SELECTED BIBLIOGRAPHY AND READINGS ON THE UTILIZATION OF RESEARCH RESULTS IN THE THIRD WORLD

A report prepared for IDRC's Communication Division

by

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Ottawa,
Friday, January 12,
1990

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TABLE OF CONTENTS

INTRODUCTION

This paper presents a review of selected literature on the complex issue of utilization of research results: what has been written about how research results are translated into concrete development.

This review is primarily focussed on research activities carried out in support of development in third world countries, often funded through such donor agencies like IDRC, CIDA, US AID, the Ford Foundation, or the Swedish SAREC.

In introducing the subject of utilization of research, it is helpful to present a case study of a simple waterpump that was introduced in South Vietnam in the early sixties.

> The pump consisted of a motor, an impeller, and a sleeve, and was "developed" in 1963 by a local farmer with mechanical skills. Its major economic advantage was that it could move the same volume of water in one hour that a water wheel manned by two people over five hours, and could lift water from the delta to the arable land at twice the height of the water wheel. Because the pump was made from locally available materials, was easy to assemble, and addressed a pressing local need for irrigating land, its use spread like wildfire. By 1966, there were no more water wheels to be found. The dissemination process -- which used no formal communication program, or any form of extension help -- occured strictly through word-of-mouth. Some farmers walked twenty kilometers to see such a pump.
>
> The author attributes the overwhelming success of this "spontaneous" dissemination of the technology to three factor: the clear profitability of the motor pump over existing methods (waterwheel), the doubling of land available for double cropping, because of the more than double height to which water could be lifted, and the lowering of seasonal unemployment, because of increased double cropping.
>
> **R.L.Sanson, "The Motor Pump: a Case Study of Innovation and Development", Oxford University Papers, Vol.21,No.1, March 1969.**

In effect, the pump story is about an indigenous innovation that turned out to be remarkably successful and reached 100% utilization in its particular environment.

What makes this case noteworthy is that all the components of the innovation-to-utilization process -- 1) a user-manufactured technology, 2) a most appropriate choice of technology for the environment in terms of simplicity of design, availability of materials, and offering an near perfect solution to real problem and need -- are precisely the ones that many innovators, donors and agencies are trying to replicate when engaging in developing and promoting a technology.

Other technologies are less appropriate, as the next case shows:

> This case involves the marketing of a new "North American-type" breakfast food in Kenya. The author stresses the high cost (a ratio of 90:1 between the "top" of the market "rice krispies" and the "bottom" of the market maize flour) and the low nutritional value of new brands of generally wheat not maize-based breakfast cereals. He points to the intensive advertising methods combined with other cultural influences (elitism, contacts with the west etc.) which stimulate these demands. Where they are produced locally (import-substitution policies) they use more imported equipment and raw materials and have considerably less local value added. They also employ less people and cause a fundamental misallocation of resources to nutritionally less rewarding foods. (DH-56)
>
> **KAPLINSKY, R., Inappropriate Products and Techniques: Breakfast Food in Kenya, in Review of African Political Economy, No. 14, January-April 1979.**

This case is about the introduction of a new food technology that may not fit the environment as well as the pump, and needs all kinds of additional marketing efforts to disseminate.

THE SCOPE OF THIS REPORT

How is research leading to a new technology connected to implementation and adoption of that technology? What are the stages that have to be passed? Are there mechanisms that can be analyzed, understood, and used, to ensure that the process is managed more effectively? This paper attempts to cover some of the fundamental theories and practices that have been written over the years on the process of moving from a research-based innovation to the eventual implementation and utilization in a given sector of an economy.

One interesting finding of this review is that there is no clearly defined literature on the utilization of research results in the third world. In fact there is very little material on the topic. The literature is rich, however, on such realted and peripheral subjects as social marketing of new ideas and practies in developing countries, or science, technology, industrial and economic policies of these regions, or specific research areas such as agriculture, health, policy studies, renewable energy technologies, or areas of education, technical extension, and communications. But few references if any have been been found describing or analyzing the process whereby a research activity is identified, conceived and carried out to its ultimate implementation and utilization in a particular area of society.

Because of the very wide and fragmented nature of the literature related to the use and application of technology and research results, the slice presented here is very selective and personal, reflecting the bias of the author. It will focus on the management and organizational aspects of the technology application and adoption process. Some theoretical references are included, mostly taken from the world of economics, since economists were some of the first thinkers on the subject.

Reference to experience in industrialized countries will be referred to when necessary, to illustrate specific management theories, or to refer to particular organizational research and concepts which are simply not discussed in the developing world literature.

We know that the industrialised countries spend roughly twenty times more on research and development than developing countries. Given the immense economic implication of that effort, it is not surprising that the North has chosen to invest more energy in understanding the processes underlying research, innovation, adoption, technology transfer, industrial commercialization and utilization of technology. This is reflected in the large literature in industrialised countries on research management, technology management, and adaptation of innovation in firms and industries.

REPORT OVERVIEW

The report has nine chapters:

1. The nature of research

To understand the process of utilization of research results, we first need to define what we mean by research. Some standard definitions of research are presented here, based on work by the OECD. The scope and distribution of research in developing countries is also presented, based on recent surveys carried out by IDRC. Although the data is very crude, it is estimated that some 16 billion dollars US were spent a year on research and development in developing countries, compared to 245 billion for the industrialised countries. Over half of the money was spent on agricultural research.

2. The theoretical basis for the utilization process

In this section, the theory of research, innovation, and technological adoption are reviewed in some depth. First, a historical review of the main currents of thought on technological innovation are presented by Andrew Jamison, in an essay excerpted from a book edited by Atul Wad. Nathan Rosenberg examines the principles of technological diffusion and adoption, by looking back to examples from the industrial revolution. This is followed by a review of research carried out in the seventies by Edwin Mansfield, a noted economist in technology transfer. Other works are also presented by Dahlman and Westphal on technological adoption in industries in the third world, and a theoretical analysis of how firms decide to adopt new technologies, by Bela Gold.

3. Science and technology in the third world: policy factors influencing the utilization of research results

In this section, works on the science and technology policy of third world countries are cited. Two major works are excerpted, Goldsmith and King's work on a new role for science and technology, as well as an insightful survey on the reaction to a series of recommendations to the Vienna 1979 UN conference on science for development. These and other citations give a good understanding of the research and science context in the third world.

4. Research and utilization as a management process

This section reviews the fairly new area of research having to do with management of research and technology transfer. We review some of the classic authors from MIT (Roberts, Allen), the marketing concepts of new product launching, and end off with a review of managing research in developing countries (India).

5. The case of renewable energy and appropriate technologies

Renewable energy and appropriate technology, in the absence of any integrated theory of utilization of results, offer a unique opportunity to look at all the components in the process of adopting new technology systems by a society: technical, economic, environmental, social, and political. It is a rich literature. The experience from these technologies, although it may not have resulted in significant market penetration, provides a unique overview, of what, with a little analysis, could become an overall utilization theory

6. The case of marketing policy research to decision-makers

This is a short section, but nonetheless important, since it identifies decision-makers as an important user of research results. Communicating effectively with this target group has received relatively little attention in the scientific community.

7. The case of agriculture and rural development

Agriculture receives over half of the research funding in the third world, and agricultural extension has been the traditional method of trying to disseminate that research. But as a World Bank evaluation claims, to work effectively, extension needs heavy financial and management support, of which neither are in oversupply in the third world. Some alternatives are cited. Again, this area in itself could be the subject of much more research.

8. The case of new strategic technologies

New technologies such as advanced materials, microelectronics, computers, and biotechnology are also beginning to penetrate the third world. Bhalla explores the notion of "blending" these with traditional technologies. Other works are also cited.

9. Organising for utilization and dissemination: making it happen!

The last section explores various models which have been experimented to utilize research results, including a novel way to reward government laboratories, a network for technology transfer, and a variety of measures to encourage the commercialization of new technologies. A cautious note is raised by Francisco Sagasti, who warns us that companies in developing countries may be following the path of "least technological effort".

ACKNOWLEDGEMENTS

Many thanks are due to the IDRC library staff, particularly Susan Hodges and Bev Chattaway, who have been unstinting in their help in collecting this data. A lot of the references identified here came from the IDRC library, and the many bibliographic databases available to it. One particularly rich source proved to be a small bookled edited by D.Hurley, "The Management of Change - An Annotated Bibliography" published in 1987 by IT publications. A number of references in this paper have been quoted from this source, and are identified by the notation (DH-no.), the number being the that of the citation in the IT report.

1. THE NATURE OF RESEARCH

If we are interested in understanding how research results can be used, we must first understand the nature of the research activity itself. This question has preoccupied experts in the field of economics, science policy, innovation theory, and the history of science and technology for many decades.

It is also a subject that has been of growing concern to funders of research. As the price of research keeps growing, and donor agencies are becoming more pressed for funds, there are increasing questions being asked as to its benefits and spinoffs for society. The price tag on some research projects are reaching astronomical proportions. As an extreme example, two recent "big science" projects being considered in the US, a high energy physics super-conducting super-collider to measure fundamental particles, or a genetics project to map the human genone, have been costed in the multi-billion dollar range each. The running of research establishments is also becoming more expensive. Funders, including donor agencies and governments, faced with these growing costs, are increasingly interested in getting the biggest bang for the buck, and increasin the effectiveness of these institutions, as we have seen in a number of western countries.

In aid and development, the concern takes the form of growing questions rasied by Donor agencies on the impact of funded research on development. Specifically, in the case of IDRC, the persistent question that is being asked is what have twenty years of funding research-based activities contributed to development. In answering this question, efforts are made to identify examples of projects that have been used. Hence, the question of utilization. Utilization is one of those encompassing words, like innovation and technology transfer, at least in the IDRC parlance. Unlike innovation and technology transfer, it is not sufficiently mature as a buzzword to figure as a recognized key word in the several databases that were consulted.

THE DEFINITIONS OF RESEARCH

There are many reasons why people carry out research: to discover what makes the universe or the atom tick, and decipher some of the fundamental laws of nature, to discover a vaccine for aids, to develop a bigger and faster computer to predict the weather and break intelligence codes, or to make a company richer and more competitive on the international markets. Each performer of research has a unique reason or objective for carrying out an investigation called research, particular to his organization or group.

Much effort has been spent in trying to categorize research activities, and each of these attempts is probably valid and useful for that particular context. Basically, the reason for labelling activities is to make life easier for the person doing the labelling. Governments will label research activities to facilitate their funding decisions, as between universities, *regions, and government departments. A company will label its research depending on whether the payoff is longer term, short term, or critical to its operations, as in the case where the assembly line and production process are shut down until a technical problem is resolved. And depending which label it chooses, different accounting and tax treatments will apply.*

One of the better known set of definitions of research categories has been formulated by the OECD who developed these categories so that OECD member countries could compile research and science and technology statistics, known as science indicators, using the comparable criteria.

The Measurement of Scientific and Technical Activities – Frascati manual 1980, OECD, Paris 1981

It is useful to review some of these definitions:

> (p. 25) Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock on knowledge to devise new applications.
>
> Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
>
> Applied research is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.
>
> Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience that is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improve substantially those already produced or installed.
>
> p 15. R&D and Scientific and Technological Innovation
>
> Scientific and technological innovation may be considered as the transformation of an idea into a new or improved saleable product or operational process in industry and commerce or into a new approach to a social service. It thus consists of all those scientific, technical, commercial and financial steps necessary for the successful development and marketing of new or improved manufactured products, the commercial use of new or improved processes and equipment or the introduction of a new approach to a social service. R&D is only one of these steps.

Besides R&D, six activities may often be distinguished in the innovation process.

i) New product marketing is the set of activities necessary to the successful introduction of a new product or process into the market. Its costs are those of market research and test marketing; the nonrecurring costs of establishing distribution, maintainance, and sales channels and advertising systems including the initial outlay on advertising.

ii) Patent work is the filing of patent applications and the carrying out of searches for prior patents in connection with the product or process being introduced or improved.

iii) Financial and organisational changes may be required to finance the innovation and to permit the company to successfully exploit it. These include the non-recurring costs of financial planning, raising additional capital, corporate restructuring and retraining of sales and maintainance personnel and exclude the interest paid on borrowedfunds and the foregone interest on own unds used.

iv) Final product or design engineering is the further modification of a product or process after the R&D phase is completed in recognition of market or manufacturing requirements. For instance, it includes the cost of of industrial design for aesthetic value and of preparing production drawings, part lists and specifications.

v) Tooling and industrial engineering covers all changes in production machinery and tools, in production and quality control procedures, methods and standards required to manufacture the new product or to use the new process.

vi) Manufacturing start-up includes the cost of retraining personnel in the new techniques or in the use of new machinery, trial production runs and the cost of items damaged because of faulty equipment, procedures and operator errors.

Furthermore, in the case of innovations based on government R&D programmes, there may be a significant "demonstration" stage in the process. "A demonstration is a project invlovling an innovation operated at or near full scale in a realistic environment for the purpose of (i) formulating national policy or (ii) promoting the use of innovation." It should be noted that the data collected and published by the International Energy Agency at OECD cover Research, Development, and Demonstration ("R' D' and D").

Possibly the greatest source of error in measuring R&D lies in the difficulty of locating the cut-off point between experimental development and the related activities which are required during the realisation of an innovation.

Errors at this point are particularly significant because, though many innovations may require costly R&D, the costs of preparing the invention for production are often higher still.

THE SCOPE OF RESEARCH IN THE THIRD WORLD

Because this paper focusses primarily on research in developing countries, it is useful to review what we know about the scope and distribution of these research efforts. In effect, there is little known about the R&D effort of developing countries with any accuracy resembling the OECD statistics, and IDRC has been one of the few carrying out some seminal survey research on the subject. This exerpt from IDRC's annual review "Searching" provides as good a summary of what we know about third world research:

IDRC (International Development Research Centre). 1987. "Partners in Innovation", Searching, IDRC-257e. p 10-13.

It is extraordinarily difficult to provide an assessment of the amount of resources - both financial and human - that the Third World devotes to research. Where estimates exist, they are seldom constituted on a comparable basis; indeed, comparison of different sets of data may well reveal major discrepancies. There is a great need to improve the data available in this area. A distinguished observer, Mahdi Elmandjra, noted recently that "it was not until 1978 that the General Conference of the United Nations Educational, Scientific and Cultural Organization (Unesco) adopted the recommendation on the international standardization of statistics on science and technology. It will take many more years before we can dispose of relatively reliable and internationally comparable data on research and development expenditures."

Those estimates that do exist on developed- and developing-country overall expenditure on research and development (R&D) provide some basis for making a number of major points such as the stark contrast between the proportion of world R&D expenditure being realized in and for the two sets of countries. It is at the individual country level, however, where major decisions must be taken about the allocation of resources to research, that the need for better information is most crucial. Along with others, IDRC hopes to play a role in facilitating the collection of information and quantitative data by countries to assist in planning future research expenditure.

In the case of agriculture, most countries have a better picture of the resources devoted to research than for other sectors, although even here the information is incomplete. The International Service for National Agricultural Research (ISNAR) is developing a data base designed to provide comparative information on agricultural research throughout the developing world; data will be based, where possible, on responses from countries themselves, supplemented by information from other primary and secondary sources.

Notwithstanding the difficulties of finding or collecting data in this area, there are a number of preliminary statements that can be made to provide a sense of the situation:

One of the earliest estimates (in the 1960s) in this area was that developing countries accounted for 2% of world R&D expenditure. An estimate was made for 1973 and gave the same ratio as being about 3%.

Unesco data shown in the 1985 statistical yearbook suggest that developing countries accounted for 2.3% of R&D expenditure in 1970 and for as much as 6% in 1980. Similar data on numbers of R&D scientists show developing countries with 7.9% of the total in 1970 and 10.6% in 1980.

There is a major imbalance between the proportion of worldwide research undertaken in the Third World and its share of world population (81%) or of combined world production (21%). The figures show that over the last 20 years there has been some small reduction in this imbalance; however, the developing countries, as a whole, continue to invest usually less than 0.5% of gross domestic product (GDP) in research activities, whereas the corresponding figure for the leading developed countries is 1.5-2%.

More detailed estimates exist for agricultural research; however, even here there is a range. In 1979, one study estimated that 15% of global expenditure on agricultural research was spent in the [p. 11:] developing countries; another study completed shortly after suggested that one-quarter of global agricultural research was related to expenditures in the developing countries.

Most studies indicate that, whatever the relative proportion of R&D expenditure in developing and developed countries, the absolute amounts spent in this field by developing countries have increased enormously in the last 20 years. In agriculture, a study covering the data for 67 developing countries estimated that, in 1980, expenditures on agricultural research at 1975 prices were in the order of $1082 million, 71% higher than the amount spent in 1975 and 170% higher than the level reached in 1970.

There is enormous imbalance, even in the amount of money spent on R&D by the developing countries. A few major countries account for a very large percentage of overall expenditure, e.g., Argentina, Brazil, China, India, Mexico, and South Korea. Unesco figures on R&D scientists show that, of the number estimated to be working in the developing countries, 4%

are in Africa, 8% in the Arab world, 23% in Latin America and the Caribbean, and 65% in Asia. (Corresponding figures for overall developing world population distribution are 11, 7, 11, and 71%, respectively.) One should also note, however, the imbalance between developed countries where, of the 24 OECD member countries, 88% of expenditures devoted to R&D in 1984 was taking place in 5 countries.

If the 1960s and 1970s were characterized by rapid growth in absolute expenditure on R&D in developing countries, present circumstances would seem to suggest that the rate of growth is likely to slow and that increasing attention will have to be paid by developing-country governments to the question of increasing returns to the funds invested in research.

The R&D industry in developing countries now accounts for about $16 billion/year and yet the broad parameters of this major activity remain largely underresearched and unknown. The equivalent figure for OECD countries is about $245 billion (1984) - a further indication of the striking global imbalance in this area of development investment.

(...) As a first step in improving its knowledge of the environment in which it operates, IDRC determined to fund a study of support provided to Third World R&D by major funding agencies. This was undertaken by Professor John P. Lewis (...). A brief presentation of some of the survey's findings follows.

Professor Lewis encountered major difficulties in collecting information, by questionnaire and through visits, on a consistent and comparable basis; a considerable part of this report deals with these problems and suggests methods for donors to capture information on this set of activities more easily. As it is, there are still anomalies apparent in the data presented - probably in part because of responses of "agencies" capturing slightly different sets of activities. It is hoped that the presentation of preliminary data will contribute to better information being available in the future.

The survey data cover eight DAC countries, the World Bank, the Asian and Inter-American Development Banks, and the United Nations Development Programme. The DAC countries covered accounted for some 82% of DAC's overall ODA in 1984 and so provide a fairly representative picture of DAC funding. According to OECD statistics, the same eight countries account for 63% of all world ODA. As a group, these eight appeared to be devoting some 4-5% of ODA resources to research for development. This overall percentage would be higher if it related only to direct flows to developing countries because, typically, some 30% of ODA is to multilateral agencies (e.g., agencies of the United Nations system and the aid branch of the European Economic Community [EEC]).

Individual countries' percentages of ODA devoted to research range from nearly 10% (Netherlands and United Kingdom) down to 3.1% for the USA.

Table 1. Estimates of funding for development-related research from eight Development Assistance Committee (DAC) countries, 1984 (CA $ million/year)

Rural and area development[a]	1038	65%
Technology, science and national policy[b]	251	16%
Human resources development[c]	257	16%
Other	56	3%
Total	1602	100%

[a]Rural and area development includes agriculture and rural development and ecology, natural resources (including energy), transport and communications, and human settlements and area planning.

[b]Technology, science, and national policy includes engineering and technology, including adaptation and transfer; natural sciences; and industrial development and management, development planning, economic policy, and applied social sciences.

[c]Human resources development includes research on education and training; health and nutrition; income distribution, poverty, and employment; and population.

While the first excerpt of "Searching" provides a good overview of the overall effort in R&D in developing countries, the second excerpt gives a more in-depth view, albeit still very crude, of how this effort is distributed accross various areas. This is based on a survey of about 300 multi-lateral research institutions:

IDRC (International Development Research Centre). 1986. "Research: A Path to Development", Searching, IDRC-245e. 52 p.

Nearly 300 institutions were initially identified that were based in developing countries and appeared to have a multilateral mandate and a direct role in undertaking or complementing research. No research-funding agencies were included. Although the survey is not yet finished, 192 institutions have now been confirmed, mostly by returns to a mail survey, as fitting the general criteria of the study.

The survey covered a heterogeneous array of research-related institutions. "Multilateral" was taken in most instances as meaning that an institution covers at least three countries, both in the sense of it owing its existence to the initiative of several countries or multilateral agencies and in having an objective of providing services to more than one country. These institutions are usually termed regional or international. "Multilateral" has been used here to cover both categories. Of the 192 institutions that have returned questionnaires, probably 30 could reasonably claim to have an "international" focus in terms of covering a number of geographical regions, whereas the remaining 162 were regional. This was not, however, a hard and fast line.

The IDRC survey includes both institutions that are directly involved in conducting research as their major purpose (the Asian Vegetable Research and Development Centre and the Caribbean Industrial Research Institute, for example), and those that are research complementing by providing support services to research such as research promotion, training, information, and dissemination (for example, the Council for the Development of Economic and Social Research in Africa and the Arab Organization for Agricultural Development). Although a distinction has been made between these two groups in terms of their involvement in research, the institutions more properly belong on a spectrum. It is easy to distinguish between institutions at opposite ends of the spectrum in terms of their role in research, but the dividing line between the two categories is not a hard and fast one. At present, 82 of the 192 institutions are classified as "conducting research" and 110 as "research complementing."

The information collected to date is believed to be reasonably comprehensive and representative of the total. (...) It covers only those institutions that are based in developing countries; those based in developed countries, such as the International Food Policy Research Institute (IFPRI), represent a significant additional number of institutions.

The total resources required annually for the activities of all institutions covered in the survey may be as high as $1 billion. Those institutions involved in a major way with research account for about $500 million, of which the International Agricultural Research Centres (IARCs) make up a little under half. The research budget of institutions involved less directly in research is a further $75 million.

Research may not be a major part of the overall mandate of some of those organizations identified as "research complementing," but, nevertheless, they play an important role in research developments and coordination in their regions. All institutions were asked to estimate the research portion of their budgets, although they have clearly done this using considerably different criteria. Some of the IARCs, for instance, report as little as 40% of their total budget as research, where for the purposes of the IDRC survey almost their entire budget might usefully be counted as research.

A sectoral breakdown of institutions indicates a concentration in agriculture and social sciences (see the following table) with considerably less focus on health and industry. If education were included with the social sciences, the number of institutions in the agricultural and social sciences fields would be approximately the same.

Although the data on the resources of these institutions are still the least precise area of information collected in the survey, it seems that they employ over 5000 professional staff (the term professional was used for personnel having at least a Bachelor's degree or its equivalent.

Multilateral research-related institutions by sector and by region of the world, 1983.

	Sector Total	Percentage Total
Agriculture	63	43
Social Sciences	41	21
Education	20	10
Multisector	18	9
Health	17	9
Industry	10	5
Management and Administration	7	4
Environment and ecology	4	2
Information and communications	4	2
Engineering and technology	3	2
Physical Sciences	3	2
Energy	2	1
Total	192	100

2. THE THEORETICAL BASIS FOR THE UTILIZATION PROCESS

In this section, we will review some of the fundamental theories on the innovation process and technology transfer and diffusion.

A good overview of some of the issues linking research, science, and technology to development is given by WAD:

Wad, A. (ed.). 1988. Science, Technology and Development. Westview Press, Inc., Boulder, CO, USA. p 2-5.

