not always possible to obtain scientific results by buying a licence. Even if the licence saves a lot of research expenses, time and energy, some research work in this field must be done at home because, first, the acquired licence must be applied on the spot, and secondly, without any research work the new scientific achievement cannot be taught to the next generation. Anyway, the buying of licences is advantageous, if the country has its basis which can adopt these scientific achievements.

The purchase of a licence is not always satisfactory. To operate efficiently a licensed machine, we need skill knowhow. That means, we have to buy it. In some cases we need to buy only the knowhow, e.g. if we have got already some computers ; it is presently of no interest whether we have bought them ready, or manufactured them at home or have bought only the licence and built them on the basis of it. We are charged with a completely new task : to solve the problem with the computers at our disposal, e.g. processing statistically the data of population census. We have to link the computers operating until now separately. This is also a knowhow mastered by the famous Indian scholar, Prof. Mahalanobis.

Although there are tendencies with a contrary effect like the safeguarding of military information, temporary withholding of inventions, the bustling trade in licences and knowhow is on the upgrade. The aim of the increasing turnover of licences, the growing intellectual exports and imports is clear : search for the most appropriate method of adjustment to the world economy. The market oriented economy strives to ensure in this way the continuance and the further expansion of the high rate of profit. The plan oriented economies, i.e. the socialist countries, achieve by this method the increase in consumption by less labour input.

In the large network of bilateral international scientific and technological cooperation there exists the following relations :

— cooperation of developed capitalist countries among themselves,
— cooperation of socialist countries among themselves,
— cooperation of developing countries among themselves,
— cooperation of capitalist countries with socialist countries,
— cooperation between capitalist and developing countries,
— cooperation between developing and socialist countries.

In practice we know precedents for each case. Presently we are interested in those relations which are connected with the developing countries.

In the last decade there was an enormous development in this aspect. Unesco published, about 8 years ago, a handbook on the bilateral scientific links very useful at that time. By my estimation the number of such links have doubled since then. The form and the content of these conventions are the same as mentioned already.

Developing countries with a big scientific establishment — and fortunately there are a few, e.g. India — are equal partners in bilateral scientific collaboration. Those having not such a developed scientific life are able to profit from a bilateral convention, because they can offer research possibilities in their country, owing to their natural endowments. Researchers even of the most developed countries have opportunity to do considerable research work in biology, in the flora and fauna, in geology, and in the tropical diseases of a developing country. Therefore, the essential contents of the conventions of less developed countries can be the exchange of researchers. On the one hand, the researchers of the developing countries learn in the developed country, and on the other, the researchers of the developed countries have special research opportunities, not available in their countries.

In a certain respect there is a different situation concerning the scientific cooperation between two developing countries. In those developing countries which were once the colonies of the western countries, the old colonial system hampered such contacts and the new developing countries, fortunately, have no such a tradition. In the British Commonwealth the indigenous intelligentsia had pursued studies in Great Britain; in the French currency zone, the intellectuals of the colonies had pursued their studies in France. The scientific establishment of a developing country — whether on high or on a low level — is quite new and overcharged by understandable pretensions, not to speak about the lack of teaching staff.

In this situation — although the mutual understanding between two developing countries is easier than in other relations — only a thorough comparison of the claims and opportunities of the countries concerned makes scientific cooperation possible. There are theories according to which developing countries have nothing to do with each other in the range of science and must establish contacts only with developed countries for scientific purposes. To my mind this is not true. First, because it is not sure that the developing countries need by all means the most up-to-date scientific achievements. They do need modern scientific knowledge but only in the case that they have an adequate industrial background which can adopt imported science. Secondly, the similar situation of developing countries makes it easier to understand the mutual demands; a complementary compliance with mutual needs is more possible because the scientific level in both countries is theoretically similar.

I would like to conclude this part of the lecture — the topic of bilateral cooperation — by drawing a not purely theoretical cooperation model. I built up this model for an imaginary scientific and technological collaboration between India and Hungary. What can Hungary do for India in the field of science ? and what can India do for Hungary ? Due to the existing government-level cultural and scientific convention we practise exchange of information (books, monthly reviews, etc.) and a mutual exchange of scholars and specialists. The latter, however, is not very much planned. The main difficulty in developing our scientific contacts is neither the language — both Indian and Hungarian researchers speak English — nor the distance — with the help of jets we are practically neighbours. But the travel fees are high, that means the main obstacle is money. From the Indian side there is a slight possibility to reduce these expenses by the combination of a study trip with the participation at a European conference. On the strength of these reasons well-planned cooperation is required. Concerning the contents of a Hungaro - Indian scientific cooperation, it must be stated first that Hungarian researchers may obtain a high level of perfection in India in the fields of mathematics, physics, mechanics, water supply, statistics, oriental languages and ethnography — all these disciplines are very important for Hungary. On the other hand, Hungary may grant postgraduate qualifications for trained researchers and courses in several disciplines : mathematics, physics, chemistry, biology, especially biochemistry, medical sciences, oil science, water supply, technical physics, geodesy, and physiology. For younger people who are inclined to learn the Hungarian language, Hungary can provide skilled worker and university graduate qualifications. Hungary is able to send abroad experts in some disciplines with a definite task, e. g. mathematicians, physicists, physicians, pedagogues, pedologists, economists, etc. A skillful choice in disciplines may lead to common research work : such common researches are already outlined in the last convention. The bilateral scientific links — although they do not cover the entire spectrum of possible cooperation — are useful and indispensable, but it is absolutely impossible that a country in our age should organise its scientific contacts only through bilateral channels. International scientific relations of a country are normally based on the combination of bilateral and multilateral cooperation.

Even in the era of technical revolution the number of multilateral organisations have grown enormously. Until 1870 there were founded only 35 international organisations, until the First World War 520, and out of these 192 were active; till the Second World War there were formed 1150, and out of these 629 were active; in 1956 there existed already 1105 active international organisations, 2400 in 1968 and now we have more than 3000 such organisations. Among them, roughly 10 per cent are intergovernmental ones and the others are non-governmental organisations. There are 700 international organisations, both intergovernmental and non-governmental, with a scientific or technological profile, or which in one aspect of their activity are dealing with science or technology. The main organisation group is the UN-family with the specialised agencies. About 800 of the existing NGOs have official liaison with the big governmental agencies. Concerning the scientific and technological organisations, this number is around 400, the other 300 are independent, not belonging to any international scientific network.