> It is important to recognize, however, that the Vienna Program is a specific articulation of a much larger and complex subject of both intellectual inquiry and practical action. The relationship between scientific and technological change and socio-economic development has been a subject of study and concern for several decades, if not longer. It is a complex subject, with various disciplinary ideological and philosophical perspectives represented and often in conflict with each other, many different interpretations about the domain of the field, and even more differences of opinion as to what works and does not work, and for what end goal, in the real world.
>
> Secondly, the global context of science and technology has itself changed. The debt crisis, increasing levels of environmental degradation, social crises (famines and droughts), political instability, and increasing protectionist tendencies all have had an effect on how science and technology is perceived and acted upon. In some ways, it could be argued that whereas the Vienna conference served to make science and technology a subject of special focus and concern, today there seems to be a tendency for it to become immersed in a broader milieu of social, political and economic concerns. The large external debts of several developing countries have undoubtedly had an effect on governmental spending on science and technology. The drought in parts of Africa has influenced how some of those countries view science and technology. The rapid economic growth of the southeast Asian NIC's has channeled their scientific and technological activities in specific directions.
>
> In the first section, devoted to historical and contemporary perspectives, Andrew Jamison explores how innovation theories and science and

technology policies have evolved historically. It is important to have a historical perspective on the subject so as not to forget that the field as such is not new nor solely concerned with the problems of the third world. That is a more contemporary manifestation. Indeed, Jamison suggests that the precursors of theories of science, technology and societal change go as far back as the 16th century. These deep historical roots are important because they serve to broaden the character of the field and make it possible to establish analytical linkages between the growth and evolution of science and technology, the development of societies and the interpretations of these developments as seen by economists, sociologists, political scientists and historians. (p. 2-5)

In Wad's book, there is an important essay on the history of technology development by Jamison which, because of its value in understanding present issues, is excerpted in some detail here:

INNOVATION THEORIES AND SCIENCE AND TECHNOLOGY POLICY: HISTORICAL PERSPECTIVES by Andrew Jamison, in Wad, A. (ed.). 1988. Science, Technology and Development. Westview Press, Inc., Boulder, CO, USA. p 17-53

Introduction: Definitions and Distinctions

For something that is widely considered to be of crucial, even strategic, importance, it is remarkable that there is so little agreement as to what is meant by technological innovation. (...)

Many innovation theories are also subject to what might be called a commercial bias; for many of those who seek to analyze it, innovation has come to mean the creation of new marketable commodities. There is, we might say, a narrow definition that takes its point of departure in Joseph Schumpeter's distinction between invention and innovation, the first being the making of something new, the second being the successful launching of that new something in the marketplace. As opposed to the narrow, commercial definition, there is the broader idea of an innovation process as a wide-ranging social activity, including in its purview the entire continuum, or chain, of scientific research and technological development from he most basic laboratory investigations to the distribution of new products, and not forgetting all the organizational, or social, innovations in between. It is such a broad notion of innovation that forms the point of departure for the pages that follow.

Prehistory - On the Making of Innovation Theory (p. 22-24)

As with most areas of social and historical analysis, theorizing about scientific and technical innovation is largely a 19th and 20th century activity. Precursors can be located in antiquity, as well as in the medieval period; but it was not really until the later medieval period, in the 16th century, that a specific innovation literature began to emerge, most especially in the technical treatises of Biringuccio (Pyrotechnia, 1540), Agricola (De re metallica, 1556) Ramelli (Le Diverse et Artificiose Machine, 1588), and others. In these works, amidst technical detail and fascinating pictorial representations of existing and imagined machinery, there was also a good deal of what we might call "proto-innovation theory," i.e., ideas about the most effective ways to organize and diffuse technical development practices.

Innovation - the creation of something new - was not the center of focus, however; there was little systematic interest in technical research or development. The works were primarily technical manuals, rather than works of social or economic analysis, but they do indicate how the European society of the late Renaissance was beginning to interest itself in things technical, in facts and artifacts and technical processes. They also show how one of the most important technical innovations of all - the printing press - was a contributing factor in the emergence of innovation theory. Printing made it possible to disseminate information, and one of the main sorts of information disseminated in the early printed literature was technical information. Perhaps most importantly, however, these treatises helped to elevate the status of the technical practitioner, giving technical work a social importance that it had previously not had, at least not since the "industrial revolution" of the 12th and 13th centuries, when the Gothic cathedrals were built and the master builders occupied a privileged position in the textile cities of western Europe. **[Footnote:** An intriguing source on medieval technology, especially the industrial revolution of the 12th and 13th centuries, is Jean Gimpel, The Medieval Machine, Penguin, 1975. Lynn White's collected essays, Medieval Technology and Religion, University of California Press, 1978, are also well worth consulting, as is Arnold Pacey, The Maze of Ingenuity, MIT Press, 1976. The importance of the printing press has been stressed, perhaps overly so, in Elizabeth Eisenstein, The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early Modern Europe, Cambridge, 1979.]

Their concerns would, in the early 17th century, come to be articulated and systematized by the English philosopher-politician Francis Bacon, who has been called the first philosopher of industrial science. **[Footnote:** See Benjamin Farrington, Francis Bacon, Philosopher of Industrial Science, Collier Books, 1961. An analysis of Bacon's relation to the earlier traditions can be found in Paolo Rossi, Francis Bacon: From Magic to Science, Routledge and Kegan Paul, 1968.] Bacon saw in the new techniques of printing, gunpowder, and the mariner's compass the basis for a new kind of learning that was predicated around use rather than divinity, useful knowledge rather than scholastic discourse. His vision of the future technological society in New Atlantis (1624) was merely a sketch, and a rudimentary one at that, but, together with his more explicitly philosophical works, it helped infuse the millenarian social movements of the time with an intense interest in technical "improvements," both in agriculture as well as in "trades."

(p. 28-29) Marx and his colleague, Friedrich Engels, were perhaps the most ambitious of all 19th century writers in trying to grasp the social and historical significance of industrial technology. Even a contemporary writer like Nathan Rosenberg, who could certainly not be accused of being a marxist, has argued that Marx's "formulation of the problem still deserves to be a starting point for any serious investigation of technology and its ramifications." **[Footnote:** Nathan Rosenberg, Inside the Black Box: Technology and Economics, Cambridge, 1982, p. 34. For another recent assessment, see Donald MacKenzie, "Marx and the Machine," Technology and Culture 25, 1984.]

In particular, Marx and Engels focused on the transformation in technological innovation that was taking place in the 19th century - the shift from the artisanal mode of the first scientific revolution to the science-based mode of technical production, which we can consider a second scientific revolution. Again, it was the changes in practice - in the organization of research (university and later industrial laboratories), the inter-linking of research and industry (the industrial corporation), and the changed technology-orientation of science (toward chemical processes and electrical/energetic phenomena) - that formed the basis for changes in innovation theory. It should not be forgotten hat Engels followed these transformations at close range, by directing an industrial firm in Manchester, and that he associated with leading chemists and other scientists of the day. It was such experiences that helped form Engels' and Marx's views on the interdependence of science and technology; as Engels puts it, in a letter to a corespondent, "if, as you say, technique largely depends on the state of science, science depends far more still on the state and requirements of technique. If society has a technical need, that helps science forward more than ten universities." **[Footnote:** Letter from Engels to W. Borgius, 1894, reprinted in Karl Marx and Frederick Engels, Selected Works, Progress Publishers, Moscow, 1978, p. 704.] And it was the technical needs of 19th century Europe that were changing so dramatically, and which formed a central focus of investigation for Marx and Engels.

Marx was one of the first to try to grasp the transformation that was taking place in terms of its scientific-technical dimension. Firstly, he drew a fundamental distinction between tools and machines, criticizing his predecessors for neglecting the "essential difference between them." As he put it, "Mathematicians and experts on mechanics -and they are occasionally followed in this by English economists - call a tool a simple machine and a machine a complex tool." **[Footnote:** Karl Marx, Capital: A Critique of Political Economy, volume one, Penguin, 1976, p. 492.] Marx combined the internal and external approaches to analyze the machine as a social phenomenon; its most important characteristic was that it replaced manual labor. It did this by combining three different parts: a motor mechanism, a transmitting mechanism, and the working machine, or tool. Marx drew on the economic analysis of the division of labor and specialization of industrial tasks in the factory that had begun to be carried out by Smith, Stewart and Saint-Simon; but he could also utilize the writings of the early synthesizing theorists of innovation - Andrew Ure, Charles Babbage, and Robert Owen and his followers, including William Thomson, one of the leading Owenite political economists. **[Footnote:** See Alvin Gouldner, Against Fragmentation: The Origins of Marxism and the Sociology of Intellectuals, Oxford, 1985, for an intriguing discussion of Marx's sources.] Most especially, however, he based his theories on the actual practice of industrial transformation, as described in the various reports on factory production that were produced in the mid-19th century, especially in England, the home of the industrial revolution.

(p. 30) Thirdly, and most crucially, Marx drew attention to the new kind of relationship that was emerging between science and technology, to the new mode of scientific production. He called the new system of production "revolutionary" because it "never views or greats the existing form of a production process as the definitive one ... By means of machinery, chemical processes and other methods, it is constantly transforming not only the technical basis of production but also the functions of the worker and the social combination of the labor process." And it was revolutionary because it was based on science: "the varied, apparently unconnected and petrified forms of the social production process were now dissolved into conscious and planned applications of natural science." **[Footnote:** Marx, op. cit., p. 616-617.]

(p. 33) Four years later, Mumford (1934) wrote his magnum opus, Technics and Civilization, which more than any other single book would serve to define the history of technology as a distinct historical sub-specialty. The aim of the sub-specialty, then as now, is to show the "human values in machinery," the cultural motivations behind technical change and innovation. Characteristically, the journal of the society of the history of technology in the United States, when it began to be published in 1958, was entitled Technology and Culture in order to emphasize the orientation toward the broader social and cultural understanding of technology. Elsewhere, where the history of technology took on an antiquarian character and was primarily associated with technical museums and engineering societies, it would have little to offer to innovation theory. **[Footnote:** For review of these cultural approaches to technology, see Carroll Pursell, "History of Technology," and Carl Mitcham, "Philosophy of Technology," in Paul Durbin, ed., A Guide to the Culture of Science, Technology, and Medicine, Free Press, 1980.]

(p. 34) Two main approaches emerged. One was epitomized by Abbott Payson Usher's History of Mechanical Inventions (1929), which traced the technical history of the various machines and mechanical procedures of industrial society, trying to place a "technical history" of innovation at a central location in the new sub-disciplinary discourse. The other was epitomized by the writings of Joseph Schumpeter, which sought to elucidate the longer-range processes that governed the development of technology. Indeed, Schumpeter's cyclical theory of economic growth proposed a central role for technology; he argued that behind Kondraieff's long waves, there were fundamental technological breakthroughs - "radical innovations" - that brought about new periods of expansion for the capitalist economy. Economic development, for Schumpeter, was a process of "creative destruction," by which one system or cluster of technologies replaced another. Usher and Schumpeter thus represented micro and macro approaches to the history of technical change within the new sub-discipline of economic history.

The social theorists, perhaps especially Pitirim Sorokin, who had emigrated to the United States from the Soviet Union, shared with Schumpeter and Mumford a concern with the long cycles of historical movement, and sought to link the development of technology to the broader movements of cultural values. W.F. Ogburn, in Social Change (1922), had developed the concept of "cultural lag," the notion that cultural development lags behind the development of technology. For Obgurn, the task of the sociologist was to analyze the mechanisms by which society could assimilate its technical innovations. It was thus no accident that Ogburn was called on to direct what has been called the "first modern technology assessment," namely the report Technological Trends and National Policy, that was published by a U.S. government committee in 1937. **[Footnote:** National Resources Committee, Technological Trends and National Policy, Including the Social Implications of New Inventions, US Government Publications, 1937. The report is presented in Arlene Inouye and Charles Susskind, "Technological Trends and National Policy, 1937: The First Modern Technology Assessment," Technology and Culture 18, 1977. See also Carroll W. Pursell, "Government and Technology in he Great Depression," Technology and Culture 20, 1979.] Indeed, it may well have been due to Ogburn's concern with the social aspects of technical change that the report was commissioned in the first place; it included surveys of technical developments in various sectors, written by industrial leaders for the respective areas. In some sense, it can be considered one of the first signs of a more systematic technology policy interest.

(p. 35) A third American sociologist, the marxist Bernhard Stern, who helped found the journal Science and Society, also studied technical change in a number of writings in the 1930's and 1940's, focusing on patent statistics, diffusion patterns, and in the report to the U.S. government, "resistance to the adoption of technological innovations." **[Footnote:** These developments - and much else of relevance - are described in David Noble, America by Design: Science, Technology, and the Rise of Corporate Capitalism, Knopf, 1977.

The Stages of Science and Technology Policyand Their Relation to Innovation Theories (p. 35-38)

In 1939, the British physicist John Desmond Bernal initiated a new era in the social study of science and technological innovation with the publication of his book, The Social Function of Science. Bernal had been active in the communist party during the 1930's, and had been one of the formative influences in the "social relations of science" movement among natural scientists, which had its base at Cambridge. There were similar groups of socially concerned natural scientists, especially physicists, in most of the other industrialized countries, but none of them were as productive or active as the so-called "visible college" in England, with names like Joseph Needham, P.M.S. Blackett, J.B.S. Haldane, Lancelot Hogben, and Hyman Levy [**Footnote:** For details on the activities and concerns of this group of scientists, see Gary Werskey, The Visible College, Allen Lane, 1978.]. It was out of such a context that Bernal wrote his book in 1939, which gathered as much material as was then available about the way in which scientific and technical research interacted with social development. More than any other single contribution, Bernal's book marked the coming of the age of science policy, and it would serve, in the immediate postwar period, when meso level bodies were established throughout the world, as a first set of theories and concepts for the organization and management of science and technological innovation.

In accordance with his adherence to scientific marxism, Bernal saw science as a crucial element in the transformation of society into socialism, and he saw science primarily as a productive force, as a component of technological development [**Footnote:** For a concise presentation of Bernal's Marxism, see John D. Bernal, Marx and Science, International Publishers, 1952.]. His message was that science should not be left to the private industrialists, but that a massive state involvement - both financial as well as organizational - was required to bring the fruits of science to productive use. He was inspired, as were many natural scientists of his generation, by the social experiment in planning science and technology that had been taking place in the interwar years in the Soviet Union. And he was engaged in the battle against nazism and fascism, for he saw them as enemies of science and of reason more generally. For Bernal and the other members of the visible college, only socialism could provide he long-term guarantee for scientific and technical innovation, but Bernal's socialism was to be itself guaranteed by science. And that was why it was so important for the state to contribute to the further development of science and technology. By supporting science, society would become, of necessity, socialist.

Not long after the ink had dried on the pages of Bernal's text, Germany had invaded Poland. The second world war had begun, and scientists and governments entered into that uneasy relationship that has since characterized their interaction: the age of science policy had come. It was not merely in the Manhattan project - the building of the first atomic bomb at Los Alamos in the wilds of New Mexico - that that relationship manifested itself. In all the belligerent nations, and many of the neutrals, meso level bodies were created to coordinate the utilization of science and technology for the war effort. Many of these bodies were headed by scientists, like Vanneaver Bush and James Conant in the United States, and Solly Zuckerman in England. Many other scientists and engineers were called in as advisors to government and helped to develop strategic instruments of warfare, like radar, computers, operations research, and eventually the atomic bomb. Still others were drawn, in more peripheral ways, into the big science projects that originated in the wartime effort. Science, in other words, had largely come to be integrated into defense policy or, more generally, into the discourse of strategic thinking. And in the process, it had come to be transformed into what Jerome Ravetz was later to call "industrialized science": the craftsman's work that was science had become an industry [**Footnote:** See Jerome R. Ravetz, Scientific Knowledge and Its Social Problems, Penguin, 1973. Several of the essays in Ina Spiege;-Rosing and Derek de Solla Price, eds., Science, Technology and Society, Sage, 1977, especially those by Jean-Jacques Salomon and Sandord Lakeoff, provide extensive reviews of the changes in thinking brought about by the stages in postwar science policy. On these matters, see also Derek de Solla Price, Little Science, Big Science, Columbia University Press, 1965.].

In what we can term the first phase of postwar science and technology policy, the overriding objectives were strategic/military. Science and technology were seen as strategic national resources, and they were conceptualized primarily in military terms. There was relatively little concern with the precise nature of innovation - with going "inside the black box." What was fundamental was the quantity of innovation taking place and being diffused into the wider society. Technology, and especially nuclear science, were widely seen as having been crucial to the Allied victory, and the important task was to further develop that resource that had been so vital to the war effort.

This was thus the period in which innovation was seen primarily as a matter of "science-push." It was science that was seen as primary and fundamental to the innovation chain, and it was thus science that was primarily to be supported and subject to policy measures. Science, in the words of Bush, was the "endless frontier," the never-ending source of new things, both weapons for the military as well as products for the consumer. The interlinkage between science and technology, however, was not seen as being particularly problematic. Rather, the problem was one of insuring autonomy for science, so that new ideas could develop under the control and authority of the scientists themselves [**Footnote:** Vanneaver Bush, Science, the Endless Frontier: A Report to the President on a Program or Postwar Scientific Research (1945), reprinted by the National Science Foundation, 1960, was one of the first doctrinal texts of postwar science policy.].

Within the academic discourse over innovations, there was a fragmentation into specializations, largely according to functional areas. Historians and philosophers of science focused on the internal development and justification of scientific ideas; economists and - perhaps even more so - geographers focused on the societal spreading or diffusion of new techniques [**Footnote:** On science studies, see Arnold Thackeray, "History of Science," in Durbin, ed., op. cit., and for studies on the diffusion of innovations, see Everett Rogers, Diffusion of Innovations, Free Press, 1962.]. In between, a new kind of scientific management discourse began to develop, a discourse about the management of big science and large research establishments. It was, to a significant extent, inspired by Bernal's concerns and concepts, but it was cleansed of avowed socialist faith and primarily framed in terms of costs and benefits, effectiveness and payoffs. It focused on the question of how much governments, through their new meso level bodies, could plan science, and how expenditures for basic research could be motivated in a national economic calculation. It was a discourse largely conducted among the R&D managers themselves, but with time, they received some scholarly help from a handful of political scientists, who started to see the relations between science and government as a special area for academic investigation. (Interestingly enough, however, even some of the early academic experts, like Don Price, author of one of the first studies of the new area, Government and Science (1953), came to the subject from a practical war-time experience in the planning and coordination of research. Alvin Weinberg, who started publishing his "Reflections of Big Science" in the late 1950's, was, for many years, director of one of the large nuclear laboratories, at Oak Ridge.) [**Footnote:** Alvin Weinberg, Reflections on Big Science, MIT Press, 1967, and Edward Shils, ed., Criteria for Scientific Development: Public Policy and National Goals, MIT Press, 1966, are two collections of some of these early contributions.]

(p. 39-40) In the United States, this kind of critical understanding was operationalized, among others, by the economist and latter-day follower of Throstein Veblen, John Kenneth Galbraith, who saw in technological innovation the replacement of the profit motive as the driving force of capitalist industry, and talked of a new kind of industrial society, the "affluent society," in which wealth was not merely to be produced but to be directed and steered, as well.

On the basis of such writings - and of the external challenge of the Soviet space program - ideas about innovation grew more sophisticated and a new kind of economic concern with technical development began to emerge, in the writings of Kuznets, Schmookler, Mansfield, Arrow, Nelson, and others. In the 1960's, technological innovation came to be linked explicitly to economic development, and economists attempted to measure the contribution of technical change to economic growth rates. Much of their work was highly mathematical and difficult to understand. In general, however, there was a filling of the gap between what had previously been the somewhat disparate discourses of diffusion theory, on the one hand, and scientific ideas, on the other [**Footnote:** For a representative sampling of these writings, see Nathan Rosenberg, ed., The Economics of Technological Change, Penguin, 1971.]. Now, with the innovation economists - and a handful of historians of technology, like Edwin Layton and Thomas Hughes, who were studying the role of the engineer in technical change - the link between science and the larger economy, the technical development process itself, was being studied [**Footnote:** See Thomas Hughes, Elmer Sperry: Inventor and Engineer, Johns Hopkins, 1971, and Edwin Layton, The Revolt of the Engineers, Case-Western Reserve, 1971.]. Smookler studied patents and patent statistics, Nelson looked at the "economics" of basic research, Arrow quantified economic growth, and Mansfield looked at the technical strategies of firms; and soon Galbraith would come with a catchy phrase t describe the whole phenomenon: "the new industrial state." (**Footnote:** In many respects, John Kenneth Galbraith, The New Industrial State, Houghton Mifflin, 1967, epitomized the new conception of technology that was dominant in the 1960's. See also Jacob Schmookler, Invention and Economic Growth, Harvard, 1966, Richard Nelton, The Rate and Direction of Inventive Activity, Princeton, 1962, and Fritz Machlup, The Economics of Technological Change, Norton, 1968. The new concern with technological development was also reflected in economic history, where technical innovation was given a central place in explaining the coming of industrialization in, for example, David Landes, The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present, Cambridge, 1969. With the new concern in economic policy and in science and technology policy, as well, with "reindustrialization," which we shall briefly discuss in the concluding section, this kind of work has recently experience something of a revival; for a comprehensive theoretical treatment, see Richard Nelson and Sheldon Winter, An Evolutionary Theory of Economic Change, Harvard, 1982, and for a critical discussion and application, see Giovanni Dosi, Technical Change and Industrial Transformation, Macmillan, 1984.]

This phase, from the late 1950's to the late 1960's, can be called the economic phase of science and technology policy, for at the same time as the academics were beginning **[p. 40:]** to focus on technical development itself, new meso level bodies were being created in many industrialized countries to coordinate and finance technical development in industry. This was done indirectly in the United States, through the establishment of new departments of industry and councils for technical research and/or technical development.

This second phase was also marked by the emergence of a new kind of international coordination of science and technology policy - through OECD and some of the United Nations agencies, especially UNESCO. Where the first phase had primarily been concerned with building up a system for producing innovations, in the second phase, there was much more attention directed toward organizing the system more effectively and studying its operation. There was even a certain institutionalization in the study of science and technology policy, with university programs being established throughout the world, new journals (like Minerva, Technology and Culture, Technology Review, Impact of Science on Society), and working groups or research committees within several of the international academic organizations.

In terms of theories and concepts of technological innovation, this second phase was marked by an emphasis on the influence of the economic market mechanisms on science and technology. "Market-pull" tended to replace "science-push" as the dominant conception; the main concern, in both theory and practice, was to adapt the science and technology system more directly to the market. A number of detailed, and large-scale, studies of the innovation process were carried out in this period, and most of them concluded that market demand, or economic needs, was the main determinant of the innovations studied. [**Footnote:** These studies are reviewed from slightly different vantage points in Rosenberg, op. cit., Salomon, op. cit., as well as in Christopher Freeman, The Economics of Industrial Innovation, Penguin, 1974, second edition, Frances Pinter, 1982.] In part, this emphasis on the market was a reflection of the times, the high-growth economy of the early 1960's; in part, it was a reaction against the science emphasis of the first phase; and in part, it was a result of the professionalization of the actual workings of the system.

(p. 41) The shift in gears was signaled ideologically by the OECD report, Science, Growth and Society, from 1971. In practice, most countries expanded their science and technology realms to include a much larger number of societal sectors than had previously been involved. New environmental agencies were established, with substantial research budgets, and most of the other ministries or government departments obtained their own research councils or advisers. After the "oil crisis" in 1973, new departments for energy were created in many countries and, most everywhere, energy research and technical development became a high priority. At the same time, the science and technology system was made more democratic, as the new social interest groups were brought into the decision-making framework, either directly, with their own representatives on research councils, or indirectly, through a broadened social discourse over science and technology. There were a whole range of new initiatives to "inform" or "educate" the public on science and technology issues, particularly in the over-heated nuclear energy debate, but also in such areas as environmental research, social welfare research, occupational health and safety, and international relations.

Given this historical analysis of how technology and innovation were understood over the decades, we will concentrate on the industrial analysis approach, as exemplified by Rosenberg, Westphal and Dahlman, Mansfield and others. This is very much an economics viewpoint on the process. Nonetheless, it provides some valuable analytical frameworks for understanding some of the basic forces at play in the process of research utilization. The first author to be cited is Nathan Rosenberg, in a series of collected essays on technology and industrial development. Rosenberg states that there are a host of difficulties, institutional and otherwise, which impede the successful adoption of technology. He goes back to the 19th century arms industry to illustrate the point that personal skills is one of the key vectors for transfering a technology:

Nathan Rosenberg Perspectives in Technology, N.Rosenberg (ed.),Cambrige University Press, 1976.

> In the mid 19th century, the transfer of technical skills occured between Britain and the US. This was dependent on the transfer of personal skills. (Based on study of arms industry). Sam Colt owned a successful plant in Hartford, but it failed when it was transplanted to the US, because british workers were not trained in his manufacturing skills. This know-how can only be transmitted personally, because it is non-codified.

Rosenberg then examines the nature of technological innovation in the context of the industrial revolution in terms of a shift from artisanal type of work to specialized tasks in a mass production system:

> (In our economies), technological change led to the creation of specialized firms, fueling industrial growth. The same path is not recommended for LDC's. Special industrial skills are needed for specialized production of machinery. This industrialization leads to growing specialization. [For eample,] industrialization in the 19th century involved growing adoption of metal, using technology employing decentralized sources of power. This amounts to relatively small numbers of broadly similar products and processes applied to a large number of industries. Eg. Cutting metal involved a small number of operations and machine types: turning, boring, drilling, milling, planing, grinding, polishing, etc. These machines needed power transmission, control devices, feed mechanisms, friction reduction, and knowldge of the properties of metals.

In today's parlance, these were the equivalent of today's new technologies: microelectronics, computers, etc. all-pervasive and critical to technological advance. Rosenberg goes on to discuss the importance of consumer demand in the context of growing industrialization: willingness of the public to accept a homogeneous (vs. handicraft) final product. This was the decisive factor in the transition from a highly labour-intensive handicraft technology to one involving a sequence of highly specialized machines. Products accomodate machines, rather than consumers. He gives a striking example of handguns, which in the pre-industrialised days used to be made to order, like a tailored suit.

Part of the success of industrialization and mass manufacturing in America can be traced to the training of engineers. In the US, engineers are more effectively subordinated to the business discipline and commercial criteria than their British counterparts. Rosenberg quotes a British editor's reaction to US auto manufacturers and assembly lines as one of pride in the fact that British engineers and workers chose "to maintain their reputation for high quality [artisanal] work rather than cheapen their reputation" by becoming part of a mass production system, rather than reacting strongly to an obvious competitive threat.

Another example is given by the many models of train locomotives. Traffic conditions, loads, patterns, etc. prevailing at that time in the U.K. required essentially five different types of steam locomotives. There were 500 in currennt use!

One aspect of increased mass production is standardization of parts. The impact of standardization affected capital costs, and parts interchange.

Quoting from Freeman "Innovative process is now highly dependent upon a successful collaboration between producers of the final product and specialized makers of componenets."

A key factor in industrial innovation, according to Rosenberg, is the capital goods sector. Producers of capital ggods are the major source of innovation, because they are motivated financially. Creating a capital goods industry is a major way of institutionalizing internal pressure for the adoption of new technology. In America, producers of Capital goods have always played a major role in persuading and educating machinery users about the superiority and feasibility of new techniques. They have a strong economic motivation to innovate.

Not all technologies are equally easy to transfer:

> Industrial technology is easier to transfer than agricultural technology. It's self-contained, operates in a relatively closed system. Agriculture includes ecological relationships, interactions between human enterprise and specific features of the natural environment, beyond control of the farmer: biology, biochemistry, botany, genetics.
>
> The performance of an industry will frequently depend not only on resources within that idustry, but on the availability and the effectiveness of

> industries which stand in an important complementary relationship with it....Unless an economy is well equipped with these complementary sources, [agriculture] is not likely to experience rapid improvements in efficiency. eg machinery producing sector, agricultural research stations, educational institutions, fertilizer industry, genetics, chemistry.

One important insight of Rosenberg's is his analysis of the rate at which a new innovation will be implemented or diffused. This analysis is critical to understanding the utilization process:

> A new technique establishes its advantages over old ones only slowly -- slowness of diffusion is linked to this process. Technological novelty of inventions may be spectacular, but the economic impact is more gradual -- downward slope of real costs.

In analysing this, he is somewhat critical of the traditional perspective of the economist, a view with which he agrees when it comes to explaining the contribution of technological innovation to economic growth, but which is fundamentally limited by its use of the production function. This model does not explain, argues Rosenberg, the rate at which an innovation is adopted by a firm, nor the mechanism by which it happens:

> (p. 66-68) But economics' view is through production function model (which transforms inputs into outputs), which has limits. Schumpeter's analysis (based on clustering of innovations) applies only to major innovations, equivalent to significant shifts in production function. Clustering of innovations is also linked to business cycles. (...)
>
> Economic effects (eg. productivity increases) are linked with the innovation process, not with the invention. What determines the length of the time interval which separates the making of an invention and its innovation?
>
> The most frequently cited attempt to examine this time lag was John Enos("Inventions and Innovations in the Petroleum Refining Industry" in The Rate and Direction of Inventive Activity, Princeton University Press, 1962). Enos brought together information concerning 46 major innovations, eleven of them in petroleum refining. Enos finds an average interval of 11 years between invention and innovation in the petroleum refining industry and an average interval of 13.6 years for the the other 35 innovations. The observed variance, however is very large: from 79 years in the case of the fluorescent lamp, 56 yeard for the Gyro-compass, and 53 years in the case of the cotton picker, to one year for freon refrigerants and 3 years for DDT, the long-playing-record, lucite plexiglass, and shell moulding....Enos identifies the date of an invention as "the earliest conception of the product in substantially its commercial form" and innovation as "the first commercial application or sale".

Rosenbergs "bottom line" for a technological innovation is the question "does a profitable technology exist?" Without that, there is no innovation, only inventions. In short, the eventual utilization of the technology is already embeded in the definition of "innovation". However, and this is important for us, the transformation from a potential innovation to an effective economic contributor is not instantaneous, but rather a slow and deliberate process, which requires considerable effort. He cites the seminal work of Kuznets in refining the concept of National Income Accounting, a concept that had been first articulated a couple of hundred years previous, to the point where it became a usable technique of accounting.

> (p. 76) An innovation acquires economic significance only through an extensive process of redesign, modification, and a thousand small improvements which suit it for a mass market, for production by drastically new mass production techniques, and by the eventual availability of a whole range of co*mplementary activities, ranging, in the case of the automobile, from a network of service stations to an extensive system of paved roads.
>
> [p. 88 There is a]...danger... of attaching excessive significance to breakthroughs in the early stages of the inventive process, and neglecting the later stages. Good ideas usually acquire significance only when they are refined and elaborated and have gone through what is often an exhaustive process of patient modifications and revision. Only then do they become useful in an operational sense...We seriously underrate, not only the significance of these later stages in the process of social science innovations, but (that) we vastly underate the sheer size and complexity of the task, and therefore the magnitude of the intellectual chalenge involved. [For example, in the case of] national income accounting – the concepts were known long ago, but it took Simon Kuznetz'estimating techniques and hard work to make concept operational.

One of the foremost authors who has rigourously researched the processes of research, innovation, technology transfer, industrial utilization and industrial development is Edwin Mansfield. Most of his research is based on careful quantitative measurements and case studies of American and other firms. It is useful to review excerpts of one of his recent works, largely based on research carried out in the seventies. He begins with some precise definitions for the various concepts used in the subsequent discussion:

Mansfield, E.;Romeo, A; Schwartz, M.; Teece, D.; Wagner, S.; Brach, P.; "Technology Transfer, Productivity, and Economic Policy", Norton, New York, 1982.

(p. 1...5) Science is aimed at understanding, wheras technology is aimed at use. Changes in technology often take place on no new scientific principles.

Research is oriented to the pursuit of new knowledge, whereas development is oriented toward the capacity to produce a particular product. The outcome of research is generally more uncertain than the outcome of development. Nonetheless, in development there is often considerable uncertainty regarding cost, time, and the profitability of the result.

A technological innovation is defined as the first commercial introduction of new technology. Reseach and development is only a part of the process leading to a successful technological innovation. [Economists recently moved to a more complex model of the innovation process]... The first part of this process takes place in the interval between the establishment of technical feasibility and the beginning of commercial development of the new product or process. This time of commercial development may be substantial (although it is shorter now than it was fifty years ago). [Average -- ten years for key postwar inventions] The second part of this process takes place in the time interval between the beginning of commercial development and the first commercial application of the new product or process. This time interval contains a number of distinct stages -- applied research, preparation of product specification, prototype or pilot plant construction, tooling and construction of manufacturing facilities, and manufacturing and marketing start-up. (Average time for post-war innovations -- five years)

Mansfield is very clear on the principle that the transition between R&D and commercial implementation and iffusion of a technology is one of management and organization for a firm. The challenge for a firm is to manage this process effectively, to gain maximum economic advantage.

(p. 6) A central problem facing a firm that attempts to be innovative is to effect a proper coupling between R and D, on the one hand, and marketing and production on the other. The great importance of this problem is emphasised by recent work of Chistopher Freeman and Edwin Mansfield. (C.Freeman "A study of success and failure in industrial innovation," in Science and Technology in Economic Growth, ed. B. Williams (london, McMillan 1973); Mansfield et al in The production and Application of New Industrial Technology and Research and Innovation in the Modern Corporation.) Many R&D projects are designed without sufficient understanding of market and productions realities. Many marketing and production people are unnecessarily impervious to the good ideas produced by R and D people. To try and reduce these problems, some firms promote frequent contacts between R and D people and people in other parts of the firm, there being considerable evidence that person-to-person contacts are the most effective way of transferring ideas and technology. Firms are also trying to break down resistance -- in the R and D department and elsewhere -- to ideas stemming from outside the firm. Even in R and D intensive industries like chemicals and pharmaceuticals, a large proportion of the innovations are based on innovations made outside the innovating firm.

Like Rosenberg, Mansfield observes that diffusion of a technology in firms is never an instantaneous process, but depends on a number of measurable factors, tied to the mechanis of the diffusion and utilization process. (Note: these are fairly fundamental factors in the context of industrialized countries firms. If we transport ourselves to a developing country, other endogenous factors have to be superimposed on these. J.A.P.)

(p. 7) Once a new process or product is introduced, the diffusion process (the process by which the use of an innovation spreads) begins. The diffusion of a new technique is often a slow process. For example, measuring from the date of first commercial application (can take over ten years) for industries to begin using a sample of important new techniques...the rate of diffusion varies widely. Sometime it took decades for firms to install a new technique, but in others cases they immitated the innovators very quickly. ...tendency for diffusion process to go on more rapidly in more recent times than in the past.

...[The] rate of diffusion of an innovation depends on--
. the average profitability of innovation
. the variability among the firms in the profitability of the innovation
. the size in the investment required to introduce the the innovation
. the number of firms in the industry, their average size, the inequalities in their sizes, and
. the amount they spend on R and D.

(These variables) explain a large proportion of the variation among innovations in the rate of diffusion.

...firms where the expected returns from the innovations are highest tend to be quickest to introduce an innovation. ... big firms tend to introduce an innovation before small firms.
...where firms are small, firms with younger and better educated managers tend to be quicker to introduce new techniques.

(p. 8)...firms, once they hear of the existence of an innovation, may wait a considerable time before beginning to use it. In many cases this is quite rational. But to some extent, this may also be due to incomplete or erroneous information, prejudice, and resistance to change. The sources of information sometimes vary depending on how close the manager is to adopting the innovation. For example, in agriculture, mass media are most important sources at the early stages of a manager's awareness of the innovation, but friends and neighbors are most important sources when a manager is ready to try the innovation. Also, there is evidence of a "two step flow of communication." The early users of an innovation tend to rely on sources of information beyond their peer group's experience; after they have begun using the innovation, they become a model for their less expert peers, who can imitate their performance. (Rogers)

A key theoretical contribution of Mansfields' has been his authoritative analysis of the effective contribution of R&D and technological change to economic growth. While he was not the one who first discovered this (the initial work was done by Solow, for which he later received the Nobel prize), Mansfield certainly contributed to the refinement of the idea, particularly at the micro-level.

(p. 9) The fact that technological change plays an important role in permitting and stimulating economic growth seems self-evident. But difficult to quantify. Hard to separate the effects on economic growth of technological change from those of investments in physical capital, since, to be used, new technology frequently must be embodied in physical capital -- new machines and plants. ...Nor can the effecs of technological change easily be separated from those of education, since the social returns from increased education are enhanced by technological change, and the rate of technological change is influenced by the extent and nature of society's investment in education.

Robert Solow [in "Technical change and the Aggregate Production Function" Review of Economics and Statistics 39 (1957) p312.] claimed that "90 percent of the increase in output per capita in the non-farm US economy during 1909 and 1949 was attributable to technological change, whereas only a minor percentage of the increase was due to increases in the amount of capital employed per worker. In a more comprehensive calculation, Edward Denison ["The sources of Economic Growth in the United States" (new York: Committee for Economic Development, 1962] later revised this downward to 40%

<u>On International Diffusion of Technology:</u> (p. 14)

Because of the diferences among nations in technological levels and capabilities, there is a continual process of international diffusion of technology. Knowledge can be transmitted in various ways -- by emigration of engineers and skilled workers, by export of goods and servoces, by licensing, and by direct investments, among others.

(p. 16) One reason why it is so difficult to measure international technology flows is that technology can be transferred accross national borders in a variety of ways.... a considerable amount of technology is transferred without any appreciable payment for it. eg. scientists and engineers exchange information at international meetings, and one country's scientists and engineers read the publications of other countries' scientists and engineers. There is presently no way to measure it (total flow of technology for which there is no payment).

Other channels: export of goods eg. advanced computers., and establishment and utilization of overseas subsidiaries.

On basic R&D, applied R&D, and Productivity Increase(p. 138)

When (a firm's) expenditure on applied R&D are hed constant, there is a statistically significant and direct relationship between the amount of basic research carried out by an industry and its rate of increase in total factor productivity. Distinction between basic research and applied R&D not always clear, basic research may be acting as proxy for long term R&D. First evidence that composition as well as size of an industry's R&D expenditures affects its productivity growth.

On costs of Technology Transfer and Utilization (p.216)

There is evidence that that transfers to governments in centrally planned economies involve substantial extra costs, sometimes because of high documentation requirements and differences in managerial procedures.

(p. 217) Investment in Innovation and Diffusion. One of the most expensive parts of the innovation process is the construction of new plant and equipment. Detailed manufacturing drawings must be prepared, tooling must be provided, and manufacturing facilities must be constructed. In a sample of thirty-eight innovations in the chemical, machinery, and electronics industries, this stage accounted for about 40% of the innovation cost on the average. Becauseinvestment in plant and equipment accounts for a relatively large proportion of the cost of many innovations, measures that encourage investment are likely to encourage innovation. And since the profitabilioty of R&D is dependent upon the profitability of the entire business venture of which R&D is part, measures that reduce the after-tax costs to the firm of plant and equipment are likely to increase the profitability of R&D.

On Patents.(p. 217)

Contrary to the assumption of some economic models, patented innovations are often imitated within a few years of their initial introduction. It is a myth that a patent nearly always results in a seventeen-year monopoly over the relevant innovation. Nonetheless, patents do tend to increase imitation costs, particularly in the pharmaceuticals idustry. [In their sample as a whole], the median estimated increase (due to patents) in the ratio of imitation cost to innovation cost was 11 percent...(According to sample) about one-half of the patented innovations would not have been introduced without patent protection (bulk was in drugs industry). In non drug industries, lack of patent protection would have affected less than one fourth of the firms sampled.

60 % of the patented innovations in the sample were imitated within four years.

An important contribution of Mansfield's analysis has been a better understanding of how government policy instruments can be used to encourage innovationand industrial development. This is of interest to us as we later move to examining the context of developing countries, and their science policies. A parallel can also be drawn between the guidelines for governments on programs to encourage innovation and those for donor agencies in sponsoring research-based activities.

Public policy toward Civilian Technology.(p. 224)

...[Many] economists point out that the marginal social rates of return from investments in civilian technoloy has been very high, both in agriculture and industry.

Government can stimulate additional R&D in the private sector through tax credits, R&D contracts and grants, expanded work in government laboratories, loan insurance for innovation, purchasing poicies with greater emphasis on performance criteria and life-cycle costig, altered regulatory policies, and prizes....general tax credits are innefficient, but involve less direct government controls. [This raises the distinction between selective and more general policy initiatives which governments can take to stimulate innovation in industries.]

(p. 226) In any selective government program to increase support for civilian technology, it is vitally important that a proper coupling occur between technology and the market. Recent studies [eg. Chris Freeman, A study of Success and Failures in Industrial Innovation, in Science and Technology in Economic Growth, ed. B.Williams London:MacMillan, 1973; also Mansfield et al. in The Production and Application of New Industrial Technology; and Mansfield, Rapoport, Schnee, Wagner, amd Hamburger, Research and Innovation in the Modern Corporation, New York:Norton, 1971] of industrial innovation point repeatedly to the key importance of this coupling. In choosing areasand projects for support, the government should be sensitive to market demand. To the extent that it is feasible, potential users of new technology should play a role in project selection. Information transfer and communication between the generators of new technology and and the potential users of new technology are essential if new technology is to be successfully applied. As evidence of their importance, studies show that sound coupling of technology and marketing is one of the characteristics that is most significant in distinguishing firms that are relatively successful innovators from those that are relatively unsuccessful innovators.

(p. 228) [A country's] technology policies cannot be separated from its Macroeconomic policies. Measures that encourage economic growth, savings and investment, and price stability are likely to enhance (our) technological position. ...Indeed, improvements in our general economic climate may have more impact on the state of US technology than many of the specific measures that have been proposed to stimulate technological change.

The other useful article, by Carl Dahlman and Larry Westphal, examines the issues of innovation and technological adoption at the micro-level, the firm in a developing country. This article is based on a review of the literature in the preceeding eight or nine years, and as such is a handy compendium of the latest concepts up to the early eighties. The authours first debunk the traditional concept of technology as a "blueprint" as simplistic:

Carl Dalhman, Larry Westphal "Technological Effort in Industrial Development -- an Interpretative Survey of Recent Research" in F.Stewart and J.James eds. Economics of New Technologies in Developing Countries. London : Frances Pinter, 1982 p. 106

(p. 106) Identical technologies are employed with vastly unequal levels of technical performance in different economies, and even by different firms within an economy.

[The authours then attempt to isolate what really consists of the trechnology, particularly as it applies to industrial technologies, in order to better circumscribe what really is being transferred, when discussing technology transfer.]

[In the case of] capital goods -- technology is embodied in the hardware, the rest is disembodied technological knowledge and related social arrangements -- knowledge can be transferred, but the ability to make effective use of it cannot be. This ability can only be acquired through indigenous technological effort, leading to technological mastery through human capital formation.

Another issue are the particular conditions that affect the acceptance of a new twechnology at the local level:

[When choosing technologies at the developing country level...] the central problem is lack of experience of the decision-makers.

Implementation of appropriate technology choices often requires complementary investments to enhance local technological mastery.

Local circumstances (vs engineering norms) can include:

. site characterisitcs, stage of development of local construction and engineering services (plant establishment);

. availability of skilled mainatainance workers and capability of local machine shops for spare parts (plant maintainance);

. level of labour skills, characteristics of intermediate inputs (plant opration).

Transferring a technology to a recipient so that the latter has full "technological mastery", as previous authors have observed, is a very complex task, and often implies another level of innovation and adaptation of the original technology:

Technology mastery is defined as the operational command over technological knowledge.

Manufacturing technology is characterized by a considerable element of tacitness, difficulties in imitation and teaching, and uncertainty regarding what modifications will work and what will not (as quoted in Nelson, 1979).

A new production activity requires a great deal of iterative problem solving and experimentation as the original concept is refined and given practical expression. [Innovation is often a continuous process.]

[For example, in the case of] Brazil's USIMINAS steel mill: there was a sequence of minor technological changes within the plant carried out by plant engineers over a period of years, which resulted in a doubling of capacity and factor productivity.

Enos showed that once a radical innovation is introduced (for cost reduction), subsequent reductions in production costs due to modifications and adaptations of technology can often be greater than the cost reduction obtained in the initial innovation.

There a number of ways a developing country can access foreign technology:

Foreigh technological knowledge can be accessed by --
. sending nationals abroad for training, work experience
. consulting technical and trade journals
. copying foreign products (reverse engineering)

Best form (most complete) is the turnkey plant.

Government policies -- can help foster optimal technological choices, avoid socially undesirable components, promote use of local suppiers.

When it comes to the impact of government policy to encourage innovation and industrial development, the authours are in agreement with previous statements in this paper:

Policies such as creation of technological infrastructure, S&T plans, promotion of local technological supplies, fiscal incentives/direct subsidies, regulation of technology imports, etc... HAD FAR LESS IMPACT on technological change and the acquisition of technological mastery than macro policies such as trade, credit allocation, investment, licensing etc..

[The authors ask themselves whether this ...] true intrinsically, or is it due to the fact that these policies were poorly implemented, often at cross purposes.

Also, the spate of R&D institutes which were created by governments as a simplistic solution to industrial innovation, had virtually no contact with or impact upon producing firms (see Diana Crane Research Policy 6, pp 374-395).

Another useful article that is included in this collection is a somewhat theoretical discussion on the decision processes actually used in firms when adopting new technologies. Bela Gold, a noted author, is also writing from an economist's perspective.

Bela Gold, "On the Adoption of Technological Innovations in Industry: Superficial Models and Complex Decision Processes", in Macdonald, S., Lamberton, D. McL., Mandeville, T. 1983. The Trouble with Technology - Explorations in the Process of Technological Change. St. Martin's Press, New York, NY, USA. p. 104 - 116.

The technological competitiveness of firms and industries is determined not by the rate at which significant innovations are developed, but by the extent to which they are applied to commercial operations. The importance of such adoption decisions is further emphasised by the fact that evidence of resistance to the utilisation of demonstrably effective technological advances tends to discourage managerial commitments to risky and costly efforts seeking additional advances.

[The author points out weaknesses in the traditional diffusion models.] But each of the fundamental elements of this conception is unrealistic. First, far from being essentially fixed, almost every technological innovation in industry undergoes numerous significant changes in its service capabilities with time. (...)

A second general shortcoming of the traditional approach to the diffusion of technological innovations is the assumption that the population of potential users is readily identifiable and essentially fixed. Actually, most studies have failed even to identify the group of prospective adopters realistically because of an understandable eagerness to utilise the convenient industrial categories offered by unavailable statistical series.

A third basic weakness of many models of technological diffusion, especially those based on the projection of past statistical data, is their pervasive tendency to ignore significant dissimilarities in the economic conditions which characterised the various periods. (...)

It would seem to follow, therefore, that the saturation curve so widely used to depict diffusion patterns, or to assess diffusion rates, or to estimate shortcomings in diffusion levels, is misleading. Instead of one fixed estimate of potential users for the entire period of diffusion, with which actual adoption levels are compared, such charts should show the successive increases in the population of potential adopters associated with important changes in the applicability and economic benefits of the original innovation.

[The author then describes a saw-toothed S-curve, which he believes might be even more accurate in noting that successive stages of innovational developments are associated with changes in potential users as well as actual adopters.]

The most significant implication of this conceptual [p. 108:] reorientation is that more effective understanding of diffusion patterns and of the factors affecting them requires more knowledgeable estimates of: the population of prospective users in any specified stage of an innovation's development; the number of additional adoptions likely to result from changes in the input and output pressures on prospective users, even without significant improvements in the innovation; and the number and kinds of additional adopters likely to be attracted by alternative further technological improvements in the innovation, and by reductions in its investment requirements and operating costs. Incidentally, careful research has also led to a serious questioning of the traditional use of sigmoid curves to depict diffusion patterns.

The author also discusses simplifying assumptions and realities in the way firms decide internally on the adoption of a new technological innovation.

(p. 108-109) The first grossly unrealistic assumption about the intra-firm context of decisions involving the adoption or non-adoption of technological innovations involves the arbitrary foreshortening of needed analytical perspectives. This results from focusing immediately on evaluations of a particular innovation - and how such evaluations might differ among those firms which adopt it and those which do not. But such an approach ignores the frequently dominant, and always important, role of the pre-decision environment. For any period to be covered by current managerial planning and commitments, this covers the specific nature and relative urgency of all of the needs to be dealt with, the availability and relative net advantages of non-technological as well as technological options, and the availability of technical, managerial and financial resources to implement such alternative measures.