It is very expensive to maintain such organisations. The budget of these organisations is covered by the contributions of the member-countries (namely by member-organisations or persons in the NGOs). In the big IGOs the member-countries share in the budget by a percentage key which is calculated on the basis of the per capita GNP of the given member-countries. So in the UN-system the USA covers about 25 per cent, India 1.20 per cent, Hungary 0.33 per cent and the less developed countries 0.02 per cent of the budget — a total of $ 370 million for 1976. In addition, these organisations have big programmes, like the technical assistance or the development fund, and for these purposes the member-states make an additional contribution calculated according to different keys. The programmes of these organisations are financed by these means.

Dealing with multilateral scientific cooperation, I do not want to speak about the special funds mentioned, as this concerns the second topic, i.e. international aid. But apart from it, it must be stressed that membership puts big financial burden on the member-country or member-organisation, but these burdens are not equal. Although it goes without saying that — independently from the financial consequences

— all countries, scientific societies, universities, enterprises are looking for opportunities to join these forums on political reasons, the small countries, even the developed ones and the developing countries enjoy a relative financial advantage as compared to the big developed countries. The small and relatively developed countries and the developing countries participate in the programmes of these organisations substantially at the expenses of the big and developed countries. In the mid-sixties I tried to make a reckoning on these expenses in an international comparison and have reached the following interesting results :

I registered the per capita national income of some countries and parallelly the per capita expenditure concerning the international membership-dues of the same country. It turned out that, although the per capita national income of the USA was quintuple in comparison with the Hungarian one, the American per capita expenditure for international memberships ran up to 35 times higher than the Hungarian share. Concerning the developing countries, the position is still better. Such a comparison can be made for all countries, and each calculation proves that it is worth just for the developing countries to become members of the biggest international organisations too. Since the mid-sixties there have been more developing member-countries in the UN and therefore their relative financial advantage has even improved somewhat.

I do not consider it necessary to make here an analysis concerning the organisational patterns, although this problem includes a lot of interesting questions. I think, it would be better here to speak about the inter-relations of multilateral cooperation. It is well known that there are universal international organisations; theoretically all countries — developing, developed, socialist and capitalist — have the right. Then there are regional organisations to a certain extent for strictly geographic regions and partly setting off the regional principle but later expanding according to social systems, e.g. the developed capitalist countries have the OECD, the Common Market, the socialist countries, the Council for Mutual Economic Assistance, (CMEA called COMECON by the Western Press). It follows that there exists no country which would or could be a member of all international organisations. Thus Australia has nothing to do with Scandinavian scientific cooperation. There is another selection in the membership of international organisations and this is made according to their profile. Hungary can not be interested in oceanographic research. I wonder whether Burma would take part in an international organisation dealing with Antarctic research. Having made this two-way selection, we have still a bulk of organisations within the bounds of our interest. By my estimation — only in the scientific and technological field — the number of international organisations in which countries with a normal scientific developmental level must be interested is about 300.

What can be obtained through the international scientific organisations ? First, there are all the five categories of learning — natural sciences, agrarian sciences, medical sciences, social sciences and technology — fostered by the international organisations. A large group of them manages complex scientific problems, like water research, biosphere research and so on. Generally the international scientific organisations organise diverse manifestations of scientific activity; they organise conferences, meetings in scientific problems; they gather, systematise and disseminate scientific information; they plan scientific research, ensure postgraduate training for specialists, finance scientific projects; some international institutes and laboratories run on proper research work, organise discussions on scientific topics, etc. Attending such programmes and sessions, people can make acquaintance with their partners abroad, collect information in their research subject, learn new scientific methods, receive scholarships for training. The experience collected this way enables to introduce the new scientific achievements in their own countries. To show how many kinds of activities can be carried on by an international scientific organisation, the International Council of Scientific Unions (ICSU) is a good example. This is the biggest scientific NGO, in category "A" related to the Unesco. This NGO has twelve Asian members.

CMEA is basically an economic organisation but has an important scientific and technological profile as well. The present state of cooperation of CMEA Member Countries in the field of science and technology can best be characterised by the fulfilment of the Complex Programme for the development of socialist economic integration, adopted in 1971. On the basis of this programme cooperation is organised in the sphere of the following activities :

1. Coordination of scientific and technological plans and cooperation in elaboration of high priority problems. 2. Elaboration of economic and scientific analyses and predictions. 3. Exchange of experience among the institutes, enterprises of the same profile and organisation of their direct cooperation. 4. Transfer of scientific and technological research. 5. Exchange of scholars and specialists for postgraduate training. 6. Elaboration and exchange of scientific and technological information. Eighteen big research themes are fixed in order to develop the natural resources of the member-countries. Hungary participates in 16 complex research themes, e.g. biophysics, research of industrial catalytic processes, semiconductors, selection in agrarian cultures, hybridisation.

To conclude the topic of international scientific cooperation, I would like to mention a totally new phenomenon of international scientific collaboration. Until now we have dealt only with the organised forms of cooperation. But there exists a new, anti-organisational method to cooperate. I want to mention the "invisible college" which is not at all organised, although it exerts perhaps the greatest impact on scientific life. The invisible college consists of the best experts of the world grouped according to disciplines. To belong to the invisible college means a lively and direct contact between top-level specialists. It ensures a quick exchange of information which has become hindered by the information bursts.

Making use of the opportunities of both the bilateral and multilateral cooperation forms, and also of the invisible college members, such complex approach helps us to realise the most important tendencies of our scientific life.

PETER VAS-ZOLTAN

International Aid

All aid, coming from abroad can be characterised by the characteristics that they are free of charge, or the beneficiary has to cover only a relatively smaller counterpart. Aid coming through bilateral channels is called generally foreign aid. International aid comes collectively from more than one donor country. The international aid is one element of the international capital flux. The composition of the world capital flow is calculable on the basis of several UN or OECD documents. Taking all elements of the capital flow together — the foreign trade, technological transfer, financial transactions, international loans and credits, etc. — it seems that 20-22 per cent of the total is to be considered foreign and international aid. I must say that I can hardly assume the responsibility for this figure, because it cannot be calculated exactly : e.g. military aid is, in most cases, concealed, whereas economic aid takes sometimes the form of a commercial convention and altogether the essence of capital movement is difficult to recognise in many cases. By another calculation — made by me in early seventies — 90 per cent of the total capital flow goes through bilateral channels and only the remaining 10 per cent through the international organisations.

We are going to talk about one element of foreign and international aid, i.e. about the scientific and technological aid. Further, I shall call it bilateral and multilateral technical assistance. Multilateral international aid — about 10 per cent of the total — is totally technical assistance.

International and foreign aid — in its entirety — is a very important achievement, because it is *one* of the implements aiming at the solution of the biggest economic problem of our epoch : the reduction of economic backwardness, the restriction of the economic gap between the developed and the less developed countries. I want to stress that it is — among others — only *one* means and on no account the single panacea which could solve the problem. Anyway it could serve as an effective instrument for the improvement of the present situation of the world economy. The major part of international aid, outside of the technical assistance, although it can be useful, is at any rate less effective than the technical assistance. I do not want to deny that a food aid in some cases is not only useful, but even of vital importance. Unfortunately, it seems, that our epoch cannot exist without military aid. The efficiency of technical assistance is far higher than that of the other kinds of aid : it is the only kind of aid which makes possible the development of a country's internal productive forces, and that is the only way to become economically independent. All other kinds of aid remedy certain sicknesses, retrieve acute gaps, but do not accelerate development.

To be sure, technical assistance by itself is not enough to further economic development. It must meet the endeavours of the beneficiary country, and must be received by an adequate industrial background.

I do not think it necessary to analyse the economic backwardness in this circle; I would like only to refer to a single aspect of it : uneven economic development. The basic motive of uneven development takes its origin in the uneven development of the productive forces, first of all of technology. In addition to the latter, there are other factors contributing to it. Although there have been in the developing countries some changes of the economic structure, their production has remained less diversified, less elastic, and reacted more slowly upon economic challenges, than that of the developed countries. Their position is not comforting in an international comparison. If we examine the formation of both the production and the number of population of all countries from 1950 to our days, the share of the population of individual developing countries in the world population seems slightly faster to grow, than their share in the world production. This directs attention to the lack of essential changes in the structure of the economy of the developing countries. The conclusion is unsolicited : favourable change is to be expected unless the developing countries concentrate their efforts to technological development. These efforts could be backed up by technical assistance. I do not want to diminish the importance of technical assistance; on the contrary, I want to prove its indispensability, but parallelly I have to stress the bilateral nature of technological development. If the developing countries are able to differentiate their exports — that can be done only on the basis of diversified production — they can grasp the opportunity rendered by an expanding world market. Thus the developing countries may shape an industrial policy aiming no more at import substitution. It is obvious that the specialists grasp these problems better than I, and I did not want to tell them any novelties; I just wanted to put the role of technical development at its place in this connection.

Until now I have spoken about the economic aspect of technical assistance. Now I would like to pass to some of its other aspects. Let us briefly treat the political side of the problem. Who are the partners to grant international aid ? What is the situation with the donor countries ? After World War II, the main capitalist countries started granting international aid. The socialist countries got connected with this activity later. In our days we are glad to see that this process starts to take shape among the developing countries too. Net donor countries, which receive less assistance than they grant, are the capitalist and the socialist countries; net beneficiary countries — receiving more than they can afford — are still the developing countries.

Both capitalist and socialist countries are in the position to grant technical assistance, but it is manifest that the developed capitalist countries are far richer than the socialist donor countries. Despite this disparity, socialist assistance — which can by no means be neglected even from a financial point of view — has a special political importance; the mere fact that there exists an opportunity to turn for aid also to the socialist countries strengthened the position of the developing countries requiring aid. They have the possibility to choose the partner; they are not at the mercy of imperialist countries. On this occasion let me remind you of the fact that the International Development Association (IDA) reduced the interest rate of loans since the socialist countries have joined the countries granting international aid. The IDA is a sub-office of the International Bank for Reconstruction and Development, its member-countries are only capitalist countries, and it is the loaner of developing countries.

Coming back to the other aspects of technical aid, its organisational patterns must be mentioned.

The first question concerning the organisational problems, although it is not only a question of an organisational character sounds as follows : of which kind should be the aid, multilateral or bilateral ? Moreover this is one of the issues on which practically all formal and informal statements agree. Multilateral aid is the most competent method and form of assistance. This is expounded in great detail and supported by accurate arguments by the late Secretary-General of the UN, U Thant, in his appraisal of the UN First Development Decade/ E/4071. The three inferences of his reasoning are as follows : 1. Multilateral assistance provides far better co-ordinating and channelling possibilities than bilateral aid. 2. The possibility of a professionally controlled realisation of expenditures is greater than in the case of bilateral aid. 3. Multilateral connections are preferred by developing countries upon both economic and political considerations.

Although U Thant spoke generally about foreign aid, his words are valid for technical assistance too. I would like to underline the very cautious but greatly resolute allusion of the quoted text to political considerations. His political considerations aim here at the defence of the political interests of the developing countries. He had his reasons for doing so because it cannot be denied that the evaluation of foreign aid, in general, is unfortunately negative.

First, the amount of aid granted by the developed countries is very small. This is certified by the fact that the foreign aid programme during its 25-year-old activity hardly had an effect on the economic development of the developing countries.

Secondly, the distribution of aid is strongly influenced by the political considerations of the main capitalist countries. The Nobel Prize winner, the Swedish economist, Gunnar Myrdal speaks in his book "The Challenge of World Poverty" even about double-dealing and hypocrisy in their behaviour in regard to the aid policy. To avoid misunderstanding, I want to make certain that I am not speaking about the foreign capitalist private investments having obviously political terms; moreover, I am not speaking only generally about foreign aid, but I do emphasise here the circumstances of multilateral capitalist aid and those of technical assistance too.

Till the mid-sixties the distribution of the UN technical assistance, expanded programme of technical assistance and special fund has been influenced by the political considerations of the highly developed capitalits countries. In my book "UN Technical Assistance" published in 1972, I documented with statistical data — based on UN publications — that it were those developing countries where the impact of neo-colonialism was strongest at that time which had received the overwhelming majority of the aid. Developing countries which served as a basis for neo-colonialism had an advantageous position in aid supply. Since the end of the sixties, when more and more developing countries have become members of the UN, the situation in respect of technical assistance has improved.

I must emphasise that this improvement concerns mainly technical assistance because the situation in the field of other kinds of aid, mainly in the field of bilateral aid, did not change. In the budget year 1973-74 the foreign aid of USA ran to an amount of $ 12 billion, 42 per cent of it consisted of military aid, 40 per cent of the total amount was granted to Israel and to some puppet governments of Indo-China. In addition to its economic nature, already mentioned earlier, technical assistance grants better political conditions than the other kinds of aid. In the light of its economic nature and political aspects we have to pass to the actual content of technical assistance. Which results can be achieved by technical assistance ? What can technical assistance do for a country ? Which are the favourable precedents of technical assistance?