A second grossly unrealistic simplifying assumption concerning the intra-firm context of decisions about adopting technological innovations is that such decisions are based on expected profitability after adjustments for probable risks and uncertainties. This is merely a tautology rather than a useful analytical insight, for it says in effect that a profit-seeking firm makes decisions which seem to favour profits and, hence, that if an innovation is adopted, it is expected to be profitable. As a matter of fact, however, diffusion patterns suggest that numerous firms arrive at quite different evaluations of the same innovation more or less simultaneously. Hence, effective understanding of diffusion patterns requires more thorough study of how expected 'net benefits' are estimated and to what extent such 'evaluations' are really only rationalisations of decisions arrived at on less obvious and less objective grounds.

A third grossly vulnerable basis for studies of decision-making about technological innovations in individual firms is the widespread reliance on ex post findings and interpretations. Some well-known studies are even unclear about how long ago the relevant decisions were made (often 10 to 20 years ago or more), and about whether the respondents cited were effectively involved in making such decisions (often not. The results of such studies are accordingly open to serious misinterpretations because of the enormous differences between hindsight perspectives and expectations about the unknown future.

In describing the evaluational bases for decisions, Gold points out some common errors companies make in evaluating the <u>potential</u> benefits of proposed technological innovations:

(p. 110-111) For example, our field research suggests that the most common sources of errors in estimates of the expected technological benefits of innovations centre on:

(1) underestimating the time needed to achieve effective functioning of innovation, often by a considerable margin;

(2) overestimating the average utilisation rate as a basis for appraising benefits;

(3) underestimating the need to make adaptive adjustments in the preceding and subsequent operations of an integrated production operation - or in the reallocation of orders and support resources between a new facility and older facilities devoted to similar operations; and

(4) underestimating the problems and costs of gaining labour acceptance of associated changes in tasks.

Economic evaluations of the expected effects of technological innovations are frequently based on a wide array of simplifying assumptions, among which the following seem to be the most common and most influential:

(1) that expected reductions in man-hours per unit of output will be accompanied by roughly comparable reductions in unit wage costs;

(2) that expected reductions in material requirements per unit of output will yield parallel reductions in their unit costs; and

(3) that resulting costs savings can be carried over into increased profits.

Indeed, our research reveals that some companies in the United States no longer permit the inclusion of expected wage costs savings in justifications for proposed capital projects, on the grounds that these all to frequently prove unrealisable.

Finally, Gold also criticises the lack of adequate evaluations of technological innovations already installed, and their real economic impact on their company environment.

(p. 114-115) How effectively are the results of technological innovations determined? Such findings would obviously tend to have an important bearing on the rate of diffusion inasmuch as evidence of significant rewards is generally regarded as the most powerful incentive to increasing diffusion. Oddly enough, however, there is an astonishing paucity of published research evaluating the actual effects of such innovations after they have been installed, in contrast to the considerable literature on estimating the probable effects of technological innovations before decisions are made to adopt or reject them.

Inquiries suggest that the reason for such neglect is the widespread assumption that the purposes, methodologies, applications and interpretations of such undertakings are so obvious as to offer no interesting problems. Our field research, however, yields the strongly contrasting view that such post-installation evaluations are shot through with difficult problems and dubious bases for many of the results which are reported within firms.

Analysis of the problems and effectiveness of post-installation evaluations of the effects of technological innovations offers several potentially important contributions to the management of innovational processes. To begin with, such appraisals could provide a direct comparison of results with the expectations which led to adoption decisions. Even more important, comprehensive evaluations could explore the specific loci and causes of deviations between expectations and results, thus indicating the relative accuracy of various component estimates and also identifying any variables which were ignored. Moreover, such evaluative efforts may reveal insensitivities in the performance measurement system to innovational impacts, thus counselling changes in order to minimise consistent anti-innovation biases.

Some Shortcomings of Current Evaluation Efforts

Only a limited array of post-installation evaluation methods has emerged as a by-product of our field research on the effects of technological innovations. Hence, the following judgements must be regarded as preliminary and tentative indications of possible shortcomings. Most of the 'make good', 'follow-up' and 'post-audit' evaluations examined concentrated primarily on simply measuring actual results, including: the costs of acquisition, construction and installation relative to budget; the acceptability of technical performance; and resulting operating costs. Except for comparisons with allowed budgets and expected total unit costs, few methods were characterised by comprehensive comparisons of actual input requirements, factor prices, product quality and price, output levels and other aspects of performance with the respective estimates which led to the decision. Especially glaring is the common failure to consider the time required to achieve the 'acceptable' levels of performance before evaluation efforts tend to be initiated relative to expectations. Also disappointing is the virtual absence of any systematic efforts to 'learn from results' as a means of improving ex ante estimates of the effects of prospective technological innovations in the future.

Our explorations suggest, in addition, that formal evaluation efforts, except for comparisons of actual expenditures with allowed budgets, seem to be much less common with respect to very large projects - especially when their results seem unfavourable. In explaining such lapses, the two most common reasons given were that each such project is necessarily unique and hence evaluations would have no feedback value in considering future projects, and that there was no interest in 'spilled milk' or in 'flogging dead horses'.

3. SCIENCE AND TECHNOLOGY IN THE THIRD WORLD: POLICY FACTORS INFLUENCING THE UTILIZATION OF RESEARCH RESULTS

There are two works worth citing here to lay the foundation for the later policy writings on cience and technology in third world countries, both of which are related. The first is Maurice Goldsmith and Alexander King 1979 symposium procedings on a New role for Science and Technology, the other is the 1979 UN Conference on Science and Technology for Development. Both are cited here, because in a sense they already identified many issues leading to our preoccupation with the utilization of research results in the third world.

Goldsmith, M., King, A. (eds). 1979. Issues of Development: Towards a New Role for Science and Technology - Science, Technology and Global Problems. Proceedings of an International Symposium on Science and Technology for Development, Singapore, January 1979. Pergamon Press, Oxford, New York, Toronto, Sydney, Paris, Frankfurt. p. 10 -13

SCIENCE, TECHNOLOGY AND THE ECONOMY

It was only in the early 1960s, however, that the role of research and development in economic growth became the subject of serious study by the economists. It was shown, for example, that of the economic growth of the United States during the first half of this century only about 40% could be explained by increases in the traditional productive factors of capital and labour. The remaining 60%, designated at first as the residual factor, was assumed to be due to improvements in technology, materials, management skills, and higher levels of education, i.e. in the quality of labour and of capital utilization. This recognition of the importance for economic growth of technological improvements and of the human factor, coincided with the enormous increases in research and development expenditures in all the industrialized countries which followed the end of the Second World War, a period when it was accepted that science was a good thing in itself, with the assumption that the more science that was done in a country, the greater would be the benefit to the economy - and presumably to society.

This generalization proved to be false, and many examples can be cited of huge efforts of research and development, which proved to be technically successful, but economically disastrous. Incidentally, this facile notion that scientific activity automatically results eventually in economic growth has been supported by the elites in some of the Third World countries; academic snobbery has been a significant export of the industrialized world.

Recognition of the complexity of the process of technological innovation followed from studies done by OECD in the late 1960s on the so-called technological gap between the European countries and the United States, and by the work of many academic research groups. It was shown that no direct correlation existed between the proportion of the national expenditure of a country and its economic growth; [p. 11:] indeed, the extent of the national technological effort seemed to have little effect, on either economic or trade performance. It appeared that diffusion of technology across frontiers was sufficiently rapid to compensate for inadequacies in the domestic research and development effort. This appears to be true, however, only with regard to countries above a certain technological threshold, with a mature industrial infrastructure, and a sufficient spread of research and development activity to enable them to scan world scientific and technological advances, to select what is appropriate to their needs rapidly and accurately.

The considerations do not apply, however, to the diffusion or transfer of technology from the advanced industrialized to the less developed countries. In the latter, or at least in most of them, the necessary threshold for spontaneous diffusion has not yet been reached, nor can it be until a real scientific and technological capacity has been built up, working symbiotically with both the educational and the productive systems. Nevertheless, the experience of the industrialized countries with their growing understanding of the nature of the process of technological innovation is essential to the countries of the Third World, if they are wisely to select technology for import, assimilate it, and later develop their own.

The process of technological innovation is extremely complex, and it is necessary that its complexities be thoroughly understood by political leaders, planners, industrial managers, and scientists. Successful innovation demands, of course, the initial technological novelty, either generated domestically or imported from abroad. Careful selection from the immense number of processes and products available in the world technological repertory is a prerequisite if the innovation is to serve well the needs of the developing society. Amongst other factors which determine success or failure in the new enterprise are availability of capital, a wise fiscal system which protects initially, but not to the extent of discouraging efficiency and high quality, entrepreneurship, management skills, marketing ability, the general level of education, and that of middle level technical skills, a good social climate, and even national psychology and cultural tradition. Thus, the availability of technology is the beginning, but is far from being the totality of industrial innovation, in countries of all types.

TECHNOLOGY AND DEVELOPMENT

This is not the place to discuss the economic disparities between the industrialized and the developing countries. At the time of the first conference of the United Nations on Science and technology for the Benefit of Less Developed Areas, held in Geneva in 1963, there was considerable hope that the gap could be speedily narrowed and, in particular, that a massive transfer of technology from the industrialized North, would go far to reduce hunger, disease, and poverty in the disadvantaged countries to the South. This, alas, has proved to be only marginally true, although at first sight growth rates in the Third World in recent decades seem impressive. During the 1950s and 1960s, countries in Africa, Latin America, and non-Marxist Asia have achieved an average growth of the economy of about 5% per annum. This compares favourably with the record of the already industrialized world, but it starts from a very low base line, and much of the new wealth created found its way to the already well-to-do as a consequence of the inequities of the social system in some countries, so that the great masses have benefited little from the new technology, improved agriculture, and the inflow of aid capital and loans. Furthermore, the per capita gains in income in many places were reduced to about a half as a result of population increase, while substantial purchases of arms reduced the benefits of growth still further.

(...) Nowhere are the disparities between the industrialized countries and those of the Third World more marked than in the fields of scientific research and technological development. True, some countries such as India have a sophisticated scientific structure; the oil-producers, of recent years, have begun up such a capacity, and even in the least developed countries there are small groups of people with scientific training and understanding, usually acquired abroad. In the aggregate, however, the world's now massive research and development effort is concentrated in the few highly industrialized countries.

One may question, of course, whether the existence of a capacity for such activities is a cause of economic progress, or a consequence of it. Probably both are true to a degree, but it is certain that technological advance has been one of the main sources of power and prosperity of the industrialized world, and that if research and development are likewise to become a motor force of economic development in the global sense, and not merely a means for the rich to become richer, all participating countries will require to build up the means, the awareness, and the experience which an indigenous technological capacity involves.

If, then, the experience of the industrialized countries is that science and technology have been major instruments of economic development, it would seem an easy assumption that this would be true, also, for countries at an earlier stage of economic development. Indeed, we might have expected that their progress would have been more rapid than in fact has been the case, since the technologies and skills already existing evolved slowly, and with considerable expense, in the industrialized countries during the two centuries since the industrial revolution. Certainly, great advances have been made by the direct transfer of skills and techniques: communications form a world-wide network; certain devastating diseases such as malaria, smallpox and tuberculosis are under control; agriculture in the Third World has been greatly assisted by the use of fertilizers, and the introduction of high-yielding varieties by genetic selection based on research. Nevertheless, on the whole, and especially in the industrial sector, advance has been much slower than desirable, if the economic gap between the rich and the poor nations is to be bridged in a reasonable time.

The relative failure of the process of technological transfer is due to many causes, in addition to the lack of indigenous technological capacities which we stress so strongly; some of these derive from intrinsic ineffectualness of the process itself, where the profit motivation of the so-called donors does not always harmonize with the basic needs of the receivers; others are due to social and political factors in the recipient countries.

In all developing countries, with the exception of those exceptionally rich in resources, a major difficulty is the availability of capital. In Third World countries with very little in the way of surplus resources - the classical 'savings' of the economists - capital is exceedingly scarce and subject to greater competition than in the industrialized countries, since it is in urgent demand for the building up of every sector. Furthermore, the technology of the already industrialized countries has been deliberately evolved to increase the productivity of manpower and hence is both capital- and energy-intensive. In so many of the Third World countries, on the other hand, unemployment and underemployment are widespread, and so a dominance of capital-intensive industry is not necessarily to be welcomed. Consequently much of the technology 'on the shelf' is not, a priori, appropriate to the economic and social needs of the Third World. The choice of technologies with new work positions costing, say $5000 each as compared with others at $200 per capita may, in reality, be a choice between half a million jobs with high economic yield, or eight million jobs with a lower per capita outcome.

A further obstacle to successful transfer of technology is the local lack of availability of sufficient skills - managerial, engineering or manual - which must be provided through an appropriate, highly developed, and sustained educational system. In many countries, the general basis of education is insufficiently evolved, both quantitatively and qualitatively, and its building up, including the funding of the necessary resources, the training of teachers, etc. is a very long business. In addition, there is often a lack of both middle and higher technical training, and of facilities for management education.

At present, the main political preoccupation with regard to the use of science and technology for development is concentrated on the transfer process itself, and on improvement in the access of Third World countries to advanced technology. The arguments here have become highly politicized, and centre around the effectiveness and motivation of the multinational corporations as the main agents of transfer. Governments are obviously not themselves skilled in questions of industrial production and management, and, especially in the market economy countries, ownership of technology is in the hand of industry itself, and its owner shareholders.

The second citation is from a summary document prepared several years after the 1979 UN Conference in Vienna on Science and Technology for development. The first part of the excerpt covers those resolutions of the General Assembly outlining the mandate of the conference, as well as those resolutions emerging from the conference (the Vienna Program of Action, or VPA) that have an impact on the utilization of research results.

Pati, Subas C. 1986. Experiences with the Vienna Programme of Action. A Study on the Follow-Up Activities by Developing Countries on the Recommendations of the United Nations Conference on Science and Technology for Development (UNCSTD), Vienna, 1979. 84 p.

The main objectives of the conference as reflected in the General Assembly's resolution were as follows:

(i) Strengthening the technological capacity of the developing countries to enable them to apply science and technology to their own development.

(ii) Adopting effective means for the utilization of scientific and [p. 4:] technological potentials in solution of development problems of regional and global significance, especially for the benefit of developing countries.

(iii) Providing instruments of cooperation to developing countries in utilization of science and technology for solving socio-economic problems that could not be solved by individual action in accordance with national priorities.

(...) The Preparatory Committee suggested the following agenda to be adopted in the conference:

1. Science and technology for development:

(a) The choice and transfer of technologies for development;

(b) Elimination of obstacles to the better utilization of knowledge and capabilities in science and technology for the development of all countries, particularly for their use in developing countries;

(c) Methods of integrating science and technology in economic and social development;

(d) New science and technology for overcoming obstacles to development.

(p. 19) The Vienna Programme of Action (VPA) adopted at the UNCSTD normally had the status of a recommendation to the UN General Assembly. During its thirty-fourth session the Second Committee dealt with the Programme of Action in great detail. The comprehensive resolution that the General Assembly adopted to approve the outcome of UNCSTD represented a first step on the way to pulling the Programme of Action into effect.

The VPA focused on the following three broad target areas:

1. Strengthening the scientific and technological capacities of developing countries; (...)

(p. 20-21) According to VPA the following recommendations were to be implemented at the national level of developing countries:

- (...)
- Each developing country should formulate a policy on transfer and acquisition of technology as an integral part of its national policy for scientific and technological development.
- (...)
- Joint industrial projects with the objective of maximizing the results of utilization of their resources, capital and skills should be stimulated and established.
- (...)

To be implemented at the international level the VPA recommended:

- Developed countries should support and facilitate the internal efforts of developing countries to achieve development through endogenous scientific and technological capacities.

- (...)

(p. 22) In the second target area, i.e. restructuring the existing pattern of international scientific and technological relations, VPA has classified the recommendations into four major categories, namely:

(a) Acquisition and transfer of technology;

(b) (...)

The suggestions to be implemented by the developing countries are

- they should cooperate with developed countries in improving the conditions and terms for the acquisition of technology;

- (...)

The recommendations to be implemented by the developed countries are:

- they should take adequate measures to encourage and facilitate the transfer of technology by their small and medium-sized enterprises;

- (...)

(p. 23) The recommendations of VPA to the international organizations for achieving the objectives of the second target area are:

- Organizations within the UN System should play a more active role in informing, advising, assisting developing countries concerning all aspects related to the transfer of technology to enable them to obtain more favourable terms and conditions.

- They should provide assistance in the formulation, negotiation and implementation of projects for the transfer of technology.

- They should assist the developing countries in setting up suitable institutions to deal with the transfer of technology.

- (...)

- Greater use should be made by international organizations of the expertise in developing countries including consulting organizations.

- (...)

Of greater interest to us, however, is the survey that the author carried out to see what kind of change these resolutions brought about several years after the conference. A number of the obstacles or impediments listed here are very much the same ones that make utilization and implementation of research in the third world so difficult.

(p. 32) For this purpose enquiries were sent to 230 persons in 94 developing countries which had participated in the Vienna Conference.

The persons to whom queries were sent can broadly be categorised into four categories, namely:

- Focal points of the country for the UNCSTD
- Persons who participated in the ACAST Colloquium
- Persons who are presently responsible for formulating and implementing the national science and technology policy
- Other internationally reputed scientists and technologists.

OBSTACLES IN IMPLEMENTING VPA (p. 61-65)

In the earlier chapter the answers given by the respondents relating to the various obstacles faced in their respective countries were itemized. The respondents have mentioned the various types of obstacles faced by them in implementing the recommendations of VPA and it is seen that some of these obstacles are insurmountable for certain developing countries. Taking into account all the replies the obstacles can be summarized and broadly classified into following groups:

(a) General obstacles
(b) Planning and technical obstacles
(c) Education and manpower obstacles

(a) <u>General obstacles</u>: obstacles which arise from the social, political, financial, cultural constraints are grouped as fundamental obstacles and can be outlined as follows:

- Lack of political will in the country to utilize science and technology for socio-economic development.

- Unstable political situation, changes of government in quick successions, ethnic politics hamper the development of science and technology in the country.
- War and revolution (both political and religious) prevailing in the country.
- Resistance to adopt modern technologies due to cultural barriers.
- Acute shortage of finance for the scientific and technological activities.
- Defective fiscal politics adopted in the country.
- Assignment of wrong priorities in the national development plans.
- Improper distribution of meager funds allotted for S&T activities.
- International political and economic situation.
- Mistrust and conflicts between neighbouring countries over implementation of joint cooperative projects.
- Scarce tapping of the national resources.
- Instability in the local economy.
- Inefficient provision of basic needs.
- Excess bureaucratic interference in the research activities of scientists and technologists.
- Constant conflicts between the bureaucrats on one side and the scientists and technologists on the other.
- Lack of appreciation and reward for the achievements of scientists and technologists.
- Lack of awareness for the significance of S&T in socio-economic development among the population.
- Other serious local, political and economic problems which are diverting the attention of the authorities.
- Attitude of certain developed countries and multinational corporations.

(b) Planning and technical obstacles: Perhaps the most important and significant obstacles the developing countries are facing are in the planning, policy-making and technical spheres. These obstacles can be listed as

- Absence of a well-defined national science and technology policy.
- Lack of capability to formulate suitable science and technology policy.
- Non-availability of institutional mechanisms for coordinating, integrating and evaluating the scientific and technological activities.
- Absence of expertise and physical facilities for R&D work.
- Absence of proper planning of R&D activities in terms of national needs and priorities.
- Random import of foreign technology.
- Inadequate scientific and technological infrastructure.
- Lack of a mechanism to control and influence the choice, terms of acquisition and transfer of technology.
- Weakness and deficiencies in the national planning systems.
- Absence of a national S&T information system.
- Lack of information about alternative technologies available in the world market and non-availability of access to international scientific and technological information.
- Difficulties in getting informations relating to new developments of science and technology.
- Weak linkage between S&T research and production sections.
- Non-availability of facilities for proper assessment of technologies to be imported.

(c) <u>Educational and manpower planning</u>: A constant set of recurring obstacles in the scientific and technological development of developing countries is related to manpower. It includes the education and training, the supply and demand, the placement and retention and the welfare and job satisfaction of administrative, scientific, technological supervisory and other skilled personnel. These obstacles are:

- Acute shortage of trained and skilled personnel in the field of science and technology.

- Lack of training facilities for research workers, technicians, professional personnel and entrepreneurs who can play an active role in S&T development processes.

- Absence of a comprehensive plan for human resources development keeping in view the needs for the future.

- Unsuitable educational policies.

- "Brain-drain" exodus of qualified personnel brought about by political, economic and social conditions.

- Lack of proper training system, which led to a lack of understanding of science and technology.

- Misdeployment of S&T manpower at different levels.

- Lack of encouragement of S&T personnel by the authorities.

What follows is a fairly broad bibliographical selection of issues related to science and innovation policy in third world countries. This collection of citations and the attached abstracts have been excerpted from a very useful annotated bibliography, largely written from the perspective of appropriate technology.

Hurley, D. (ed.). 1987. The Management of Technological Change - An Annotated Bibliography. IT Publications in association with the Commonwealth Secretariat. Russell Press, Nottingham. 113 p.

The Hurley reference numbers are identifiedby the notation (DH - no.):

CLARK, N., The Political Economy of Science and Technology, Basil Blackwell, Oxford, 1985.

This is an excellent introductory book which presents a clear overview of the major issues in the political economy of science and technology (S & T) policy. It first deals with the historical development in Western countries of S & T policies and of ideas relating to S & T. Thus the introduction defines the multidisciplinary concept of S & T policy and chapter 2 traces early thinking and experiences during the [p. 17:] transition to capitalism in Europe. Chapter 3 reviews ways of measuring the activities of the S & T system within a developed economy (e.g. social cost benefit analysis, patents, innovations etc.) and more radical contemporary views.

Chapters 7 and 8 relate these issues to developing countries by first outlining various perceptions or theories of underdevelopment and development and then specifically looking at technological aspects of these processes. Clark has short sections on: technology transfer; appropriate technology; learning and technological capabilities; radical technical change; rural technology transfer; and indigenous science and science and technology planning. These chapters also contain a useful bibliography.(DH - 25)

JAMES, J. and WATANABE, S. (eds), Technology, Institutions and Government Policies, Macmillan series of ILO studies, London, 1985.

This is a book with an introduction by the editors and 7 readings, split into "conceptual" and empirical studies of the impact of government policies on technology decisions.

The introduction sets out the objective of the book; to bridge the gap in the literature "between the macroeconomic environment and micro decisions for technology". The editors argue that the comparative neglect of macro questions has made it difficult for decision-makers to incorporate technology issues in planning at the national level.

The first conceptual chapter by F. Stewart on "Macro Policies for AT: An Introduction Classification", is basically a taxonomy of "general government policies according to their impact on technology decisions at the micro level". Her static model of technology choice assumes technology to be "a function of 4 variables: the firm's objectives; the resources available to it; the nature of the markets it faces; and the knowledge it possesses about technological alternatives". She then links government policies to technology choice via its effects on any of these variables. She also takes cognizance of the dynamic nature of technology, especially in an international trade context, and suggests an emphasis in government policies on the development of a dynamic indigenous technical change capacity.

Enos ("A Game Theoretic Approach to Choice of Technology") argues for [p. 22:] changes in the conceptualization of choice of technology from a neoclassical microeconomic theory base to a game theory base. There are two fundamental respects in which a game theory approach to thinking about technology choice may be more appropriate. The first is that "choice of technology should be described as a process which extends through time, taking at least a few years, and more likely a few decades, to come to completion". The second is that choices are not made by lone individuals but by an interacting collection of people and institutions with differing power and influence, one of which is of course the government.

Bruton's essay ("On the Production of a National Technology") searches for conditions which could lead to the emergence of an indigenous technological capability (ITC). Starting from the perspective of an individual firm he concludes that a fundamental condition for ITC to expand from such firms for such developments (fiscal policies, legislation, trade etc.). He also looks at the conditions for an adequate supply response, one of which is a responsive capital goods sector.

The final conceptual paper by James raises the issue of integrating technological considerations into other policy mediums e.g. what role does AT play in policies to eradicate certain types of poverty?