I would like to mention that not all projects of the Expanded Programme of Technical Assistance, Special Fund and the active Development Programme are considered as successful. We must take notice of some unnecessary projects, of wasted amounts, of non-adequate programmes. It occurred that international organisations made mistakes by granting assistance which was not practicable for the beneficiary nation, like the World Health Organisation did it for many years ago in Burma. There are widely-known scandals when bribery frustrated the result of the assistance. But there are excellent examples too.

In the early fifties malaria has been almost entirely eradicated in Sri Lanka by the employment of DDT. As a consequence mortality rate decreased by 50 per cent within 7 years. To diminish the mortality rate to such a degree, Great Britain needed 70 years. In 1962 the Food and Agricultural Organisation had launched a million dollar programme in Kenya. This was the surveying of the irrigation potential of the Lower Tana Valley. The project was accomplished within two years. In Zaire the Kinshasa National Institute for Construction and Public Works was established by the Unesco. ICAO granted $ 1,600,000 for the establishment of the Zaire Federal Civil Aviation Training Centre in Nigeria.

As of 31 December 1973. there were approved several UNDP programmes for the following Asian countries : Bangladesh $ 1,160,000; Bhutan $ 1,047,150; Brunei $ 4,000; Burma $ 13,264,522; Indonesia $ 3,950,548; Hong Kong $ 473,264; Fiji $ 3,950,548; India $ 49,684,786; Indonesia $ 40,153,690; Iran $ 30,870,345; Iraq $ 23,470,063; Japan $ 694,548; Jordan $ 15,521,230; Khmer Republic $ 11,148,993; Laos $ 4,324,297; Malaysia $ 20,440,592; Mongolia $ 12,097,328; Nepal $ 15,775,748; Pakistan $ 16,787,687; Philippines $ 22,299,257; Republic of Korea $ 18,115,174; Republic of Vietnam $ 6,718,847; Seychelles $ 167,500; Singapore $ 12,057,697; Sri Lanka $ 18,851,730; Thailand $ 22,512,321; and Western Samoa $ 4,275,596; and in addition to this as intercountry projects for Asia and the Far East $ 36,065,935 were approved (UNDP Compendium of approved projects as at 31 December 1973. UNIDO/MIS/ Series A/No. 4, p. 383). Ten years ago the UN published a book about the technical assistance with the title "150,000 skills in 15 years". A similar attempt now would list more than 300,000 skills, according to my estimates.

Without augmenting the number of examples I shall try to summarise the fields where international organisations could provide technical assistance.

Economic Surveys

Finances; Industrial development and productivity — Building trade, chemical industry, engineering and tool-making, treatment of ores and metal-using industries, manufacturing, printing, paper-industry, small-scale industries, and textile industry.

Exploration of natural resources and power generation — Nuclear energy, topometry, cartography, sources of energy, mineral and fuel sources and sources of water power.

Statistics — Economic and financial statistics, national income statistics and demography and statistics on living conditions.

Transport and communication — Railways, inland water ways, bridges and shipping, urban traffic and development of trade and market research.

Human rights — Organisation of the jurisdictional system and legal status of women.

Social welfare — Urbanisation, family and child welfare, housing and planning, social problems of health administration, landed properties, civil services, rehabilitation of handicapped persons, social development, social defence, institutions furthering social welfare, fight against narcotics.

Public administration — Local and regional administration, organisation and methods. personnel administration, postal administration and administration of public finances.

Within this technical assistance framework each specialised agency of the UN has its own competency, e.g. the Unesco is dealing with education, scientific research and training, communication and information and the World Health Organisation with public health services, communicable diseases and medical training.

I think there is no use to continue the outline of the contents of technical assistance. I would prefer to speak briefly about two aspects of the behaviour of the developing countries with respect to the technical assistance.

I am convinced that the developing countries could receive a larger quantity of technical assistance, on a more efficient level, when they had planned better their claims and when they would follow the new possibilities with keener attention. You all have people in international organisations — India has a lot of them — and they have the biggest opportunity to help. Although they are international functionaries, they continue to be citizens, to be patriots. It is not incompatible with their duty to tip off their national authorities on the new opportunities of scientific and technological cooperation, on programmes with a possibility to join. I am sure that some of them do so, but I am afraid that there are missed opportunities as well. I do not think that a country has to join all programmes, but it has to know them at least, this knowledge enables a good selection.

I hope I shall not be misunderstood mentioning the second aspect : there is to be felt a certain sense of conservatism in connection with the technical development in nearly all developing countries. It is not pronounced, but there exists a fear of technical innovations, people who fear for their usual way of life, are anxious that technical development spoils the nature of their society. The change of technology naturally introduces new features into man's life, but it is not compulsory to give up the national way of life, the national character of the society as a consequence of the changes. Although there were published hundreds of books on this theme in the field of sociology, I fail to notice any propaganda against such opinions, governments do not canvass for the contrary of such views though a good propaganda could lay down the ideological basis for economic development. There is nothing new in it; we know that in Japan, in the MEIJI-era there existed already a slogan of this character. "Learn the techniques from the Barbarians and maintain the samurai morals" — this being the evidence of an endeavour aiming at the establishment of the balance between the reception of the new technology and the old scale of values.

To finish this lecture, I shall try to enlighten the socialist conception and approach to the problem of international aid. I do not want to say that all ideas expounded here were not parts of a socialist conception, but what follows is more an attempt to summarise them.

In the present international situation a level has been reached by the developing countries when their political weight exceeds their economic significance. Therefore the liquidation of their backwardness appears to be an extremely urgent demand. Though the socialist countries have not been colonial powers and never contributed to the economic backwardness of these regions, they participate in sharing the burdens of international aid and, within it, that of the technical assistance. However, the main part of the burden ought to be shouldered by the former colonial and presently neo-colonialist powers, thus repaying at least to a certain extent all the wealth they had been able to use for their own benefit by exploiting the colonies. Actually, repayment can be effected only to some extent since the developing countries of today cannot be fully compensated for the century-old sufferings and for the actual dire poverty, of their peoples.

Owing to historical circumstances, the Hungarian People's Republic joined in the work of the United Nations belatedly, but has since endeavoured to display vigorous activity, concentrating mainly on tasks and possibilities, which warrant forms of activity complying with her actual social conditions. Thus there are two reasons why the field of technical assistance is important for Hungary. First, as a member state entitled to a share in modern technological achievements she herself is in need of adopting the latest results of technical development, and secondly this framework is a particularly suitable domain where a small country with relatively developed productive forces can contribute to the solution of international problems by intellectual exports rather than by the export of goods.

PETER VAS-ZOLTAN

The Brain Drain

Let me begin on the topic of brain drain with some subjective remarks. Although these remarks look like autobiographical data, they strictly concern the subject.

About twenty years ago I started my research work on international scientific organisations. I came to the conclusion that though they assume important tasks, they dispose of only scarce financial resources. The greater part of these resources comes from the highly developed capitalist countries. I made further investigations for finding out where the big capital flow for scientific purposes goes. This research led me to multilateral technical assistance. I had to state again that the overwhelming majority of this capital flux — although in respect to other capital flows it is not very high — had been placed at the disposal of aid programmes by the developed capitalist countries. The same statement could be made concerning bilateral aid too.

A question comes up: why do they do it? In general it is easy to answer the question; these actions are one of the means to expand their political influence. The answer is justified, but does not shed light on the scientific connections. Does the fact that the overwhelming part of the burdens falls to the most developed countries has a special scientific aim? The answer is 'yes'. This aim is the brain drain.

The term "brain drain" has become common and unambiguous in literature and in journalism as well as in the living speech. It expresses a characteristic international movement of our times, the migration of usually highly qualified professionals. On summarising the concept of brain drain, we make no attempt to define it in a single sentence, because the longest sentence imaginable could not cover all important aspects of it. The main criteria of brain drain will be examined from four aspects:

As a Political Problem

When the best of professional manpower leave their home country and settle in a more developed one, it is a political phenomenon; but it only rarely occurs that the motives are exclusively political. As a phenomenon, it expresses the internal difficulties of the country left behind as well as the mercilessness of international competition, a struggle waged by unequal forces. It involves a peculiar contradiction: it simultaneously indicates the lack of production and the overproduction of professional manpower in the drained country. In this sense, brain drain is a symptomatic phenomenon, but at the same time it is one of the internal difficulties as well. To some extent it has an objective basis, as the attraction of a more developed country compared with those of the less developed ones has always existed in the course of history. It is for this reason that it cannot be considered simply as an imperialist manipulation, although it is definitely a specific form of capitalist competition. This objective effect assumes a political character as a result of worldwide polarisation due to power relations. In this process, the United States has become the leader of the capitalist world, and this has resulted in a narrowing of choice, with the main capitalist country becoming the place of destination. The net effect of the brain drain is that the development of science and technology has been accelerated in the US and has been slowed down in the drained countries. Settling in a new country is always a political decision even if it does not involve taking sides politically on the part of the individual. And this also makes a difference between the old type of migration and brain drain, mainly because as compared to the earlier migration of scientists, brain drain has appeared at the time of the scientific and technological revolution when scientific research is on its way to becoming a directly productive force. That is another proof of the fact that science is the internationally most mobile element of the productive forces. Barring international strife, brain drain is the only non-cooperative element within international intercourse which has been so immensely intensified in our age; and this again enhances the political character of brain drain. Further, brain drain has a political character also because it is one of the most marked manifestations of neocolonialism. Without exposing brain drain, the nature of neo-colonialism can not be understood completely.

As an Economic Problem

The economic aspect of brain drain cannot be divorced from the political aspect. First of all, we should like to emphasise that it is in contradiction with the greatest international economic objective of our age, namely, the narrowing of the gap between the developed and the developing countries. It expresses at the same time the complexity and the interdependence of different societies. It derives from the disproportionate economic, technological and scientific development of the capitalist and the developing countries, entailing contradictions in the training of professional manpower and the ability to satisfy the social demand for this group. It is characteristic of brain drain that the more underdeveloped the country is economically, the more it loses by brain drain, while the developed countries profit from the process. It occurs through a complicated interplay of direct and indirect economic "push" and "pull" factors. It is stimulated by the lack of an educational system as well as the absence of manpower policy and these deficiencies naturally hinder the really efficient use of those qualified as well as those having talent. As against this, there are the higher living standards and better research and working opportunities of the more developed countries, which provide thousands of possibilities for developing human potential. In addition to these objective economic factors, brain drain is also stimulated by the actual realized intention of the developed countries to acquire intellectual capital free, and as quickly as possible.

As a Social Movement

The main flow of brain drain as a change of domicile starts from the underdeveloped countries towards the developed ones, mainly to the US. There are a few developing countries from which quite a large number out of the qualified manpower moves to a small number of developed countries, and further, there are relatively smaller numbers migrating from many developing countries to again a few of the developed countries. The flow from the West European developed countries to the United States is also significant; however, it should be mentioned that the European drained countries are at the same time recipients in relation to the developing countries. The major geographical direction of brain drain is from the south to the north, i.e. from Latin America to the US, from Africa to Europe and to the US, and from the east to the west, i.e. from the Asian countries to Europe, and from Europe to the US. The greatest number of migrants in this process is from the following professions : engineering, medicine, science (natural scientists), nursing; in somewhat smaller number, but still significant, are social scientists. The migrants are usually between 30 and 40 years of age, but the proportion of those over 40 is also significant. The process has been continually accelerating and the numbers involved increasing; its rate has speeded up particularly since the mid-sixties. Neither the isolated phenomenon of a temporary regional slow-down or standstill (at the end of the sixties the emigration from Latin America increased but only slightly) nor the temporary saturation of some professions cancels this general tendency. The trend in brain drain points towards higher qualifications, i.e. the higher the qualification, the greater its weight is in total emigration, in other words, it is selective to higher qualifications. This is supported also by the new skill-intensive immigration laws.

Finally, brain drain as a whole is the movement of scientifically trained manpower appearing in a way other than usual, and the process expresses — more or less — the dissatisfaction of the individuals involved with their home country. When we speak of brain drain, it is a fundamental criterion that the individual leaves his country against the interest or intention of that country. Even a very long study tour consented to by the home country cannot be considered as a case of brain drain, though it is primarily the receiving country which profits from the actual research work carried out in this way. It has been proved in practice for decades now that brain drain cannot be stopped by administrative measure (e. g. by travel or visa restrictions). This has to be emphasised because, examining the problem from the aspect of the individual, administrative means always offer themselves to "solve" the problem. It is, of course, not only illegal departure from a country or refusal to return to it which constitutes the process of brain drain but in most cases it is one of legal emigration. In these cases, the consent of the country of origin has been granted but it is unlikely to coincide with its interest or intention. Hence, there are various grades of moral responsibility within this process, but the essence of the matter remains the same, namely, the emigration of intellectual capital. Another important element in examining the problem from the aspect of the individual is the question of how to judge the way of acquiring and using a given qualification. The basic case is when someone acquires his qualification at home but uses it abroad. It is different when the qualification is both acquired and used abroad, for in that case we can only speak of brain drain if the individual was sent to learn abroad by his country with the definite aim that he should return after acquiring the qualification to fill a vacuum in his profession. A third case is when someone acquires his qualification at home, leaves against his country's wish, but once abroad, does not work in his profession (e.g. an engineer works as a driver); although this means a loss for the home country, it cannot be considered as a case of drain.