There are two empirical studies which are annotated separately and appear as individual entries into this bibliography. They are: 1. "Government Policy, Market Structure and Choice of Technology in Egypt" by D. Forsyth; and 2. "External Development Finance and the Choice of Technology" by J. White. (DH - 32)

DAHLMAN, C., ROSS-LARSON, B., and WESTPHAL, L., Managing Technological Development: Lessons from the Newly Industrializing Countries, World Bank Staff Working Papers No. 717, IBRD, 1985.

These authors draw on their collective experiences of newly industrializing countries (NICs) to propose key lessons relating to the management of technological development. They first describe the technological development of an archetypal firm, using this to define basic concepts. They then review "the steps the firm must take in choosing technology", i.e. identifying local needs and constraints, collecting information, evaluating costs and benefits, incorporating dynamic consideration.

They then describe how firms augment their technological capability, i.e. acquiring experience in production, investment or innovation. This leads into a review of foreign versus domestic technological elements including a discussion of the different transactions for acquiring foreign technology. This includes an analysis of the room for manouvering within each transactional mode.

Lastly, they assert that the economic environment is crucial. Thus, they review various aspects of government policy, e.g. the system of incentives, specialized technological agencies and direct government intervention. (DH - 102)

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE, Science and Technology for Development: Planning in the STPI Countries, IDRC Monograph, No. 133, Ottawa, 1979.

Science and Technology for Development: A Selection of Background Papers for the Main Comparative Report of the STPI Project, Part A: Science and Technology Policy and Development, IDRC Manuscript Reports, IDRC-MR21, Ottawa, 1980.

The Science and Technology Policy Instruments (STPI) project is a large collaborative research effort that involved 10 teams from Latin America, the Middle East, Southern Europe and Asia sponsored by the IDRC. Its principal aim was to examine ways in which developing countries could ensure the effective contribution of science and technology to development. In this volume they particularly emphasize the process of science and technology (S & T) policy design and implementation.

The reports and essays in this book can be divided into four categories. Readings (1), (2) and (16) deal with overviews of S & T and development in which issues such as "human resource planning", institution, information bases and regional and international aspects, are considered.

The secondary category (readings (3), (4) and (8) on Argentina, Brazil and South Korea) includes analyses of S & T plans within the context of broader development plans. The third category comprises descriptions of S & T planning experiences. These include: Columbian experiments in sectoral S & T planning (5); Egyptian S & T planning over 2 decades (6); Indian S & T planning and the process that led to its design and implementation (7); and readings (9) and (10) on Mexican and Venezuelan experiences.

The fourth category contains essays describing methods or presenting other, more general, considerations in S & T planning. Reading (11) suggests a normative framework for S & T planning. Essays (12) and (13) describe planning methods in India and Columbia and (14) and (15) discuss anticipatory decisions and resource allocation in S & T planning.

The paper in Part A introduces the background of research into S & T for development and the changes in attitude towards the subject. It then elaborates on many of the prevailing views of S & T in development, especially the conflict of "dependency" and more "orthodox" perspectives. The last section of this paper reviews the concept and perceived necessity for an explicit S & T strategy to form part of an overall development strategy. (DH - 29)

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE, Science and Technology for Development, The STPI Modules.

Modules 4, 5, 8 and 9 are described below, as these contain the most general discussions of national science and technology policy issues. Modules 6 and 7 are annotated separately, and these pertain more to specific issues in international technology transfer and indigenous technology development, respectively.

STPI Module 4, The Present Situation of Science and Technology in the STPI Countries, IDRC-TS22, Ottawa, 1980.

STPI Module 5, Instruments to Build Up an Infrastructure for the Generation of Technology, IDRC-TS26, Ottawa, 1980.

STPI Module 8, Policy Instruments to Promote the Performance of S & T Activities in Industrial Enterprises, IDRC-TS28, Ottawa, 1980.

STPI Module 9, Policy Instruments for the Support of Industrial Science and Technology Activities, IDRC-TS29, Ottawa, 1980.

Module 4 describes the S & T policy of each of the STPI countries by assessing historical background, the organization of state-influenced S & T activities, R & D activities, human resources etc. Each report includes an overview of the principal institutions in each area.

Module 5 reviews 10 governments' efforts to establish institutions to support technology generation. By this they primarily mean R & D but also diffusion mechanisms. The report looks first at "institution building" in Argentina, Brazil, India, Peru and South Korea. This generally involves describing the main state and parastatals structures, objectives and activities. It does not involve substantial analysis of their effects.

The second section of the report reviews S & T planning in Argentina, Brazil, Columbia, Egypt, India, South Korea, Mexico and Venezuela. This involves both a review of actual plans and the formulation procedures.

The final section looks at financing of R & D and diffusion activities both for and through state and parastatal institutions in South Korea, Columbia, Brazil, Peru, Mexico and Japan.

Module 8 focuses on the policy instruments available to governments to support the development of local technological capability. The "policy instruments described in this module are those directed towards inducing industrial firms to perform scientific and technological activities to ensure the proper absorption of the technology, whether foreign or of local origin, by the industrial sector".

Module 9 is closely related to module 8, except that it assesses four additional categories of policy instruments. These are: "technical norms and standards; information centres; manpower development programmes; consulting and engineering activities". The structure of the report is very much the same as module 8.(DH - 30)

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE, Science and Technology for Development: Policy Instruments to Define the Pattern of Demand for Technology, STPI Module 7, IDRC-TS34, Ottawa, 1980.

This paper looks at policy instruments which affect the structure and growth of industry and behaviour of industrial firms, thus defining the pattern of demand for technology. As such it gives an interesting insight into the relationship of technical change and industrial policies, although it unfortunately assumes minimal technological determinism, i.e. technology decisions are seen as dependent on the "primary decisions" of a company (e.g. selection of output mix). Nonetheless, it does reveal many of the state influences on technology demand. In this context instruments such as tariffs and quantitative controls, industrial policies involving subsidies and other supports, legal direction, credit promotional agencies etc. are analysed in specific case studies for their effects on technology demand, therefore choice and application. (DH - 113)

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE, Science and Technology for Development: A Selection of Background Papers for the Main Comparative Report of the STPI Project; Part D: State Enterprises and Technological Development, IDRC Manuscript Reports, IDRC-MR24, Ottawa, 1980.

This report has five essays on state enterprizes and their roles in technology policy. The first isolates the main issues involved in making such enterprizes promote desirable technological development. The second assesses the technological behaviour of selected Brazilian state enterprizes and their role in influencing technology policy. Then this section sets up an analytical background for evaluating the potential use of these enterprizes as instruments of science and technology policy.

The third section examines the research and development activities of one parastatal PETROBRAS, the Brazilian states' oil monopoly organization. The fourth section assesses the role of state enterprizes as instruments of technological policy in Venezuela. The conclusions being that "production goals" dominate "technology goals" and thus the achievement of the former targets leads to "easy" technological options such as acquisition of technology in packages.

The fifth section reviews technological behaviour in the Mexican state oil enterprize PEMEX (similar to PETROBRAS in Brazil). It concludes that financial constraints and the lack of complementary development of Mexico's capital goods sector has forced PEMEX to depend excessively on foreign technology. (DH - 180)

FRANSMAN, M. and KING, K. (eds), <u>Technological Capability in the Third World</u>, Macmillan, 1984.

This is one of the most outstanding recent books relating to the process of developing countries' technological change. It contains 21 substantive readings and a select bibliography. The readings are split into 5 sections, the first 4 dealing in largely abstract terms with key concepts and issues in technological change. The fifth section includes 9 case studies relating to specific technological issues in various countries.

The first section is a brief introduction by the editors which places the book in its intellectual context. Thus, "formerly research in the area of Third World technology focused largely on issues of the transfer and choice of technology from abroad but more recently attempts have been made to understand how imported technology is assimilated and changed to suit local circumstances, and how technological improvements of various kinds are brought about". The essays in section II provide a conceptual overview of many of the issues in technological capacity in developing countries. Dore attacks the nationalistic self-reliance-as-categorical-imperative syndrome (often the implication of dependency theorists), and then suggests some reforms particularly of the education system designed to change the emphasis from learning foreign technologies to creating indigenous ones. Stewart then outlines policy (e.g. trade, industry, education etc.) objectives which could complement indigenous technical change (ITC). Ranis also takes up this theme by attempting to conceptualise the role of ITC in economic development. Katz then takes the specific case of Latin America metalworking industries and drawing from their experiences, conceptualises the process of technical change which they have experienced. He first outlines the influences on the original choice of technique (e.g. factor prices, scale suitability, vertical integration, etc.) which he calls idiosyncratic and then examines the path of technological upgrading. He separates firm specific and external (e.g. state policies, competition) impetuses to change and then outlines responses to these. He also tackles the question of the infant industries argument.

Section III looks in broad conceptual terms at developments in the international economy and their effects on technological capability. Kaplinsky criticises the concentration on ITC due to its fixation with "incremental processes of learning-by-doing supplemented by inputs from the S & T system". It thus fails to recognise the recent developments in technology and what he perceives as a widening of the technological gap between developed and developing countries. Bienefeld stresses in very general terms the necessity to avoid a simple "national versus international" debate with respect to technological change. Leys re-asserts the non-neutrality of technology (i.e. it is intimately related to the social relations of production) from a Marxist perspective. Section IV has two articles which draw out the key issues in learning new technologies (i.e. learning by doing, formal education, searching etc.).

The case studies of section V, where appropriate, are annotated separately in other parts of this booklet (50, 108, 120).

The select bibliography and the bibliographies attached to each reading are a rich source of further references. (DH - 8)

LALL, S., "India's Technological Capacity: Effects of Trade, Industrial Science and Technology Policies," in Technological Capability in the Third World edited by Fransman, M., and King, K., Macmillan, 1984.

This paper attempts to trace the implications of certain policies on India's ability to develop indigenous technology. He concludes that the highly interventionist policies that characterize India since the 50's have stimulated a great deal of technological effort". He points to the development of the Indian capital goods industry behind protective trade barriers although these same policies have also created restraints to technical change and thus "inefficiencies". Lall outlines the restrictive aspects of these policies in terms of constrained innovation and growth due to, for example, low levels of competition, direct controls on foreign technology imports etc. Lall implicitly accepts a strong positive role for foreign technology and stresses the need for "liberalization" albeit with a certain level of careful selectivity. (DH - 58)

STEWART, F., Technology and Underdevelopment, Macmillan, London, 2nd ed., 1978.

Stewart, one of the foremost economists writing on the issue of technology and development, places strong emphasis on the often negative role of foreign technology in developing countries. She criticizes the nature of the interaction between such technology and host countries and the inaptness (primarily expressed in terms of employment effects) which characterises much technology transfer. She links the poor development of indigenous capital goods industries to the apparent necessity to import machinery and technical knowledge and thus asserts a strong role for such a sector. She also attacks the myth of "consumer choice" and claims that consumer demand in developing countries is highly manipulated. She recommends several measures to control the perceived bad points of multinational corporations (e.g. regional economic associations of groups of developing countries). She also points to certain objectives of technological appropriateness such as labour intensity, linkage creation etc. (DH - 17)

STEWART, F. and JAMES, J. (eds), The Economics of New Technology in Developing Countries, Frances Pinter, London, 1982.

According to [Hurley] the papers reflect new dynamic concerns of how technology changes over time rather than the static question of choice of technique (capital vs labour intensive) which dominated research in the 1960s and 1970s.(...)

Except for an introduction the book is divided into four parts. The first part focuses on the choice of technique. Cooper explores the criteria for choice of optimum technique in a theoretical paper using the Dobb-Sen approach and applying it to the capital goods sector. The other two papers in this section are mainly empirical and are separately annotated. Forsyth et al. develop the concept of "technical rigidity" by investigating the physical/chemical properties of production in different industries. Eno's paper is more concerned with the selection mechanisms with a case study of the South Korean petrochemical industry.

The second part of the book is concerned with production-efficiency, [p. 12:] learning and technical mastery. Pack attempts to assess the extent and causes of production-efficiency using data on the textile industry in Latin America in 1950. The other two papers are primarily concerned with changes in productivity arising from the accumulation of experience. Dahlman and Westphal introduce the concept of "technological mastery" which they believe arises mainly out of experience. In contrast, the paper by Bell, Scott-Kemmis and Satyarakwit describe a case of a steel firm in

Thailand where virtually no learning took place. This suggests that learning is not automatic and points to the need for research into those conditions that lead to learning.

The third part of the book deals with the development of Third World technology. Lall's paper examines technology exports from India and argues that these are a general indicator of technical accumulation. Morehouse's paper is also concerned with India and shows how production of the Swaraj tractor based on local technology is as efficient as production based on imported technology. Biggs' paper is an attempt at a more systematic appraisal of R & D systems.

The fourth and final section of the book is concerned with products. These two papers share a separate annotation. The paper by James and Stewart looks at the welfare impact of new products in developing countries using the Lancaster framework. The paper by James looks at the question of products standards (which is an important part of product's policy) and their applicability to developing countries.

Although the book does not have a separate bibliography the references found at the end of each paper give a good guide to the literature. The introduction to the volume also gives a good overview. (DH - 19)

JAMES, J., and STEWART, F., New Products: A Discussion of the Welfare Effects of the Introduction of New Products in Developing Countries, in Stewart, F., and James, J. (eds), <u>The Economics of New Technology in Developing Countries</u>, Frances Pinter, London, 1982.

This paper by James and Stewart analyses the welfare impact of new products in developing countries using the "Lancaster framework" of economic analysis, which sums products characteristics rather than utility. They theoretically distinguish situations in which the product has either egalitarian or non-egalitarian consumption effects. Eight short case studies are presented and in one (soap), the new product is shown to have purely negative effects on choice, on distribution and on production technology. Developing countries are advised to have an active products policy to reduce the undesirable effects of new products. (DH - 54)

FORSYTH, D., MCBAIN, N., and SOLOMON, R., Technical Rigidity and Appropriate Technology in Less Developed Countries, in Stewart, F., and James, J. (eds), <u>The Economics of New Technology in Developing Countries</u>, Frances Pinter, London, 1982.

This article investigates the physical/chemical properties of production processes in order to develop the concept of "technical rigidity". The authors construct an "index of technical rigidity" (ITR) which summarizes an engineering based assessment of the opportunities for substituting labour for capital in manufacturing subprocesses. Eight fundamental physical barriers to this substitution include the use of high or low process temperature, the application of fluid pressure on materials in process and so on. The ITR is then applied to a number of industries in five developing countries. The results are complex - while the ITR helps to explain substitution (or its absence) in some industries, in some countries the effects are not uniformly in the same direction.

Their overall conclusion is rather pessimistic - arguing that 'corrective' policies (e.g. removal of factor price distortions, wider dissemination of information on available techniques, legislation on technology choice by multinational corporations) "will have at best a marginal effect as adjustment of technology is already widespread in developing countries, and as the drift of innovation is tending to raise minimum economic levels of scale and, hence, increase technological rigidity". (DH - 110)

BIGGS, S., Institutions and Decision-Making in Agricultural Research, in Stewart, F., and James, J. (eds), The Economics of New Technologies in Developing Countries, Frances Pinter, London, 1982.

Biggs attempts a systematic appraisal of research and development (R & D) systems in order to explore the scope within R & D for benefitting the rural poor. He contrasts an "ideal" R & D system, with appropriate two-way links between R & D institutions and local producers and international scientists, with the "normal" system which is beset by "imperfections", and where dominant influences on R & D often produce dysfunctional research.

He compares and contrasts three schools of thought about the direction of technological change in developing countries: the induced innovation theory stressing factor prices; the structuralist view which sees technological change as the outcome of dominant class interests; and the institutional view (of which this study is an example) that it is determined by interest groups and arrangements in R & D institutions.

This leads to the enumeration of a number of criteria for reducing imperfections in national R & D systems. These refer both to the research goals (e.g. "justifying research against national development goals") to research methodology "client group oriented research", "specific problem-solving research", "interdisciplinary analysis") to research procedures and rewards (of integrated field and experiment station programmes") and to monitoring and evaluation. (DH - 133)

COOPER, C., "Policy Interventions for Technological Innovation in Developing Countries", World Bank Staff Working Paper no. 441, IBRD, 1980.

Cooper uses a wide definition of innovation; "the introduction of a process or product that is new to an economy of a developing country, regardless of whether it has been used before elsewhere". This [p. 18:] includes modifications or adaptations of processes or products that are new to the economy. With this in mind the paper assesses the "potential social payoff of alternative measures that might be taken to promote innovation in mainly non-agricultural sectors of a developing economy".

Part 1 describes the process of innovation - search activities, adaptations of production techniques or development of new techniques etc. Part 2 notes some of the special problems that developing economies encounter in building up innovative skills - he argues for example that the availability of foreign technologies, apart from commonly cited problems, also inhibit the development of indigenous skills.

Part 3 draws together some of the main policy implications both in terms of mediating imports and stimulating indigenous innovative activity. Part 4 "analyses the pattern of innovative activity that might be needed in developing economies"; "with an emphasis on the potential importance of local machine-making in innovation in industries that mainly use mechanical technologies as opposed to chemical, electrical or electronic technologies". In conclusion he proposes a strategy of "selective control over technology imports accompanied by measures to encourage the growth of local innovative skills". (DH - 27)

SAGASTI, F., National Science and Technology Policies for Development: A Comparative Analysis, in Ramesh, J., and Weiss, C. (eds), Mobilizing Technology for World Development, New York: Praeger Special Studies, 1979.

This short paper reviews some of the issues involved in science and technology policy formulation in developing countries, based on a five-year association with the Science and Technology Policy Instruments (STPI) Project. Explicit and implicit science and technology (S & T) instruments are discussed and 6 general characteristics of S & T policies are summarized for seven countries (Argentina, Brazil, Columbia, Korea, Mexico, Peru, Venezuela). The six characteristics refer to i) the role of the state in orientating the industrialization process; ii) reliance on positive or negative control mechanisms; iii) the mode of state intervention; iv) characteristics of the array of policy instruments; v) coherence of S & T policy and degree of integration with industrial policies; and vi) recent trends and changes in government industrial or S & T policy. (DH - 34)

KATZ, J., "The Creation of Technology in the Argentine Manufacturing Sector", IDB/ECLA Research Programme in Science and Technology, Working Paper No 1, UNECLA Buenos Aires Office, July 1978.

The main concern of this paper is domestic technological learning and its relationship to research and development (R & D) investment, technology imports and dynamic comparative advantage. This is carried out through a study of the Argentine manufacturing sector.

The author argues that there is a complementary relation between importing technology from abroad and generating technology locally. He analyzes the forces causing the flow of internal technological efforts and differences between industries in domestic technological expenditure.

The author argues that a significant proportion of the internal technological effort is concentrated in the engineering groups of local subsidiaries of multinational corporations. This raises important questions related to appropriateness of the results of technological learning in developing countries and to technological dependence. (DH - 57)

LALL, S., Developing Countries as Exporters of Technology, Macmillan, 1982.

This book reviews the experiences of India as a developing country exporter of technology. The principal conduit for these transfers examined is large corporations in the industrial sector. Lall provides "a tentative explanation for this by arguing that official protection of local "learning", while fostering varying efficiencies, has enabled local enterprises to accumulate substantial stocks of technical know-how". (DH - 90)

HERRERA, A., "The Generation of Technologies in Rural Areas", in World Development, Vol. 9, pp. 21-35, 1981.

The author first criticizes the weakness of attempts to generate and diffuse appropriate technologies (AT) due in his mind to the lack of a coherent concept of development as a reference point and the assumptions or paradigms emanating from rich countries which underlay current attempts.

He then proposes an interactive research and development procedure with a premium on communication with rural dwellers and more emphasis on traditional technologies at least as contributors to new solutions to social problems or objectives. He also stresses the need to understand the dynamic socio-economic elements in which a technological problem is always immersed. (DH - 171)

4. RESEARCH AND UTILIZATION AS A MANAGEMENT PROCESS

This section covers some of the most important literature on ways of managing research and the utilization process. The underlying hypothesis is that research organizations, be they private or commercial, or public and governmental, are organizations just the same, subject to human principles of leadership, motivation, reward and performance. A lot of the literature has focused in industrialised countries. Some pioneering effort has been achieved at MIT, in Cambridge, Mass, with the works of Ed Roberts and Tom Allan. Not very much has been written on the research process in developing countries, where conditions, as noted by PATI in the previous section, in reporting on the failures of the recommendations from the 1979 Vienna UN conference, are less than ideal.

We will start by documents indicating that there is official concern about the performance of research efforts in developing countries.

> *(For IDRC, the best document outlining this concern is PPR X, which notes the difficulties of finding "success" stories from past research efforts, and outlines six types of outputs one should expect from a research project:*
>
> > *hard technologies (handpumps, dehullers)*
> >
> > *biological products (new seed varieties)*
> >
> > *health products (contraceptive vaccine)*
> >
> > *knowledge (relation between sanitation and health)*
> >
> > *policy advice (structuring macroeconomic policy)*
> >
> > *the introduction of new elements of public debate.*

PPR X advocated a number of initiatives that IDRC could undertake to increase the utilization of research results, including the idea of experimenting with new approaches in managing projects.

Another organization that has expressed similar concern is SAREC, the Swedish Agency for Research Cooperation with Developing Countries:

Kihlberg, Mats (ed.). 1987. SAREC's First Decade: Swedish Support for Research in Developing Countries - A Progress Report with Some Guidelines for the

Future. SAREC (Swedish Agency for Research Cooperation with Developing Countries), Stockholm. 62 p.

(p. 2-13) The first Annual Report [of SAREC in 1975] discussed what should be included in the term **national research capacity**. The field of operations was described and specified and a fairly broad definition was arrived at.

Research capacity involves:

> The ability to independently identify and define research tasks and their relationship to problems and development activities;
>
> The ability to select, plan and carry out important research, or to commission and direct such research which cannot successfully be undertaken with domestic technological, financial and human resources;
>
> The ability to assess, sift and adapt research results for domestic application;
>
> (p. 13) The ability to offer the country,s own research workers an environment which is sufficiently stimulating to counteract migration to technologically advanced countries;
>
> The ability to disseminate and apply research results;
>
> The ability, in terms of finance and staff, to utilize and participate in the opportunities offered by international research co-operation.

It is important to devote attention to all these aspects in research co-operation.

(p. 24-25) In reply to an external review of its own operations, commissioned by parliament in mid-1984, SAREC made the following points regarding international research programmes:

> "One of the major problems with international programmes has been to disseminate and apply the results research has produced. Hitherto few studies have been concerned with this. The "Impact Study of the CGIAR" is an attempt to investigate the impact of research results at a national level through a review of the international agricultural research institutes. It followed a Swedish initiative and SAREC intends encouraging further studies of this kind.

> One way in which SAREC can contribute to the dissemination of research results is to support direct contacts between international centres and national institutions in programme countries. Such contacts can also be utilized for the training of researchers. To some extent this is already occurring within the WHO and CGIAR programmes. To promote this type of co-operation, and directly utilize international and regional centres to support national research environments, are central to the African programmes now in preparation.
>
> (p. 25) Some of the evaluations which have been undertaken indicate that research within the international programmes is often of high scientific quality, but that it sometimes is so restricted to a single discipline that, in the short-term at least, it is difficult to find applications transferable to the developing countries.
>
> The conclusion is that there are important reasons for continuing to support international research programmes. Often highly qualified research produces results in fields of immediate concern to developing countries. But more should be done to promote the dissemination and application of these results at the national level."

One of the pioneer researchers in the Technology Management area is Tom Allen, now at the Sloane School at MIT.

Allen, Thomas J. "Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization" M.I.T. Press, 1984, Cambridge, Mass.

In this classic book, Allen reports on over ten years of research, observing with great care how research scientists communicate with themselves and with the outside world. He used twin pairing of development research projects to measure sources of information, and their effect on the evolution of technical innovations. It also provides a good analysis of the difference between the scientist and the engineer. In it he also has his famous chapter on the "gatekeeper" within a laboratory context, always on the lookout for relevant information for his colleagues. He also evolves techniques for mapping of "information" networks, and how to manage them constructively.