Before passing to the practical problems of brain drain, I must mention some kinds of ideological manoeuvring which are intentionally trying to mislead public opinion on the topic of brain drain.

It is a general practice to equate the concept of brain drain with migration — in better cases they are only confused. It is clear that the brain drain can only be a very special case of migration, and migration is only one of the elements of brain drain, even from the most formal point of view.

Although migration may well have some undesirable side effects, in general it is a positive phenomenon; brain drain, however is on the whole a negative process. We agree with the report of the British Parliamentary Committee on Manpower Resources for Science and Technology which clearly states that temporary migration is definitely desirable, for in this case the person concerned returns home with additional knowledge gained abroad, while in the case of emigration the country loses him. This concept of migration instead of brain drain helps those forces which benefit from it.

We also have to oppose another view which is based on a legend. According to this, brain drain has always existed and the recent process is only the continuation in the modern world of a well-known ancient phenomenon. The essence of brain drain lies in its being a new social phenomenon with a definite orientation; it is accelerating and is becoming increasingly strong and it developed these traits mainly in the sixties. This again is in the interest of those benefiting from this process; overemphasising the "eternal" and objective nature of the process, there is an attempt to point out its unchangeability.

There exists a third typical theory. During my research work on brain drain I was told sometimes: "You would not dare to write about how the America of the socialist countries — i.e. the Soviet Union — drains the top level professionals from its socialist partners." This statement is a sheer misunderstanding. Although the process of the brain drain occurs mainly outside the socialist countries, it is also directed against these. The socialist countries have no influx of foreign brain power and their quite insignificant losses — due to desertion for political or other reasons—have been considerably smaller than those of the developed West European countries. It is a fact that from time to time some top level professionals refuse to return and they offer their knowledge to one of the developed capitalist countries. In these cases however, it is generally the political attitude that is decisive. But between the socialist countries the relationship is characterised by friendly cooperation which excludes brain drain.

The fourth and the most tendentious theory denying the importance of brain drain is the myth of flood-back. From 1960 onwards, there were published a lot of books, monographs, studies, articles, daily news items which described the destructive effects of the brain drain, explained its causes, defended or attacked and justified or criticised it, but whatever their approach, they went on publishing data about the increasing number of outflow of intellectuals. It was in 1970 that the first news came that the National Aeronautics and Space Administration (NASA) and Boeing programmes would be out, leading to the dismissal of many highly qualified professionals. In 1971 there began to spread the view that brain drain already belonged to the past. At first this was held only in scientific circles but it soon pervaded public opinion as well. Interestingly, this turn in public opinion can be connected to a definite point in time: on the 10th June, 1971 a column by Art Buchwald in the 'International Herald Tribune' had a great effect as regards the general attitude towards brain drain. This article did not actually deal with the brain drain, it simply described — in Buchwald's satirical way — the tribulations an American physicist had undergone. This eminent expert had lost his job, and after innumerable trials he had reached the point when he was happy to apply for a vacancy as a driver. What Buchwald wrote was not unfounded this time, it was said, not only was the US unable to employ foreign scientists but could not even provide jobs for her own professionas. Buchwald was in no way responsible for the inferences which went far beyond his intended description of the situation. By that time, there had been numerous publications from which it was possible to conclude that there had been a decrease in the employment of highly qualified manpower, hence not only the process of brain drain had come to an end, but emigrated scientists would return home. The Financial Times, The Sunday Times, the Frankfurther Allgemeine Zeitung, the Business Week, Le Monde and some other of the biggest dailies published articles about the changed situation in the brain drain. Certainly there was an undeniable change; the brain drain had a temporary recession in 1968-1969; in the US many intellectuals became unemployed, and as a result the US temporarily lost her capacity to absorb foreign scientific manpower. But after this slight recession the brain drain continued on an increasing scale. To be convinced of this fact, it is enough to look at the statistics published by the National Science Foundation since the spring of 1971. It is evident that the brain drain could not decrease. Let us take the example of physicians; there is an output of

8000 doctors a year in the US, in contrast, while the annual demand is for 12,000 new doctors. Assistant Secretary of State, Mr Charles Frankel announced at a Senate hearing : today, approximately one out of three doctors entering practice in the US is an immigrant trained abroad. According to 1970 data, 25% of the medical practitioners employed in the British National Health service were foreign-born, among the younger generation of doctors 44% had come from overseas, primarily from India and Pakistan; in many of the British health institutions almost no British nurses can be found; 3.6% of France's professional manpower is foreign, several thousands of Vietnamese can be found working.

Although these tendentious theories cannot be taken earnestly, there is a counter-argument with regard to brain drain, which must be taken seriously. That is, the literature on brain drain consistently uses Human Rights to justify the process. Brain drain is realized through individual decisions. According to Article 13, S. 1 of the Universal Declaration of Human Rights "Everyone has the right to freedom of movement and residence within the borders of each State", S. 2, "everyone has the right to leave any country, including his own..." It is clear that civic rights and duties can only be interpreted correctly if their regulations are treated as an entity. As a UN report in 1968 stated : "... the problem is to reconcile the exercise of these rights and freedoms of the individual (in this case the migrant) both with the interest of the States concerned..." (A/7294). This report points out the essence of the interpretation. Any approach to Human Rights which attempts to justify brain drain is unacceptable because it relieves the individual of his moral duties by providing a formal and dogmatic interpretation of these rights; because it separates the principles of rights and duties; because it condones the enrichment — without cost — of the prosperous, developed countries at the expense of the less developed ones. This is essentially contrary to international interests. We think it is incorrect to treat the problem of brain drain as one of Human Rights. All human activity cannot be reduced to the principle of human rights. Brain drain is an independent phenomenon, a new one in international relations, its regulation is desirable, but it does not belong to the range of human rights.