While Allen concentrates primarily on communication within the scientific establishment, and how that affect efficiency, Ed Roberts, also at the Sloane School, examines the process of innovation as a strategic weapon in the hands of a company. His analysis is very much from the perspective of a corporate captain, who has to master the research and *technological innovation process to gain a technical advantage over his competitor. Because of the importance of this notion, detailed excerpts from one of his most recent review books are presented here. The book "Generating Technological Innovations" contains several major papers published over the history of MIT Management of Technology program. The excerpts are from the introductory chapter, authored by Roberts:*

Roberts, Edward B. 1987. Generating Technological Innovation. Oxford University Press, New York, NY, USA. 299 p.

INTRODUCTION: (p. 3-5)
Managing Technological Innovation - A Search for Generalizations

Edward B. Roberts

The management of technological innovation is the organization and direction of human and capital resources toward effectively (1) creating new knowledge; (2) generating technical ideas aimed at new and enhanced products, manufacturing processes, and services; (3) developing those ideas into working prototypes; and (4) transferring them into manufacturing, distribution, and use. Technologically innovative outcomes take many forms: incremental or radical in degree; modifications of existing entities or entirely new entities; embodied in products, processes, or services; oriented toward consumer, industrial, or governmental use; based on various single or multiple technologies. Despite obvious variations in managerial issues, across these differences in intended outcomes and settings, a number of consistent generalizations emerge from over twenty years of systematic managerial research. This introduction seeks to identify those generalizations (shown below in italics), and this book aims at providing more depth, detail, and illustration of them.

The first generalization is <u>innovation = invention + exploitation</u>. The invention process covers all efforts aimed at creating new ideas and getting them to work. The exploitation process includes all stages of commercial development, application, and transfer, including the focusing of ideas or inventions toward specific objectives, evaluating those objectives, downstream transfer of research and/or development results, and the eventual broad-based utilization, dissemination, and diffusion of the technology-based outcomes.

Invention is marked by discovery or a state of new existence, usually at the lab or bench. Innovation is marked by first use, in manufacturing or in a market. This distinction is critical, because for too many years related research writings and even managerial practice have focused only on managing "creativity," with relatively too much attention devoted to the lives of great inventors [p. 4:] or famous scientists and their radical breakthroughs. Yet most organized scientific and engineering activity, certainly within the corporation, is beyond this idea-generating stage and produces not radical breakthroughs, but rather a broad base of incremental technological advance, sometimes leading cumulatively over time to major technical change.

The next two generalizations about technological innovation [relate to the] process of how technological innovation occurs. First, technological innovation is a multistage process, with significant variations in the primary task as well as in the managerial issues and effective management practice occurring among these stages. [There are] six stages, but the precise number and their division are somewhat arbitrary. (...) What is key is that each phase of activity is dominated by the search for answers to different managerial questions.

At the outset, for example, emphasis is on finding a motivating idea, a notion of possible direction for technical endeavour. Coming up with one or more technical and/or market goals that stimulate initiating a research, development, and/or engineering (RD&E) project is the task undertaken during stage 1. The relevant managerial question for this stage is, How do more and better targets get generated? Which people, which structures, which strategies can be employed toward more effective idea generation for these objectives? Good managerial practice at this stage frequently involves loose control, "letting many flowers bloom," fostering conflict or at least contentiousness, stimulating variety of inputs. At a later stage, the stage 5 commercial development as an alternative example, the task involves in-depth specification and manufacturing engineering of ideas that have by now already been reduced to an acceptable working prototype. The managerial issues in this stage involve coordinating a number of engineers of different disciplinary backgrounds toward achieving, within previously estimated development budget and schedule, a predefined technical output ready for manufacture in large volume, reliably, and at competitive production costs. Effective managerial practice in this stage might well involve tight control, strong financial criteria for resource use, single-minded adherence to plan, especially in regard to those resources - in many ways the opposite of what is encountered in stage 1.

The next generalization [embodied in the schematic presentation] is that innovation occurs through technical efforts carried out within an internal organizational context, but involving heavy interaction with the external technological as well as market environment. Proactive search for technical and market inputs, as well as receptivity to information sensed from external sources, are critical aspects of technology-based innovation. All studies of effective innovations have shown [p. 5:] significant contributions of external technology and awareness of customer needs and competitor activity.

SUMMARY OF SIX POINT FLOW DIAGRAM:

1. Recognition of opportunity
2. Idea formulation
3. Problem solving
4. Prototype solution
5. Commercial development
6. Technology utilization and/or diffusion

The details of Figure I.1 [NOT INCLUDED HERE] specify a set of key flows and decision points that occur during the process of innovating. A number of major managerial elements that are embodied in those details will be treated in the discussion that follows. Two aspects of the diagram, however, are potentially misleading and deserve immediate mention. First, for ease of presentation, all stages are shown at equidistant intervals, inappropriately suggesting perhaps the similarity of these phases from a time duration and/or resource consumption perspective. This is by no means true. In particular, stage 5, commercial development, usually takes as long as the several earlier stages combined and requires more resources than most of the other stages together. Second, for simplicity sake no feedbacks are pictured in Figure I.1 from later stages back to earlier ones. Yet, inevitably, these feedbacks exist and cause reiteration to occur among the stages. For example, involvement in the problem-solving process, stage 3, generates new insights as to alternative idea formulations, stage 2; and efforts at transfer into manufacturing as part of technology utilization, stage 6, often create new requirements for problem-solving, stage 3. Thus the real process of technological innovation involves flows back and forth over time among differing primary activities, internal and external to the dominant innovating organization, with major variations in tasks, managerial issues, and managerial answers.

Three dimensions provide a framework for synopsis of factors affecting successful innovation: staffing, structure, and strategy. (...) For each dimensions a number of managerial generalizations can be identified, supported by the research literature and the selected articles contained in this volume.

STAFFING

Two primary questions arise in regard to staffing the technological organization: What kinds of people need to be involved for effective technical development? And what managerial actions can be taken to maximize their overall productivity? In regard to people requirements, as explained by Roberts and Fusfeld (1981) in Chapter 1, a number of "critical behavioral roles," not just technical skills, must be practised by the people involved in a technical development. Roberts and Fusfeld identify five key roles for achieving successful innovation, although others have since added to this list (e.g., Maidique in Chapter 2 argues for six key roles).

STRUCTURE (p. 10-11)

The design of organization structures that will enhance technological innovation requires focusing on both the organization's inputs and its outputs. Effective RD&E organizations need appropriate technical and market information inputs, and their outputs need to be integrated toward mission objectives and transferred downstream toward their ultimate users.

MARKET INPUTS

Managerial research has repeatedly demonstrated that 60 to 80 percent of successful technical innovations seem to have been initiated by activities responsive to "market pull," i.e., forces reflecting orientation to perceived need or demand. The studies less frequently indicate how technical organizations uncover these needs. As mentioned in Chapter 1, market "gatekeepers" frequently aid the technical organization to understand better its customers' requirements, priorities, and preferences. Organizing to gain meaningful market inputs for research and engineering use may depend upon explicit assignments of such responsibilities to cooperating marketing staff or to RD&E people themselves. The product development cycle should be organized, as suggested in Figure I.1, to bring market inputs into design repeatedly during the early product specification stage and again during prototyping through active involvement of selected customers. Depending on the company and industry, the manufacturing organization of the developing company is anywhere from one- to two-thirds of those eventual "customers." Manufacturing will (or won't!) "buy" the developed improvement in materials, components, manufacturing equipment, or overall [p. 11:] production process for its own internal "consumption." That prospective "customer" needs at least the same degree of involvement with the design and development process as does an outside firm or individual.

Rather than seeking collaboration to provide market information to the RD&E process, many companies have substituted marketing-oriented control of RD&E. Organizational subordination of research and engineering to "product managers" (inevitably marketing or sales people) or tight budgetary control of RD&E by these units may force market-based criteria to dominate technical project selection. But this is usually accompanied by short-term quick-fix orientation, erosion of technical capability, and gradual destruction of product/process competitiveness. Analyses by Souder (1978) have demonstrated that strong and positive relations between R&D and marketing organizations significantly improve the track record on new product introductions. In my view this is best achieved by welding partnerships among equals, rather than by compliance from subordinates.

Market-research techniques have long been used to help define consumer preferences in new product designs (Urban and Hauser, 1980). These methods have been less helpful for developing industrial goods. Recently von Hippel (1986) has demonstrated that potential industrial customers whose needs place them along the leading edge of technological demands can be used to specify detailed desired performance characteristics and features for as yet nonexisting products. Urban has suggested that the R&D organization itself should include the staff capabilities t apply these new methodologies (1986).

OUTPUT TRANSFERS (P. 14-16)

But in addition to generating outputs, the technical organization needs to be designed to enhance output transfer downstream toward eventual customers and users. Downstream is where innovation takes place and where benefits are realized! Studies of major research laboratories, among other RD&E organizations, have indicated high degree of dissatisfaction with the extend and effectiveness of transfer of results to potential recipient groups. Three different clusters of bridging approaches were found helpful in increasing transfer - procedural, human, and organizational. Most organizations used a variety of these approaches, often several simultaneously. Roberts' findings have been supported by recent comparative case studies of IBM (Cohen et al., 1979) and Union Carbide (Smith et al., 1984), among others.

Procedural methods include joint planning of RD&E programs by performing and expected receiving organizations (often resisted by R&D as an "invasion" of its turf); joint staffing of projects, especially pre- and posttransfer [p. 15:] downstream; and joint project appraisal after project completion, done cautiously if at all after failures in order to avoid destructive fingerpointing.

Human bridges are the most effective transfer mechanisms, especially the upstream and downstream transfers of people. Movement of people upstream (1) brings with them information on the context of intended project use; (2) establishes direct person-to-person contacts that will be helpful in later posttransfer troubleshooting; and (3) creates the image that the project eventually being transferred has involved prior ownership and priority inputs from the receiving unit. Later movement of people downstream: (1) carries expertise for posttransfer problem solving; and (2) not unimportant, conveys the risk-reducing impression that the receiving unit will not be stuck with solving posttransfer problems by itself. Other human bridges that are widely used include rotation programs, market gatekeepers, joint problem-solving sessions, and other formal and informal meetings.

Organizational techniques for enhancing transfer are complicated to design and implement and consequently are left as last in this discussion of alternatives. "Integrators," sometimes called "transfer managers," or integrating departments are frequently appointed to tie together the sending and receiving organizations. This person or unit is given the responsibility for moving the project from the sender into operating condition in the receiver organization, either lacking authority in one or the other organization or being matrixed between both.

More ambitious organizational approaches include dedicated transfer teams, established solely for the period during which technical results are being transferred to their "customers," done especially for moving purchased process technology. The "design and demonstration organization" described by Frontini and Richardson (1984) is another type of temporary organization, set up to show project feasibility at a scale beyond pilot plant level, to help reduce resistance to later full-scale implementation. In Chapter 6 Quinn (1979) discusses the organizational issues facing the major corporation seeking to create new businesses and suggests parallels between the individual entrepreneur's approaches and the means by which a large corporation can achieve growth and change. Quinn's article anticipates the multifaceted discussion of corporate entrepreneurship in Part III of this book.

STRATEGY

Strategic management of technology includes both strategic planning and strategic implementation aspects at either of two levels: (1) over-all, for the entire technology-dependent firm, government agency, division or product line; or [p. 16:] (2) more focused, for just the technology development/acquisition process/department/laboratory of the entire organization. As recently as ten years ago, neither of these levels of strategy was the subject of much serious scholarship, or even of management-consulting practice. Few researchers carefully studied the overall management of the technology-intensive company. And fewer still addressed the questions of how to incorporate technological considerations into overall business strategy.

Strategic planning focuses upon the formulation of an organization's goals and objectives, and upon developing the policies needed to achieve those objectives, including identification of the organization's primary resources and priorities. But developing corporate strategy with such a global perspective, including technological dimensions, is quite new. Indeed, the evolution of corporate strategic planning as a field of practice is divisible into three decades: the 1960s, during which multiyear budget projections became the earliest forms of financial planning, sometimes labelled "long-range planning"; the 1970s, when market growth/share matrices and market attractiveness considerations added a new dimension to strategic analysis; and the 1980s during which technology as a strategic factor became so widely acknowledged as to cause firms and even countries to realize that financial, marketing, and technological considerations needed to be integrated in overall strategy development (Roberts, 1983).

(p. 17-18) Each stage of a technology is associated with different strategic implications. [p. 18:] The earliest stage in a technology's life cycle tends to feature frequent major product innovations, heavily contributed by small entrepreneurial organizations, often closely tied to lead user needs. The intermediate stage of a technology may include major process innovation, with continuing product variation, with increasing numbers of competitors, both large and small. The late stage of a technology features less frequent minor product and process innovations, contributed primarily by large corporations, motivated mostly by cost-reduction and quality-improvement operational objectives (Utterback and Abernathy, 1975). These key dimensions of a technology should strongly influence choices made by a firm or government agency in developing its technological strategy.

These excerpts should give the reader a sense of the power of some of the concepts underlying management of technology and innovation. Another area of research, again spurred largely from North American business research is the ***new products*** *literature, a subset of the marketing discipline, of which one of the better known authors is a Canadian, Bob Cooper. Here are some highlights from his recent book, "Winning with New Products". New Product introduction is the lifeblood of market-oriented companies. It is also a very risky game. Cooper outlines in a businessman's language actions which can be taken to reduce the risk of failure in introducing a new product on the market.*

Cooper, Robert G. 1987. Winning at New Products. Gage Educational Publishing Company, Toronto, Ontario. 273 p.

THE NEW-PRODUCT GAME PLAN (p. 35-37)

1. New-product development and commercialization is a high-risk but vital endeavour of the modern corporation.

Of every seven new product ideas, only one becomes a commercial success.

Of every four new products that are fully developed, only one becomes a commercial success.

One out of every three new products actually launched into the marketplace fails commercially.

Almost half the resources that U.S. industry devotes to the development and commercialization of new products is spent on products that fail or are cancelled.

2. There are no easy answers to what makes a new product a success.

3. Companies that follow a new-product game plan do better.

4. New-product success is amenable to management action. (p.37)

5. A strong market orientation is needed in new-product development. (p. 38)

6. The nature of the product is central to its success. (p. 39)

7. More homework must be done before product design and development are undertaken.

8. Better, more consistent, and more systematic product evaluation is required. (p. 40)

9. A well-conceived, properly executed launch is vital to success. (p. 41)

10. Organizational structures that provide for multi-functional inputs and internal communication and coordination foster successful new products. (p. 42)

A SEVEN-STAGE GAME PLAN (p. 48)

Idea; preliminary assessment; concept, development, testing, trial, launch.

THE FINAL PLAY: INTO THE MARKET (p. 183)

<u>The Marketing Plan</u>

The marketplace is the battleground on which the new product's fortunes will be decided. Thus, the plan that guides the product's entry to the market is a pivotal facet of the new-product strategy. In this chapter, we'll look at the factors involved in developing a marketing plan for your new product.

First, what is a marketing plan? It's simply a plan of action for new-product introduction or launch. It specifies three things:

> the marketing objectives;
> the marketing strategies; and
> the marketing programs.

<u>The Market Analysis</u> (p. 189)

The market analysis lowers the microscope on the market for the new product. A good market analysis covers the important topics:

> <u>Market overview</u>. What are the quantitative and qualitative aspects of market size, growth, and trends?
>
> <u>Market segments</u>. What market segments are aimed at? How is each segment unique? What are the quantitative and qualitative aspects of their size, growth, and trends?
>
> <u>Buyer behavior</u> (in the segments in question). The who, what, when, where, why, and how of the purchase process are set out. Who buys? Who are the purchase influencers? What do the buyers buy, and when, and where? Why do they buy what they buy? What are their choice criteria and what are their preferences, wants, and needs?
>
> <u>Competition</u>. Who are the competitors? In which segments? What are their strengths and weaknesses? How good are their products? How does the customer rate their products? What are the competitors' strategies in pricing, advertising, and distribution? How well are they doing in market share and profitability? Why?

There are two points to remember: First, much of this market information will not be readily known at the outset of the new-product project. By the time the project is entering the product-development stage, however, market studies should have been undertaken and a thorough market analysis, with action implications, should have been completed.

The second point is that a good market analysis goes a long way toward charting a winning market strategy. If the market analysis lacks insight and information, the marketing plan probably will be vague and not very hard-hitting. A sound market analysis is the foundation upon which a winning launch plan is built. Don't skimp at this stage.

The Macroenvironmental Analysis (p. 190)

A macroenvironmental analysis looks beyond the immediate marketplace for the new product. Trends and factors that lie outside the firm and the product's market that may impact on the market and product are analyzed:

the economic situation;
the political, legislative, and legal situation;
demographic trends;
social trends; and
technological developments.

The next work offer a first-hand analysis of how some major research organizations have gone about to ensure maximun utilization of research results. The three authors, Lane, Beddows, and Lawrence, develop an interesting set of models for managing laboratories. To prove their case, they compare two different very large American institutions, the National Health Institute, and AT&T's Bell Laboratories. In the process, they develop useful models for analyzing research structures:

Lane, H.W., Beddows, R.G., Lawrence, P.R. 1981. Managing Large Research and Development Programs. State University of New York Press, Albany, NY, USA. 166 p.

The two contrasting attitudes on how best to manage research can be summarized as follows: (p. 7)

FOCUS: Society's Problems vs. Science's Problems

ORIENTATION: Maximize Output (Applied Research) vs. Maximize Knowledge (Basic Research)

TIME HORIZON: Short Term vs. Long Term

LOCUS OF CONTROL: Managers/Administrators Evaluate (External) vs. Scientists Evaluate (Internal)

DEGREE OF CONTROL: Tight Control vs. Autonomy

The Two Organizations (p. 8-9)

We studied programs in two very large, complex, highly visible and unique institutions. NIH, with a budget of approximately $2 billion, is perhaps the wold's focal point for biomedical research support. Its organization is as complex as its scientific mission. It is a non-profit organization that can be characterized as polycentric and relatively open to political pressure. Each Institute is essentially a centre of power revolving around a central administrative and policy core. The programs we studied were contained within these semi-autonomous institutes. AT&T, on the other hand, is profit-oriented and is a much more highly integrated organization displaying more central coordination and control than NIH. Bell Laboratories, the [p. 9:] primary locus of research and development activity in the Bell System, is, in its own right, unique in size and accomplishments. Its budget exceeds $600 million and it employs more than 16,000 people including some Nobel Laureates.

Another difference that was dramatic, but not extremely important for our purposes, was the number of personnel directly employed. All the NIH programs had very small staffs compared to AT&T programs, for the simple reason that the NIH program staff only provided senior management or top level guidance to the program; almost all of the technical work and its direct supervision was "bought" elsewhere by grants and contracts. In contrast, the AT&T efforts were all "in house."

We compared two very different sites and found some very similar processes across the gap of "incomparability." The focus was the management process and our findings, we believe, can increase understanding of the management of large research development programs, particularly in the balancing of technical and political considerations. In most instances, these processes took place at a program level with NIH; and while many of these issues also were addressed at the program level at&T, some were addressed at the corporate level.

The Bell Laboratories Organization (p. 100)

Bell Labs is a mission-oriented research organization structured (...).

Areas 10 and 20 are the science and technology generators of the Bell System. The research area (Area 10), oriented primarily toward discovery, is organized by scientific disciplines: physical research, materials research, chemical research, mathematics, behavioral sciences, communication sciences, and operations research. Electronics technology (Area 20) does fundamental and applied research on the usefulness of new technological concepts, as well as in the field of manufacturing design. Areas 30, 40, and 50 were the organizational homes of the two exploratory development and two development programs we studied. Bell Labs is a complex organization that must manage and integrate a wide range of disciplines, orientations, and geographical locations.

Managing Knowledge Transfer (p. 102-104)

In addition to managing activities within each of the organization's areas, Bell's executives had to manage the transfer of knowledge through the stages of the technical logic. These stages, discussed in Chapter 3, are shown again in Figure 18.

Figure 18:The Technical Logic of R&D

Discovery (1,2,3)

Exploratory Development (4)

Development (5) Engineering Design
Production Processes

Production (6)

Implementation (7)

Our research suggests that a continuum of uncertainties faces R&D organizations, (...).

Mansfield et al (1971) stated that R&D "is an activity which is aimed at reducing uncertainty ... aimed at learning." Each subsequent stage of the technical logic deals with a different mix of uncertainties - generally a decreasing degree of scientific, engineering, and production uncertainty and an increasing degree of market and political uncertainty.

There are implications for management. First, programs should be organized to reduce the appropriate uncertainty. This means defining the research focus to represent a realistic assessment of the existing state of knowledge. As one individual at Bell Labs pointed out, it does not make sense to develop production specifications for something you don't understand. Mounting an engineering effort to solve an uncertain scientific problem is ineffective and inefficient, as was seen in the artificial heart case. A realistic assessment of the research problem also should provide an indication of the time and resources required to resolve the relevant uncertainties before the program can proceed to the next stage.

Second, the organization has to be differentiated to handle the various areas of uncertainty with which it must deal, and be able to shift [p. 103:] responsibility to the sub-unit best equipped for the task. The organizational structure at AT&T reflects the different orientations, or technical sub-logics, which must be part of the R&D process. As the organization reduces the scientific and technical uncertainties, it increasingly turns to the relevant social and political uncertainties. In the Bell System, following resolution of any remaining technological problems in the exploratory development phase, overall responsibility for the program often shifts to Western Electric or to some marketing group, for example. It marks a crossover point where the Bell System organizationally recognizes the shift in task focus. Such crossover points recognize the growing dominance of a new sub-logic, better suited to removing the remaining uncertainty.

Our study also suggests a change in dominant orientation from a scientific to an engineering focus as one moves from discovery to exploratory development and into engineering design; and a shift toward the other pole, implementation, beginning around the development of production processes stage. Organizationally, the development stage appears to reflect a type of cross-over point (...), which we will describe in more detail shortly.

A strong desire for appropriate management of both research activities and system development programs, along with a concern for the transfer and use of knowledge, was apparent throughout the Bell Labs. An interest in application [p. 104:] in Area 10 seemed to dispel any notion that successful, renowned research scientists ignore application. There also was a positive orientation toward implementation in exploratory development and development programs. In fact, strikingly consistent in the interviews with various people deployed along the technical-logic continuum was their understanding of their respective orientation and role in the organization, as well as the orientations and roles of groups at other positions on the continuum. The descriptions that follow illustrate Bell's approach to organizing for technical tasks and to managing the continuum.

<u>Linking Tasks and Organization</u> (p. 119-120)

Bell Labs has been quite successful in generating knowledge and producing technology. Without claiming to be the only reason for this success, we believe the organizational arrangements of the type described in this chapter make a significant contribution to that success. Not only were specialists [p. 120:] groups in place to resolve problems specifically related to the stages of the technical logic, but the importance of linking these groups to ensure the transfer of relevant information and skills was emphasized. It was clear to us from interviews with Bell's executives that organization, as well as technical specialties, mattered to them. Knowledge and organization were necessary components in developing and producing communication systems. The link between Bell's task and its organization is reinforced by the concept of the Bell System as one system with physical and organizational components.

The physical component is the telephone network itself and programs had to be justified in terms of the total operating communication system. All parties - researchers, developers, and managers - were fully attuned to this governing image of a single system. Bill Warters, the man who probably had the largest and biggest stake in pressing on with the millimeter waveguide development, said it all in commenting that the most recent delay was "personally disappointing but not disappointing from a Bell System standpoint. If it's not economical, it is not right".

The "one-system" concept emphasized technical and market feasibility of each project before funding full-scale development. There also was emphasis on acquiring and using intimate knowledge of all segments of the environment bounding the system under development. The end result would be a product designed to fit into and enhance the existing network.

New technology created waves lapping Western Electric, often creating difficult times and tension. The more successful Bell Labs was in creating technology, the fewer people were required by Western Electric which relied on Bell Labs for its product specifications. As Western Electric added a person to build electronic devices to increase telephone line capacity, it might lay-off three building cables. Both the development of tightly integrated circuit-board components, requiring mounting of fewer elements, and the convergence of telephone technology with computer technology, bringing competition by many qualified component suppliers, could significantly affect Western Electric's direct labor requirements. Organizations must adapt to these changes. As one Bell Labs executive puts it:

> Our organizational arrangements are dictated by the things we do and are dependent on the technology involved. You have to build your arrangements around the physical phenomena. The organization has to mirror this.