Although we do not accept the view, which — referring to the Human Rights — condemns every defensive step taken by the countries losing out in the brain drain process, we do agree in general, that brain drain cannot be prevented by merely administrative means. Experience has shown that — except for some special cases — administrative measures hardly limit the brain drain. On the other hand, the same experience has made it quite clear that brain drain can be promoted by administrative measures. Legislations can easily pass laws which are able to increase brain drain through immigration; it can easily facilitate the employment of highly qualified intellectuals or make visa regulations selective so that professionals having higher qualifications might obtain the visa more easily.

In 1964, when brain drain was noticeably increasing, although it had not yet reached its peak, leading American statesmen quite openly spoke about the usefulness of brain drain for their country. President J.F. Kennedy expounded in his work "A Nation of Immigrants" (published in 1964) that the contribution of immigrants to the science and culture of the US was far more important than their activity in other fields, such as economic or political life. Secretary of State, Dean Rusk, reported in a similar way at a hearing of a sub-committee of the House of Representatives in the same year. I quote it : "The significance of immigration for the US now depends less on the number than on the quality of the immigrants. The explanation for the high professional and technical quality of present immigration lies in part in the non-quota and preference provisions ...... that favour the admission of highly qualified migrants, but still more it depends on world conditions of postwar economic and social dislocation ...... Under present circumstances, the US has a rare opportunity to draw immigrants of high intelligence and ability from abroad; and immigration, if well administered, can be one of our greatest national resources ......We are in the international market of brains ......" I think this needs no further explanation. The State's intention to win over manpower of "high intelligence" was made clear and this was followed by appropriate legislation. American legislation adapted itself to the country's increasing demand for professionals in two ways : first, through the development of international cultural and scientific exchange programmes, and secondly, through the successive amendments to the immigration laws. All this has been supplemented by the changing and modification of visa regulations.

While the regulation of scientific and cultural communications relates only indirectly to brain drain, the repeatedly modified immigration laws have directly contributed to pulling professional foreign manpower. These modifications were of a twofold character : the immigration laws were changed from a strict, national quota system — used before the war — to a looser, less isolationist and more elastic system; on the other hand, nationality ceased to be the basis of judgement, its role having been replaced by skills. Both the Immigration and Nationality Act of 1952 and its more liberal successor, the law of 1962, were still based on quotas; the New Immigration Act of 1965 put an end to this system. It created a new system of preferential quotas and among them the so called "third preferential quota" concerned the professional or highly skilled immigrants. An analogue legislation was passed in UK, Canada and Australia. The main tendency of all these changes was to make immigration rules more elastic, more liberal and to give preferences in a skill-intensive way.

What are the causes of the brain drain ? This question has a very large literature. First of all, the precondition must be separated from the cause proper. We do not consider it as a cause if someone is sent abroad on a study tour, although it may be an important precedent, moreover, it can sometimes also serve as a condition. We do not consider the skill-intensive immigration laws as a cause. We shall ignore the so-called coagulation-theory, which says that brains migrate to brains.

All real causes can be categorised according to a pair of antithetical factors (push- and pull-factors). Push-factors repel, prompt a person to leave his home country while pull-factors attract people to the country where they settle down. We collected eighty-one individual factors, although they are not of the same rank and value.

Push-factors can be objective, beyond the competence of the country and independent of the individual, as : the general economic backwardness of the country — relative overpopulation — neo-colonialist pressure — political instability — economic gap — technological gap — salary gap — under-employment — poor working facilities — lack of scientific tradition in the country — absence of scientific colleagues — lack of practised supporting staff needed for research work — the isolation of domestic scientific manpower from the outside world — insufficient funds for research.

In contrast there are pull-factors with an objective character, like : a higher level of living —high salary — large research grants — allocation of substantial funds for research — modern educational system — attraction of urban centres.

Other push-factors are also of an objective character, but certain special causes have a role in the individual's decision ; political instability — lack of receptivity to change jobs in the home country — career expectations — cultural factors — desire to travel — influence of the family or friends.

Their contrast—pull-factors are: relative political stability — attractive job opportunities — cultural factors — accessibility of scientific partners — personal aspiration — expectation of use of modern, usually expensive equipment — general logistic support.

Again other push-factors are such causes which depend partly on the country's government, but independent of the individual: social settings — lack of realistic manpower policy — employment procedures — excessive centralism — mistakes in planning — overproduction in education — internal salary maladjustment — qualitative underemployment — lack of urban way of life — cultural and social considerations—unfavourable political atmosphere — restriction of freedom of research — administrative interference with research work — lack of professional opportunities — under-utilisation of professional skills — lack of supporting staff — discrimination in salaries between categories and professionals — lack of science policy — conservatism of domestic organisation of science — old-fashioned system of education. The parallel push-factors are here: opportunity for further professional training — employment availability — better educational opportunities — prestige of foreign training.

And finally there are subjective causes, depending partly on the government and on the individual's decision. These push-factors are: — the lack of manpower planning — miscalculations in manpower plans — working climate — job content — discrimination on non-economic grounds. The adequate pull-factors in this respect are: the expecting working climate — relevance of foreign training — availability of choice of job needing qualification.

Needless to say, none of the actual cases is motivated but by a single factor; it is quite certain that it will not be enough to give only a single factor as an explanation in the case of an individual. A lot of sociological surveys treated already these questions. The result of some examinations through questionnaires shows a diversified picture concerning both the intention of individuals and their motives.

May be, I dwelt longer on theoretical problems and on the causes of brain drain, but I think that without these we cannot approach the remaining very important practical questions. There are still left two: the loss resulting from the brain drain in the developing countries which is about equal with the income gain of the developed countries and the various proposals for the solution of the problem.

A vast number of studies describe the magnitude of the problem of the brain drain. These studies have brought forth considerable statistical material to highlight the significance and seriousness of the question. International anxiety and concern have been natural reactions to such data.

Between 1960 and 1970 roughly 40 % of the skilled immigration came from developing countries, mainly from India, the Philippines, Pakistan, South Korea and Taiwan. About 75% of the total immigration of qualified manpower was absorbed by the US, Great Britain and Canada. Approximately 50% of the total flow consisted of engineers and scientists, and some 20% of physicians, surgeons and dentists.