The one-system concept provided managers throughout Bell with a powerful image that forced them to recognize such interdependencies and to understand actions aimed at balancing the organizational system. The manifestation of this type of thinking was seen in the array of structures, systems, and interpersonal processes used to face-off organizational units to a particular stage of knowledge development and, simultaneously, to tie them together.

(p. 121) A strength of the Bell system is the degree to which it distinguishes differing task situations and matches its administrative processes to fit them. The mirror metaphor and the one-system image were in active use in the Bell system. Both seemed to function as heuristic aids for fitting the organization to its task and environment and as criteria for managerial action.

What can the Bell experience teach other R&D organizations like NIH? The Bell System is more highly differentiated and integrated than NIH. It simply has more organizational units focused on the various stages of the innovation process and on linking them together than does NIH. It is organized specifically to move knowledge and equipment through this pipeline. NIH is primarily a research institution that is not organized for development and implementation processes, although we have been that it becomes involved in these areas, often with less than positive results. If the political system wants NIH to get fully into the development business, it will have to give thought to ways of organizing to achieve this purpose. And it will have to be more realistic in its expectations. We have seen that the process of moving knowledge from discovery to implementation is complex and time-consuming even when you are organized to do it. The Bell experience illustrates the important relationship between technology generation and organization. The successful R&D organization will be conscious of the different orientations necessarily embodied in it and will organize to reduce internal barriers to promote transitions in technical stages.

As a final comment, it should be noted that management in developing countries adds some distinct complications. Some have already been alluded to in PATI's review of the impediments to the Vienna Program of Action. Another short article by Dahl reviews some of the differences in relating to third world people.

Dahl, O. <u>Development as cross cultural communication</u> Uppsala? : Scandinavian Institute of African Studies, 1984 10 p. paper presented at the conference Religion, Development and African Identity Uppsala 16-21 Aug. 1984

In this paper, Dahl provides insightful analysis of cultural filters of a westerner and an african, how each one perceives the values of the other.

(* Also refer to Henri Bougoiun's book, "L'Afrique Malade de Management", in which he compares African styles of management in companies, with those in America, Japan and the Scandinavian countries.)**

(Also refer to James Austin forthcoming book, "Strategic Management in developing countries", where he develops a framework to encompass cultural, environmental, political and religious factors, over and above the normal management functions found in a typical company. The book, to be published this spring, looks at the problem in a very pragmatic way, from a user's point of view. The user, in this case, would be a North-American businessman wishing to invest in a third world country.)

Finally , here is a good overview of what managing research in India entails. The aricle is part of of a book edited by Wad, and in Wad's words, contains some sobering facts:

> (p. 8) Falguni Sen's contribution focuses on the problems of managing R&D in India, a country with a sizable scientific and technological base within the third world. It raises a fundamental issue; even in a situation where there are adequate resources and structures made available for R&D, why is it that the output of useful technological knowledge in developing countries is still so low? Sen points to bureaucratic obstacles, inadequate management resources and skills, personality issues and inadequate recognition to scientists for their work as some of the problems. He suggests a more efficient system for the management of scientific and engineering personnel, more flexibility for researchers and more encouragement of creativity as possible measures to overcome some of the present problems.

Falguni Sen, THE DILEMMA OF MANAGING R&D IN INDIA, in Wad, A. (ed.). 1988. Science, Technology and Development. Westview Press, Inc., Boulder, CO, USA. 315 p.

<u>Introduction</u> (p. 279-281)

> Management of research and development (R&D) has emerged as a separate field of academic inquiry in the past decade. This is, in part, due to a recognition of some of the peculiar nuances within R&D as an activity, which add complexities to its management. Some of these nuances arise out of the high levels of capital investment required for modern R&D, coupled with extremely high levels of uncertainty. This uncertainty lies with the probability of success, both technical and commercial, of the outputs of R&D and with the understanding of the process of doing R&D itself. The management of R&D is further complicated by the fact that its success is

contingent upon the effectiveness of a large number of other sub-units which have to implement the results of R&D. Typically, R&D units have little or no control over these sub-units. R&D's success may depend on its ability to effect change without having any authority to do so. Thus, the management of uncertainty and the management of "interfaces" between R&D and other sub-units are two of the most important aspects of R&D management. The third area of management, vital to R&D, is the management of creativity. The success of a scientific research establishment is directly related to the number of useful ideas that are generated by its people. A successful R&D organization is one that can strike the right balance between "flexibility" to enhance creativity and "control" to make the creative ideas compatible with the goals of the organization. In trying to carefully manage these three issues of uncertainty, interfaces and creativity, an R&D manager can either become overly cautious, resulting in a sub-optimal allocation of resources which does not allow a critical mass to [p. 280:] evolve within R&D and results in little or no output, or become highly risk-taking and lead to expectations from R&D which it may not be able to fulfill.

Managing R&D in a Developing Country

The nuances of managing R&D discussed above exist irrespective of the organization or country within which the R&D activity is being performed. The major differences may lie in the degree of the problems and the possibilities for solutions. In a developing country, however, a number of additional nuances may exacerbate these issues. Capital availability is scarce and may give rise to greater pressures to demonstrate results from investments in R&D. On the other hand, investment in R&D may be viewed as a way to maintain an elite group of scientists and, therefore, as an expense item requiring little demonstration of results. Scientific establishments may be viewed with "national pride" requiring no further justification for their existence. The situation can get really complicated when all three views are simultaneously in existence.

The degree of uncertainty underlying the likelihood of commercial success of R&D's results in a developing country is likely to be more, due primarily to the greater uncertainty regarding the availability of capital for implementation of R&D's results. The degree of technical uncertainty may be higher or lower depending on the peculiarities of the project in question. A lot of the R&D being done in a developing country is not at the state of the art but is a duplication with the purpose of indigenization of already existing know-how; thus one would assume that the degree of technical uncertainty would be lower. However, such a duplication is often done either to by-pass existing patents and, therefore, come up with essentially a new process or to use locally available materials to achieve the same efficiencies, or even to scale-down the process. It turns out that the degree of technical uncertainty in many cases, can be as great as developing the process from scratch.

There is a tendency for organizations in developing countries to be more centralized. Where top management commitments to an R&D project exists, this centralization can be helpful in gaining compliance of the sub-units to implement results and provide general cooperation. Complex techniques of managing "interfaces" may not be needed. On the other hand, where top management commitment does not exist, even the most sophisticated "interface management" [p. 281:] techniques may not help in the implementation process. In such situations the most effective managerial strategy may be for the R&D unit to try to gain power within the organization.

Managing creativity has always been a complex issue. Availability of slack resources is one of the characteristics usually attributed to creative organizations. This slack, it is claimed, allows for flexibility in the organization and the introduction of a culture where "errors" are not penalized. Flexibility and tolerance of errors are intrinsic to creativity management. Efficient management of creativity then succeeds in channelling these creative outputs into organizational goals, thereby reducing the wastage of resources. This channelling of the outputs without losing the flexibility necessary for creativity, it is claimed, is best achieved when individual scientists "self-manage" their own work in such a way that they are intrinsically working for the goals of the organization without the feeling of being controlled. This is usually possible in organizations where the scientists have a high degree of commitment. This commitment, in turn, is affected by a sense of commitment. This commitment, in turn, is affected by a sense of job satisfaction, a feeling of security and a sense of pride in the organization. Job satisfaction and a sense of pride in the organization can be very low in many R&D organizations in developing countries. While bureaucratic personnel policies can virtually guarantee job security, the high degree of centralization in the organization can make the top management's perceptions so crucial to a scientist's survival and growth that the guaranteed job security usually takes second place.

The purpose of this paper is to discuss some of these issues of managing R&D in a developing country. It is proposed to do this by looking at the issues and attempted solutions in the management of R&D in India.

(p. 284) R&D management theories, which have evolved in the developed world, are usually based on two assumptions of effectiveness. These are the assumption that new product development for competitive market-share reasons is a necessity and the assumption that cost-reductions to aim at becoming the lowest-cost producer in the industry are another way of providing competitive advantage. Government R&D provides a "nation" with the same competitive edge. The different expectations from R&D in a developing country like India, discussed above, lead to different definitions of effectiveness. There is a lack of competitiveness-based expectation from most R&D organizations in India. Even cost reduction, except through material substitution, does not seem to be a focus. Thus, the management problems for the different R&D organizations in India are different.

Issues in R&D Management in India (p. 284-285)

The following issues are usually discussed as being central to the management of R&D in India:

1. The appropriateness of a bureaucracy in managing an activity like R&D is usually questioned. Most governmental R&D units in India are managed by bureaucratic structures which are intimately connected to the national bureaucracy. The uncertainties inherent in the R&D process make a bureaucracy very slow in responding to the needs of research or of the researcher. At times, the rigid rules of a bureaucracy simply cannot accommodate the specific needs of research since the rules were designed for non-research organizations. Further, the uncertainties in research make it impossible to write down a new set of rules. (This becomes especially apparent during requisitioning specialty materials or equipment where the rules governing tenders and bids introduce inordinate delays and often result in suboptimal quality material.)

The bureaucratic style of managing also does not provide the necessary flexibility to reward or motivate the scientist into better and more relevant research. In a bureaucratic system responsibility for actions lies with the [p. 285:] system rather than the individual manager. In a developing country, where resources are scarce and all actions of top management can be under intense scrutiny, the bureaucratic system can provide a protection against allegations of corruption, neoptism, etc. And yet, bureaucratic managers cannot provide that leadership, strategic direction, sense of commitment to the organization -- all of which are vital to the management of activities with high levels of uncertainty.

(p. 291) The managerial controls and the strict guidelines have played their part. As discussed above, all the techniques which have been implemented have resolved some problems but created new ones. Managing science and technology for development in India has really been a dilemma. No answers exist on exactly how science should be managed for development. Maybe the time has come when the only management should be "self-management"; where scientists would internalize the organizational criteria and make them their own; where pride in working for their organizations would be sufficient to make this internalization possible; where scientists will initiate change through an adoption of innovations by working closely with the users and not dictating change by the powers of some superior rationality vested in them; and where small contributions but numerous ones will be rewarded rather than waiting for the single major discovery. It should be noted that the decentralized, highly flexible scientific organization may produce a large number of minor innovations but may not be conducive to producing major discoveries. But then, small innovations in a large number of sectors may be precisely what India needs at this point in its economic and historical development.

5. THE CASE OF RENEWABLE ENERGY AND APPROPRIATE TECHNOLOGIES:

We now move to examining the utilization of specific technologies and innovations. The case of renewable energy and appropriate technologies is worth reviewing. These environmentally-benign technologies for producing energy from renewable sources, solar, wind, biogas, wood, received a lot of attention in the late seventies and early eighties, primarily in response to environmental and anti-nuclear movements, and to the first OPEC oil crisis. Renewable energy technologies are a classical case of "technology push". The initiative came not from the user, who (at least in a number of western industrialised countries) still had the option of using the more convenient petroleum or electrical energy, but from the broad coalition of innovators, entreprenurs, and environmental agencies who were convinced that these technologies formed a better alternative for society.

To date these technologies have enjoyed only a marginal success, with some highly regionally specific exceptions. What makes this literature interesting from our viewpoint (and hence worth reviewing), is the extraordinary zeal that some of the renewable energy proponents have demonstrated in getting these technologies widely adopted. In so doing, they have probed quite effectively most of the channels through which these technologies could be disseminated, including political pressure. From this literature, we can get a very good sense for the various strategies which should be adopted to promote a technological innovation. We start with some of the classics in approipriate technology:

CARR, M., The AT Reader: Theory and Practice in Appropriate Technology, Intermediate Technology Publications, UK, 1985.

This book includes extracts from over 200 notable development writings. These are integrated into the text which is divided into ten chapters. The first reviews literature dealing with the concept and history of Appropriate Technology (AT). Thus, for example, the arguments of Schumacher, Nyerere and Robertson are presented and the critiques deriving mainly from the dependency/neo-colonial school are countered. The chapter ends by tracing the evolution of the AT movement. Chapter 2 takes up the issue of technology choice. After arguing the case for AT by drawing on such as Stewart and Chambers she then reviews some key issues (e.g. scale of production) and ends by taking specific examples of technology choice. Chapter 3 to 7 essentially comprise case studies of "technology for development". Most of these studies have been completed since 1980 and tend to be post-facto socioeconomic analyses of the application of particular technologies. Chapter 8 reviews key literature on the generation and transfer of technology. The first section concentrates on the issue of indigenous technological change (e.g. rural innovation in Indonesia) and the second on the relationship of aid and multinational corporations to technology transfer. Chapter 9 first extracts sections of articles analysing technology policy (or the lack thereof) in China, India and Kenya and articles reviewing the role of technology policy in planning. It then extracts from articles dealing with technology diffusion especially via extension. The final chapter concentrates on education and training. The first section assesses the concept and role of formal education and the second reviews case studies of alternative education/training methods (e.g. Botswana's Brigades). It ends with a brief review of the role of advanced communication technology in basic education.(DH - 4)

ECKHAUS, R., Appropriate Technologies for Developing Countries, National Academy of Sciences, Washington DC, 1977.

The book emerged out of the Board of Science and Technology for International Development (BOSTID) panel investigation (and study by Prof. Eckhaus) into the interrelationships between technological choices and economic, social and political aspects of the development process. The objective of the report is to arrive at generalizations about the character and consequences of microeconomic technology choice decisions. However, as one of its panel members remarks in a dissenting appendix, the report is marred by its narrow, mechanistic conception of technology as mere technique, a view which ignores important issues such as material requirements, scale, and the appropriation of knowledge and skill for sustained technological innovation. As a result, the choice mechanisms outlined by the author do not consider some fundamental objectives, such as national self-reliance, stemming rural-urban migration, and ensuring the acquisition of local technical capacity.

The report begins with a general examination of the interactions between technological decisions and the development process. It then proceeds to examine a number of criteria of technological appropriateness (net output maximization, cost minimisation, employment maximization, self-reliance etc) and their interrelationships (complementary, mutually exclusive etc).

The remainder of the book is concerned with technological decisions and how they are made. As such, Chapter 4 examines the role of information and its diffusion through various means. Chapter 5 examines the determinants of technological decisions and their aptness at a general level, looking at the effect of various institutions such as national and international, private enterprises, the government, bilateral and multilateral donors. Chapters 6 and 7 then look at these questions at a sectoral level, focusing on agriculture and small scale service enterprises respectively. The final chapter elucidates policies for promoting appropriate technological choice. These focus on three areas: 1) incentives through policy; ii) expansion of knowledge of appropriate technological alternatives and iii) institutional changes to improve the dissemination of technological information.(DH - 6)

SCHUMACHER, E., Small is Beautiful: A Study of Economics as if People Mattered, Blond and Briggs, London, 1973 (hardback), Abacus, London, 1974 (paperback).

In this seminal work Schumacher argues from an explicitly moral position that Western and Soviet obsession with economic growth has created a dangerously fast depletion of non-renewable resources, environmental pollution and a technology which prevents the attainment of human fulfillment especially by causing unsatisfying work to appear necessary.

By brilliantly exposing the historical mechanisms by which these undesirable trends, centred on the maximization of productive effort, have come about Schumacher makes a formidable critique of "materialistic" civilization. From this he makes arguments for an economic system with the objective of maximizing human happiness by the optimal pattern of consumption, with socially desirable production methods.

Schumacher emphasized the concept of intermediate technology (IT), i.e. somewhere between traditional and modern but making use of the best of both. His intellectual promptings (and his own practical work) encouraged the establishment of hundreds of IT (or appropriate technology) organizations and contributed powerfully to the thinking of planners with respect to the role of technology in society. (DH - 15)

McROBIE, G., Small is Possible, Jonathan Cape, London, 1981.

This book is written as a sequel to Schumacher's "Small is Beautiful" and a "Guide for the Perplexed" and was intended to show how these concepts can and have been implemented.

The first section of the book is Schumacher's last speech: "On Technology for a Demographic Society" where he combines a critique of the technology implicit in aid and trade (amongst other things), which the rich would give to the poor world, and also of the inappropriateness of advanced technology within the rich world. He summarizes the central ideas of his work and argues again for intermediate and appropriate technology (AT) which among other things would have truly democratic connotations.

McRobie picked up Schumacher's idea for the book and then attempted to write it. Part I traces the formation and development and objectives of the Intermediate Technology Development Group (ITDG) based in the UK. It then traces the activities of the group in areas like building, water, transport, etc. Finally it details the development of a growing international network of related organizations. Part II switches to AT in rich countries and after reviewing some of the conceptual issues (the destructiveness of certain new technologies) he then reviews AT movements in Britain, the USA and Canada. Part III has two sections: the first looking at the achievements of AT groups in specific areas of the Third World, and the second a review of AT effects in the UK.

The end of the book contains lists of organizations concerned with AT and further reading on AT for rich and poor countries. (DH - 11)

STEWART, F. (ed), Macro Policies for Appropriate Technology, Westview, Boulder, Colorado, 1987.

This outstanding book of readings encapsulates much of the best of recent thinking on technology and development and the role of government therein. Most of the readings are annotated separately elsewhere in this bibliography.

Chapters 1 and 10 by Stewart place policies for appropriate technology (AT) in a very interesting framework. AT is viewed in terms of "special characteristics" but takes on board a broader and more dynamic view of its implications than the earlier views. Thus, AT is seen in dynamic terms, i.e. in terms of the social implication of technological changes including initial start-up investment decisions. Furthermore, the objectives of AT are broadened to include the social impact of all types of producers.

This is most clearly elaborated when she discusses the role of government "macro policies" in influencing the path of technological change. Thus, she views "firms" as including all productive units - public or private, foreign or local, cooperatives, family farms, etc. Each of these "firms" makes decisions about technology which are determined by 4 main factors: their objectives; their resources and the prices of these; their market form; and their technological knowledge. Governments can influence decisions for appropriate technological change by affecting any of these variables. Furthermore, by adjusting the distribution of resources (e.g. a land reform) the state can also affect technological decisions. (DH - 18)

We now present three long excerpts from three books on renewable energy. Baumgartner and Burns review cases in seven countries, and present an interesting analysis based on power politics: energy prices are not the only indicator of the competitiveness of energy technologies. There are also some powerful vested interests, such as electric utilities and the petroleum industry, whose status is protected by laws, taxes, and other institutional measures. Introducing new technologies must address these factors, as well as technological performance.

The National Research Council's Board on Science and Technology for International Development's (BOSTID) study on Biomass energy examines the question from a diffusion and design point of view, and also has an insightful analysis of the equity issues that arise from the itroduction of new technology.

Finally, Szekely's review for the UN agencies brings home yet again the necessity of government involvement at all stages when bringing in new technology systems.

We begin with Baumgartner and Burns' analysis based on political power and vested interests:

Baumgartner, T., Burns, T.R. (eds.). 1984. Transitions to Alternative Energy Systems: Entrepreneurs, New Technologies and Social Change. Westview Press, Boulder and London. 292 p.

FOREWORD: TOWARD A SUSTAINABLE FUTURE (p. xiii)

by Denis Hayes

(p. xv-xvi) There is, of course, already a fairly well developed literature in the field of technology diffusion. The rapid market penetration of automobiles, jet airplanes, television, and computers have been examined with care by other books. But energy sources in general, and decentralized energy resources in particular, possess characteristics that deserve the kind of detailed attention this volume provides. By probing beneath the surface in several different countries, the authors add breadth to a field too long dominated by U.S. experiences.

Is there a simple lesson to be distilled from this volume? I think so, though the authors never explicitly draw a 'political' conclusion.

What the book makes clear to me is the fact that the 'free market' approach to energy being taken by the Reagan and the Thatcher governments stands no chance of success. Although the price of fuel is the most important single determinant of energy usage, ultimate decisions are often shaped by a combination of other elements. An energy policy that ignores institutional issues, environmental effects, social impacts, and political consequences can produce bad results, but will more likely produce no results at all.

To be sure, free market rethoric has its attractions; moreover, the track records of most public sector energy efforts have been deplorable bad. There is perhaps no stronger argument for the free market than the complete botch being made by the Reagan Department of Energy.

Yet it is impossible to reconcile a free market approach with a field in which oil production is governed by a global cartel and in which oil transportation and oil refining are dominated by an oligopoly. When Adam Smith **[p. xvi:]** formulated his concept of the marketplace, he was not thinking of such 'natural monopolies' as electric utilities. If there is something to be learned from experiences in the environmental field over the last decade, it is that market signals will not by themselves internalize the costs of pollution, nor assign appropriate future rents to depletable resources. These necessary chores must be performed by governments.

The governments of the world, then, do not have the option of piously washing their hands of the energy crisis. They must be involved; they must pursue wise policies; and they must prove far more effective in the future than they have in the past. Through its careful analysis of past programs to promote renewable resource development, Tom Baumgartner's new book provides the public sector with precisely the kind of guidance it needs.

PREFACE (p. xvii-xix)

[p. xviii:] In our view the context for new energy developments in early 1984 is no better, in some ways even worse, than that prevalent during the 1970s, the period covered by our empirical studies.

The production and use of alternative energy technologies remain largely marginal, with partial achievements only in a few narrow, specialized market niches. The developments in the 1970s, particularly those associated with the second oil price shock of 1979 and 1980 were to some extent encouraging. Entrepreneurs, change agents, and users interested in developing alternative energy technologies found conventional energy price and supply developments favoring risk taking and investment efforts, both essential to new energy developments.

(p. xix) Thomas Baumgartner and Tom R. Burns

(p. 5) The research reported here investigated alternative energy innovations and the development of new energy systems through a series of case studies. These describe and analyze several of the key technical, socio-economic and political processes whereby new energy technologies have been introduced and systems producing and utilizing them have been established and have grown [**Footnote:** We distinguish three main elements in discussing alternative energy technologies: (a) The energy flows and materials (solar, wind, forests, petroleum, uranium, etc.) which are potentially available for exploitation as energy sources. (b) The technologies designed to tap energy flows and materials and to transform them into usable energy (in boilers, generators, collectors, heat pumps, windmills, etc.). (c) The socio-technical systems -- with a certain social organization, organized knowledge and expertise, and occupations and professions involved -- which produce technologies, distribute them and use them in the exploitation of energy flows and materials. Spencer (1983) suggests a somewhat similar set of distinctions.].

Two types of technological innovation were investigated: the introduction, development and use of technologies (1) to provide energy to households and small buildings, and (2) to exploit new energy forms on a relatively large scale for the production of heat and electricity by utilities and industry [**Footnote:** Wood and peat are not "new" energy sources but the technologies which our case studies look at are.].

The case studies reported on are the following:

(1) the introduction and wide-spread use of solar water heating in Israel;

(2) the emergence and development of solar water heating in California;

(3) the introduction and diffusion of small windmills for the production of electricity in Denmark;

(4) the growing production and use of heat pumps in West Germany;

(5) the history and recent development of geothermal electricity production in California;

(6) the increasing use of wood for the cogeneration of steam and electricity by utilities and factories in Northern New England in the USA; and

(7) the development of peat for cogeneration in Finland.

(p. 5-6) The studies provide insight into the factors facilitating and blocking the introduction of new energy technologies and the emergence of new markets and entirely new industries. A general overview of the studies suggests that not only physical infrastructures but institutional and cultural contexts - and the power of different interest groups -- are critical factors determining the fate of such innovations and developments. Moreover, social agents who control and provide know-how and information play a strategic role in determining the speed of adoption [p. 6:] and diffusion of new energy technologies. In general, failure to develop adequate information and knowledge systems - technical as well as commercial -- and to provide complementary service systems can retard if not block new and useful energy developments.

The introduction of a new energy technology -- or any technology for that matter -- is not simply a matter of taking an invention and producing it for someone to use somewhere. It involves ultimately the shaping and development of social and technical systems for producing, distributing, and utilizing the technology. In many instances, existing socio-technical systems can be adapted and exploited in establishing and developing the new. Invariably, system development entails a historical process, the making of many different decisions and the solving of a variety of technical, economic, and socio-political problems. Multiple actors and groups are directly and indirectly engaged in such historical developments.