From the early fifties — when the brain drain had begun to be noticed — till 1972, about 150 thousand qualified scientists, engineers, physicians, and surgeons migrated from the developing countries alone to the USA. The order of magnitude of the annual inflow at the beginning in early fifties was 2,000; it increased till 1971 to 16,000 and in 1972 was still 15,000. The United Kingdom received from 1961 till 1972 about 84,000 and Canada in the same period 57,000 skilled immigrants.

A report of the Secretary-General of the UN of March 1974 mentions that on 1st January 1973, there were 18,478 professionally trained Indians registered abroad. From this number there returned 9,203 while the remaining 50% settled down abroad. Between 1961 and 1972, from Asia alone 65,000 qualified specialists migrated to the US, more than 29,000 to Canada and 23,000 to the United Kingdom.

This is of course an enormous loss on the part of developing countries and a net gain on the part of the recipient developed countries. The latest comprehensive report in this matter, that of the UNCTAD Secretariat of October 1975, terms therefore the process of brain drain "the reverse transfer of technology" the meaning of which is a tragical reality. Brain drain in the developing countries is technical assistance to the developed ones. The overall picture to emerge is one of substantial income transfers over the period 1961-1972 from the developing countries to the most advanced capitalist countries : a total of 44 billion dollars, of which the United States accounted for some 30 billion and Canada for 10 billion. The total inputed capital value of the brain drain in the developed countries amounted to some 50 billion dollars over the same period; of this total, immigration from Asia accounted for over 33 billion dollars. The significance of these totals may be appreciated in the context of other international flows. Thus, over the period as a whole, official development assistance from the three developed countries amounted to 46 billion dollars, compared with an estimated 50 billion for the inputed capital value of brain drain. I do not want to bore you with more data; moreover, I do not think that we need more at all.

What can be done for curbing the process of brain drain ? We could already collect a large library from the various proposals aimed at decreasing the brain drain. There are numerous individual proposals, documents turned out by international organisations, monographs and government papers. By analysing them it could be stated that although they are constructive, comprehensive and intended to defend the interests of developing countries, they have not been able either to stop or even to put a break on this process. What can be the cause of such a complete failure ? It turns out that although the brain drain is a special, autonomous phenomenon and can be treated as a separate subject, it is not independent as a problem, but closely related to such objective laws governing modern human societies which make it impossible to solve the problem itself. Its successful solution can only be envisaged together with the solution of other problems of vital importance to the developing countries. However, until this is achieved, we have to be content with seeking partial solutions. But we have not achieved even minor solutions. Why?

On the one hand, if the main recipient countries wished to restrict their immigration—which has been an actual proposal at the international forums many a time — this would mostly affect those developing countries where the unemployment of intellectuals is a direct source of political tension. On the other hand, overproduction of intellectuals seems to be a more alarming political problem for many developing countries than losing a number of these intellectuals trained at great expense. The developing countries have failed to form a "united front" to stop brain drain. Brain drain also entails some advantages : e.g. the sums of money transferred home by the professionals working abroad. Moreover, most developing countries do not intend to take even such steps to restrict brain drain which have already been worked out in the various proposals. Of course, we speak of simple and practical proposals here, in no way of utopian wishes, e.g. it is obvious that the developing countries are not able to ensure a standard of living for their researchers similar to that in the developed countries, but such works of a minimum effort like the management of recording or data collecting could be relatively easily effected. Furthermore, little effort has been made so far to arrange the salaries of the intellectuals in a way compatible with domestic levels and the overall salary structures.

Nevertheless, the struggle against brain drain need not and must not be put off until the time when countries of the Third World will have at least reached the level of today's Europe. Each reasonable proposal must be acted on, even if it can decrease the loss caused by the brain drain only to a slight extent.

It is impossible to enumerate even the most significant proposals within the limits of a paper, and I think it is also needless, as they can be read in many documents. They are best summarised in the so-called Henderson report of UNITAR, 1970, in the report of the Secretary-General of the UN of January 18, 1974 and recently in the already quoted UNCTAD study, "The reverse transfer of technology". I would like to mention only two kinds of proposals.

One of them is the example of the Columbian Institute for Advanced Training Abroad. This Institute realises a policy toward study abroad up to the point that the employment of students when they return home is solved. Some conclusions from the experience of the Institute might be recommended for general consideration :

— Students proceeding abroad for study at a very young age, before 20, are especially subject to cultural alienation, hence education abroad should be reserved for the graduate school age;

— After three to four consecutive years of study abroad, the student's chances of return to his country decline;

— If a highly trained professional has not completed required military service before leaving his country, such a requirement can be an obstacle to return, hence it is better to require the completion of such service before the student leaves;

— The more specific the aim of the student and the greater his experience and connection within his field in his home country, the greater the probability that he will return;

— While education abroad should not be limited to those who already have had some employment in a profession and have families of their own, possession of these things or of a job to which the student can return add to the probability that study abroad will not become a case of emigration;

— Contact between students studying abroad and their own mission should be maintained in regard to both continuous information and employment opportunities at home.

This experience is very easy to adopt. The main thing is that there exists in the country a special authority dealing with the professionals having their training abroad.

The other kind of partial solution of the damage caused by the brain drain could be the practice of compensation. We have already good calculations of losses, but it is quite meaningless unless the question of compensation can be raised on this basis. Prof. Brinley Thomas, the well known British brain drain expert wrote about this problem already in 1966 : "If physical capital must be paid for, why should publicly financed human capital be received free ?" The Dutch demographer, G. Beijer has arrived at the conclusion that "migrating scientists should be considered as an item in the balance of payments". Other scholars like Prof. A. Sauvy and Prof. J.C. Shearer strongly oppose this conception. Although the idea of compensation emerged in the mid-sixties, no adequate steps were taken and even the idea has been forgotten for some years.

Nevertheless, it has experienced a kind of a revival in a more sophisticated form : J. Bhagwati, a Fellow of the Massachusetts Institute of Technology—I think he is of Indian origin — has forwarded earlier in some articles and now in his voluminous book published this year "The Brain Drain and Taxation" a new proposal. The principal beneficiaries of the brain drain are undoubtedly the migrants themselves and the developed countries of immigration. In so far as skilled migrants are able to improve their economic circumstances by this means, it seems appropriate that they should share some of their gains with the developing countries as a contribution to their development efforts. This could be effected by means of a supplementary tax on the migrant's disposable income in the developed country; the revenue so raised might then be redisbursed to the developing countries as additional development assistance through multilateral channels. The UNCTAD agrees with this proposal in its report. Although the proposal is very one-sided, it does not charge the developed beneficiary countries at all, it could have a certain effect, and it is worth to meditate on it.