(p. 241-242) Generally, the introduction of a new technology entails a complex of innovations rather than a single technical innovation. Typically, some of these are of an organizational and socio-political character, for instance changing certain administrative rules and procedures or reformulating government policies. For instance, taxation rules and building codes had to be changed in connection with solar energy developments in both Israel and in California.

Even if technological innovation is based largely on old elements -- as in the case of heat pumps and peat cogeneration -- new elements or combinations of elements are involved. In the case of heat pumps in Germany, it meant designing and producing small units and selling them to a new buyer group, owners of single or small multi-family houses. The use of peat for the generation of steam and of electricity in Finland involved a scaling up of the production and transportation of the resource. This implied a different method of harvesting peat, requiring new types of equipment as well as railroad rate changes to make the whole venture worthwhile. It also required the organization, for the first time, of large-scale peat production in one place.

Technological innovation always involves some risks, even if the proponents believe that these are minimal or even non-existent. The proponents of nuclear power have discovered this but so have the producers of heat pumps in Germany who find themselves with substantial unused [p. 242:] production capacity, contrary to all forecasts. Demand is stagnating if not (temporarily?) falling partly due to disappointments with early heat pump models, partly due to the slump in housing construction, and possibly also because buyers wait for the appearance of the often announced new types of heat pumps.

Our studies suggest that one cannot know for certain beforehand if the innovation(s) will succeed or not. The uncertainty and risks are greater the more radical the new technology or the more socio-technical systems organized around its production, distribution and use deviate from established socio-technical systems. In these instances, change agents are likely to encounter more substantial and difficult to solve problems of a technical, economic, and socio-political nature.

Of course, powerful actors or coalitions of actors with ownership rights, a political mandate or technical authority may push the new development because they can effectively mobilize resources, economic as well as socio-political. Ben Gurion, the Israeli prime minister during the 1950s and 1960s, assured funding for solar energy research which was far ahead of its time. High-level political commitment to peat helped to push aside barriers blocking the development of peat use in Finland. The exploitation of geothermal energy made a step forward only when the large electric utilities and oil companies became interested and involved. In short, radically different technologies, requiring substantial changes in existing socio-technical systems, are very difficult to introduce and develop without powerful backing, at least if the technology is to succeed within short spans of time.

(p. 242-244)

(1) Our case studies of the emergence and development of new energy technologies suggest that progress is being made. However, there have been no major developments, certainly <u>no indications that a transition to alternative energy systems is taking place</u>. In the countries of our investigation, the developments described, while promising, remain only marginal. This is, in part, because nowhere are <u>all</u> the key actors fully committed to the development of the technologies. They fail to support such developments in a coherent manner.

(2) Nevertheless, one may draw some satisfaction **[p. 243:]** from the modest, although rather isolated, achievements in the development of alternative energy systems described in the case studies. Many of the technologies we have investigated were said to be too "expensive" or not commercially interesting. Nevertheless, entrepreneurs experimented, solved problems, developed production and marketing strategies, increased efficiency and managed to establish infant industries. Knowledge has been accumulated. Some diversification of energy production and energy saving systems has

been achieved. This will be particularly important when energy problems will become once again more prominent on the political agenda than at the present, and efforts will have to be once more intensified to find new energy sources and to improve energy economizing.

(3) A complex of different actors, policies, laws, and rules as well as technical and economic conditions influenced the shaping and development of the new industries and related socio-technical systems described in our case studies. The social agents involved played different roles: inventors and scientists, entrepreneurs and technicians, banks and financial intermediaries, government agencies, politicians, and socio-political movements, as well as users and consumers.

In a complex social system, there are few generalists. There must be communication and various forms of cooperation across the boundaries of specialization and the various phases of introducing and developing new socio-technical systems. Linkages among different types of actors occurred through market networks, business and ownership structures, through industry and public organizations, as well as through research and technical networks. Progress was especially marked -- for example in California and Denmark -- when movements interested in alternative energy technologies managed to cooperate with business interests in the interest of common lobbying and effective marketing of the products to sceptical consumers.

In some instances, the connections were initially weak or non-existent, thereby slowing down or blocking the technological developments. We found examples of weak connections between those designing and producing the new technologies and ultimate users (e.g. in the early phases of solar energy developments in California); between policy-makers, on the one hand, and producers and users, on the other (e.g. heat pumps in Germany); between entrepreneurs and technical experts capable of solving critical problems (in the early phase of geothermal development in California). In our view, weak linkages and, in general, barriers to communication and mutual learning and cooperation among the various key actor groups are among the critical factors slowing down or blocking technological developments. As we shall discuss in Chapter 12, a major [p. 244:] challenge to entrepreneurs, policy-makers, administrators and other change agents seeking to bring about new technological developments is to develop strategies to shape forums and networks for communication and mutual learning, with feedback across different spheres and on various levels. A related question concerns strategies to establish institutions for improving coordination, reducing transaction costs, and minimizing unnecessary risks. We argue later that the genuine risks in technology development cannot be eliminated prematurely, but must be accepted as part of the challenge. Nevertheless, communication and cooperation are one way to help minimize risks.

(4) The motivation for introducing and developing new energy technologies varies considerably among the inventors, entrepreneurs and change agents involved. It may derive largely from economic considerations, the hope for economic gain through the exploitation of new sales opportunities or the possibilities for cost reductions. Other motives may be the challenge of technical problems and the opportunity to solve interesting problems, the desire for social recognition, political motives, ideal interests (anti-nuclear feelings, environmental concerns, worries about oil dependence and vulnerability).

(p. 245)

(5) Relative energy prices provide signals, but they are not always very reliable or valid signals (...).

(p. 246)

(6) Laws, norms, rules and policies shape and influence the ways new energy systems can be built up and used, how well they fit into established energy systems, and how effective they can be operated. In some instances, such constraints retard or prevent the adoption of the new energy technology (...).

(p. 247)

(7) The preceding points strongly suggest the importance of policy-makers and government agencies making changes -- or in preventing changes -- which can facilitate new energy developments. In some instances, the changes introduced, although small, even trivial, had substantial impacts on the trends and rates of development.

(p. 250)

(8) The shaping and development of alternative energy systems typically requires not only economic resources but socio-political power. In many instances the actors (small businessmen and entrepreneurs) who are prepared to take initiatives and to try to shape new systems have very limited access to either adequate economic resources or political influence.

For successful or rapid development of new energy systems, entrepreneurs and change agents must often struggle to change laws, rules and policies which block or hinder such development. Also, they may have to contend with hidden or even open opposition of powerful vested interests. A utility company, for instance, with its special technical culture and its interests to protect its investments and profit opportunities may act to obstruct the introduction of a new energy technology or they may try to shape it so that it falls naturally under its control. This is so unless utility decision-makers have a strong professional interest in it or have few or no alternative ways to expand and grow in the future.

In some instances, certain government agencies and socio-political movements ally themselves with entrepreneurs to change policies and laws. This has been true for the ecological and anti-nuclear movements in Denmark and California. But most often the small entrepreneurs lack access to or influence in the corridors of central power. They are compelled to operate marginally and to do the best they can under difficult circumstances. This can be observed in the development of solar energy in Israel in the 1950s and 1960s, and of wind energy in Denmark. Or the small entrepreneur is forced to sell out to larger companies with the economic and political clout to bring about change. This has happened in the case of the geothermal development in California where oil companies took over and managed to get the minerals leasing act changed in ways favorable to geothermal development.

(9) Our research suggests that, in general, utilities are key actors in facilitating or hindering new energy developments.

(10) Environmental, conservationist, or other socio-political movements can play a major role in the introduction and spreading of new alternative energy systems. They play such a role through engaging themselves in the concrete processes of shaping a normative climate, and [p. 252:] through exercising or applying political pressure to create laws, rules and policies which facilitate the emergence of new energy systems. The case of wind energy in Denmark points up that a social movement can work together, directly and indirectly, with entrepreneurs and producers of alternative energy technologies and thus contribute to changing public opinion and to influencing government policies (and countering in part the policies of utilities). Similar cooperation helped to accelerate the spreading of solar energy in California.

(11) Our case studies point up that it is extremely difficult, if not impossible, to know beforehand or to predict the specific designs the new technologies were to take and the form and character of the socio-technical systems in which they developed. Among other reasons, this is because:

> A variety of possible or potential alternative energy systems may emerge, not a single, predetermined one.
>
> The energy production, distribution and use systems emerging tend to develop special characteristics as a function of the societal contexts in which their development is taking place.

(p. 255) Systems for producing, distributing and using a new or different technology must be either adapted from existing systems or established as new systems. Such systems are not mere ad hoc collections of elements. They are organized socio-technical systems. Entrepreneurs and other change agents engaged in the concrete process of adapting or building up and integrating the various relevant PDU [production, distribution and use] systems: for instance, the production of generators, towers, blades and other components for electricity generating windmills, setting up and operating the windmills, and ultimately distributing the electricity and making use of it in appliances and other electrical equipment.

(p. 255-257) In the process of trying to establish and operate PDU systems, technical, production, marketing and utilization problems are discovered and solutions attempted. [p. 256:] Some attempts may succeed. Considerable uncertainty is typical about such matters as costs, quality, reliability, market demand, and so forth until actors have worked through the planning and practical activities. Many problem solving efforts end in failure. A few may result ultimately in 'marketable' ideas (in the broadest meaning) and the establishment and development of new industries and patterns of consumption around a new technology.

Our framework points up that technological development does not simply concern improvement in a furnace or a windmill but development of the systems to produce and distribute the furnace or windmill as well as those which utilize such 'products'. Competing systems, rather than competing products, is a central concept in our framework. Products as such compete only when they can be distributed and utilized more or less in the same systems.

Change Agents, Problem-Solving, and Social Learning

A strategic factor in technological development is the availability or absence of entrepreneurs and other change agents to engage themselves in the process of introducing and developing new technologies. Actors in diverse roles are involved in this complex, collective problem-solving process: inventors, scientists, technicians, businessmen, bankers and other financial experts, marketing experts, consumers, politicians and administrators. Typically, these come into development processes in different ways and to some extent in different phases of the development process.

(1) A person or a group has an 'idea' or a concept of how to solve a problem or class of problems. The idea may be realized in the form of a technology design or model. In the world of technical ideas, we refer to such persons as inventors, for instance, engineers or scientists who invent a new technology. Even in the social and political worlds, it is appropriate to

speak of social and political inventors, respectively, who come forth with social inventions, new organisational forms and institutional innovations as well as cultural elements.

(2) Entrepreneurs are social agents – individuals, groups, and social organizations -- which implement an idea or put it into practice, for example, they produce and sell it on markets. In many instances, entrepreneurs attract capital for establishing and developing production and distribution systems; they do this through their connections, position of authority, or charisma. Administrative entrepreneurs in government agencies and networks play a similar role in developing technology production and distribution systems within the government sphere.

[p. 257:] (3) Entrepreneurs and other actors with managerial and technical skills organize labor and production processes, often adapting the innovation into forms which can be more readily produced and marketed (identifying or discovering these forms is often a complex learning and trial-and-error process).

(4) Actors with marketing and organizational skills deal with problems of distribution and selling. Often this entails influencing and educating consumers and potential users.

(5) Political leaders and movements as well as government agents, play a role in many instances in shaping laws, policies or rules which facilitate the technological development.

A complex of technical, economic and socio-political problems must in many instances be solved -- and multiple decisions made -- in the process of new technological developments. Some solutions are realized in technical networks, others in more business-oriented and financial organizations, networks and markets, still others in political and administrative institutions and arenas. Indeed, in the context of such organizational, network and market frames, the various special types of actors pointed out earlier are linked together, although many are formally independent: through market processes (flows of commodities and money), social networks including networks of formal agreements and contracts, as well as through formal organizations such as enterprises, government agencies, political institutions. Thus, on the one hand, a technical-economic system such as electricity supply based on hydropower links together waterfalls, power stations, electricity grids, and electric equipment and appliances in factories and households, respectively. On the other hand, market, network and organizational frames connect together diverse types of actors in both building up and operating such economic-technical systems. An energy PDU system is not usually based on a single social organization but a network of organizations (Lonnroth, 1978b).

(p. 258) Any given innovation or technological development is likely to activate multiple, in many instances incompatible norms and values. Often these are experienced as dilemmas by some of the actors involved. For example, energy substitution or conservation goals may be contradicted by aesthetic or environmental objectives, as pointed up in the case of developments making use of peat or coal as fuel. Such problems reflect the fact that innovation and technological development have multiple effects. These include effects directly related to actors expressed goals or the problems with which they set out to deal. They also have unintended effects. Thus, the introduction and development of new energy technologies leads to non-energy consequences, such as environmental effects and socio-political reactions. Similarly, non-energy developments in society will typically have direct and indirect impacts on energy matters.

(p. 261) The phase structure outline above is a highly simplified picture of technological development in a market or mixed economy system. One moves from ideas and conceptions which are translated into 'solutions' in the form of a particular technology, to producing marketable or useable designs, selling them (or in the public sector budgeting them) and bringing them into use. It should be stressed that the different phases do not follow a linear sequence but overlap and feed forward and back between one another. A group of users, for instance may take an initiative to invent and produce a technology to solve a problem they have encountered. Later, they may come to produce the technology for others. Or a technology used to solve a specific type of problem may become a 'solution looking for problems'. Its producers or users realize that it can be used for quite new problem sets, and this contributes to its further spread and development. Thus, the technology may come to be utilized and developed in ways which go far beyond the problem set with respect to which it was originally conceived and developed.

Entrepreneurs and the Mobilization of Social Power (p. 266-268)

The development of new technologies, particularly radically new ones, requires the mobilization and exercise of economic and socio-political power, learning and social restructuring; in shaping new enterprises, new markets and industries, in establishing new public policies and laws, and so forth.

(...)

Social power structures are critical factors in technological development for several reasons:

(1) Social power, whether based on technical authority, command of economic resources, administrative power, or political influence, is essential

to bringing about many of the changes -- technical, economic and socio-political -- entailed in new technological development.

(2) Established power structures and vested interests in [p. 268:] conventional technologies may block new developments, or, at least, they may distort or reorient them away from optimal forms. For instance, technical innovations are accepted or rejected on the basis of their degree of consistency with established concepts, norms and socio-political interests (in the latter case, for instance, in terms of the degree to which they are perceived to reinforce established positions of power and authority). Hence, public utilities tend to support large-scale energy innovation proposals, which fit into the existing systems under their control or which would be logical extensions of these systems. In Sweden, for instance, electric space heating was up until the 1950s not acceptable. When nuclear power was introduced, a key proponent, the Swedish State Power Board, won the support of the building industry for this. Plumbing engineers and related groups in opposition lost out, in part because they were disorganized. In this way, the rapid expansion of nuclear power was combined with new electricity utilization systems which supported the rapid growth of nuclear electricity generation (Lonnroth, 1978a).

Lonnroth, M. 1978a. "The Oil Peak and Beyond." Stockholm: Beijer Institute and Secretariat for Future Studies.

Lonnroth, M. 1978b. "Energy Futures for Sweden." Stockholm: Secretariat for Future Studies.

The excerpts selected from the Board on Science and Technology for International Development (BOSTID) 's study focus more on the diffusion aspect, with a section on equity issues, and how one should manage an extension service -- advice for the practitioner.

Board on Science and Technology for International Development, Office of International Affairs, National Research Council. 1984. Diffusion of Biomass Energy Technologies in Developing Countries. Second edition. National Academy Press, Washington, DC, USA. 120 p.

1 DIFFUSION OF INNOVATIONS (p. 12)

Diffusion is the process by which innovations spread to the members of a social system over time. Diffusion studies are concerned with messages about new ideas, whereas communication studies encompass all types of messages. Because the messages are new in the case of diffusion, there is a degree of risk and uncertainty for the recipient, leading to somewhat different behavior than if the messages were about routine ideas. The "classical model" of the diffusion of an innovation consists of the innovation, defined as an idea perceived as new by an individual, which is communicated through certain channels, over time, among members of a social system.

Diffusion and Social Inequity (p. 13-14)

During the 1960s and 1970s, applications of the classical diffusion model to development programs in developing countries was criticized for increasing socioeconomic inequity. Critics point out that in development programs, the nature of the social system in which the innovations were introduced and the quality of the innovation have often been disregarded. They say that the socioeconomic structure has considerable effect on the innovation behavior of individuals and that it usually favors adoption of new ideas and technologies by richer people.

Most observers agree that the major problem in many developing countries today is the unequal distribution of such resources as income, lands, skills, and information that perpetuates inequality. Critics stress that technical change results in a skewed distribution of benefits; individuals who have greater resources usually benefit more from the innovations introduced by development agencies than individuals with fewer resources, thus widening the benefits gap.

In addition, some of the basic assumptions of the diffusion model have been criticized: (1) that communication by itself generates development, regardless of socioeconomic and political conditions; (2) that increased production and consumption of goods and services constitute the essence of development and that a fair distribution of income and opportunities will necessarily derive, in time; and (3) that the key to increased productivity is technological innovation, regardless of whom it may benefit or harm. Critics of these assumptions point out that the main inhibitions to development may be mainly structural rather than informative and that restructuring of a society may be needed to make the diffusion of innovations more effective in the development process.

The social structure has been found to be a powerful determinant of individuals' access and response to the mass media. The more privileged farmers who own land and enjoy a higher socioeconomic status have more communication opportunities and are the most likely to adopt new agricultural technologies. A farmer's failure to adopt innovations may be due more to a lack of opportunity than to resistance to change. Farmers with more land, money, and knowledge can more easily obtain the credit and information they need to adopt technical innovations. Most of the poorer and less progressive farmers in developing nations lack such resources.

Development agencies tend to provide assistance to a relatively small number of wealthy, educated, and information-seeking farmers; following this progressive (or "easy-to-convince") farmer strategy leads to less equitable development.

Some critics have also argued that innovations may be uncritically viewed by development workers as "good" for all farmers. The social **[p. 14:]** and economic consequences for the community as a whole have not always been considered, such as whether a technological innovation is appropriate for everyone, or whether it favors some groups of individuals at the expense of others.

<u>Decentralized Versus Centralized Diffusion</u> (p. 14-15)

In addition to the centralized diffusion model, an alternative model of decentralized diffusion also exists. Schon pointed out that theories of diffusion have characteristically lagged behind the reality of emerging systems. He particularly criticized the classical diffusion theory, which he termed a "center-periphery model," and which rests on three basic premises:

> that the innovation to be diffused exists fully realized in its essentials, prior to diffusion;
>
> that diffusion is the movement of an innovation from a center out to its ultimate users; and
>
> that directed diffusion is a centrally managed process of dissemination, training, and provision of resources and incentives (Schon, 1971).

The traditional centralized diffusion model not only prevails in theoretical writings, but has become the "dominant normative model for diffusion." The best-known example of a center-periphery model of diffusion is the Federal Extension Service of the United States Department of Agriculture (USDA), which coordinates with he state agriculture extension services. This program (with an annual budget of more than $350 million) represents the largest public investment in a diffusion system in the world.

[p. 15:] In their early days, extension services in the United States identified and then disseminated the agricultural practices followed by the most successful farmers. In later years, a superstructure of agricultural research was connected to agricultural extension services to serve as a source of innovations. Most extension workers tended to forget that innovations could come from farmers' experience as well as from formal research and development.

Agricultural innovations stem from R&D activities by the USDA and by state agricultural experiment stations. The agricultural extension services operate in close collaboration with these organizations through state extension specialists, who are stationed in state agricultural universities. The responsibility of these extension specialists is to convey information about agricultural innovations to county extension agents, who in turn diffuse these innovations to farmers. Thus, the agricultural extension services represent a centralized diffusion system. Not only has this diffusion model been widely copies in agricultural extension services in developing nations, but it has served as a basis for the design of several other U.S. diffusion systems, in such varied fields as vocational rehabilitation, mass transportation, energy conservation, and education.

Schon's main criticism of this centralized diffusion model is that it may apply to certain classes of innovations "lying near the periphery," but that it fails to capture the complexity of innovations that evolve as they diffuse (reinvention) and that thus originate from numerous sources (not just the center). The diffusion process should not consist only of centrally developed information, but should also be shaped by user demands and solutions to problems from other users.

In many developing countries, agricultural extension agents have low status; they are often drawn from agricultural colleges at which they have had relatively undistinguished careers, failing to be selected for scholarships for further study abroad or for the more prestigious positions in the Ministry of Agriculture. Few are from the rural areas or are particularly motivated to solve rural problems, and seldom do the training courses prepare them for communicating convincingly with farmers. They usually find that the farmers know more about agriculture than they do, and they become demoralized and ineffective. Giving them additional responsibilities for energy is unlikely to be any more successful, yet the prospect of erecting a parallel extension structure for rural energy is daunting.

An alternative model of diffusion, based on decentralized, horizontal diffusion of innovations among adopting units depends mainly on peer networks for transferring technological innovations among local-level units.

Table 1.1 Characteristics of Centralized and Decentralized Diffusion Systems (p. 19)

Centralized Diffusion Systems	Decentralized Diffusion Systems
Centralized control of decisions by national government officials and technical experts	Local control by community officials/leaders
Diffusion from top down from experts to local users	Peer diffusion through horizontal networks
Innovations come from formal R&D by technical experts	Innovations come from local experimentation by non-experts
Low-risk innovations with relatively high advantage	High-risk innovations with relatively low advantage
Projects that are of low priority to local organizations	Projects that are of high priority to local organizations
Technology-push, emphasizing needs created by the availability of the innovation	Technology-pull, created by locally perceived needs and site-specific problems
Low degree of local adaptation and reinvention	High degree of local adaptation and reinvention

Diffusion Networks (p. 20-21)

One of the key elements in the decentralized diffusion systems is that of communication networks, defined as the interconnected individuals who are linked by patterned flows of information. It has long been recognized that interpersonal communication channels from peers are most important in persuading individuals to adopt new ideas.

Most individuals do not actively seek technical information from the most competent sources. Instead, they tend to seek information about technological innovations from sources that are local, easily accessible, and interpersonal (usually from neighbors).

The diffusion, or the lack of diffusion, of renewable energy technologies is influenced to a greater or lesser extent by the following groups of individuals within a country:

Policymakers, Planners, Politicians. Central government authorities play an important role in disseminating technologies. In many countries they are the key to approval of a technology initiative or to its funding. Often, however, renewable energy technologies as an entire category may not be perceived at this level as a serious alternative to conventional energy technologies. In other cases a critical decision may be taken to promote certain technologies as a matter of national priority - fuel alcohol in Brazil, for example.

Industrial Entrepreneurs. Industrial entrepreneurs may influence diffusion by adopting a technology and producing its key elements: stoves, gasifiers, and stills, for example. Their decisions affect diffusion by making essential components available, by influencing public and commercial perceptions of the technologies, and by supplying capital for their development. However, in many countries there is no incentive for entrepreneurs to become involved; there may be no profit opportunities among poor people, or no special role for entrepreneurs where many can manufacture inexpensive devices.

Provincial Government Officials. There may be a difference in perceptions of the value and feasibility of energy technologies between planners and officials at the national level and those at the provincial level, particularly concerning regional versus national priorities.

Private and Nongovernment Organizations. These voluntary organizations frequently have a key role to play because of their close contact with potential recipients and their ability to recognize needs, identify opportunities, and motivate the recipients.

Local Government Officials. These officials have an important role in diffusion because they are responsible for conveying national policy or reporting local needs to the national government. They may include important personnel such as extension agents and public health officials.

[p. 21:] Village Leaders. Traditional social leaders may also be important in diffusion as arbiters of consensus for or against innovation. Their role in organizing community use of the technology or land resources may be crucial.

Family. In many cases perceptions at the family level will determine the extent to which a given technology will be adopted.

Individuals. There may be different responses to technologies at the individual, as opposed to the family, level. Wives may have a different perception of the need for fuelwood from husbands; wives may welcome an innovation that leads their husbands to play a larger role in helping them (running a biogas plant for the house), or may resent an intrusion into their affairs (building a mud stove).

Schon, D. 1971. Beyond the Stable State. Temple Smith, London, England.

3 NEEDS OF THE POOR (p. 27)

The immediate beneficiaries of biomass energy technologies should be the poor, both rural and urban, in developing countries. Their energy needs give this study its focus, not because biomass-based technologies can entirely resolve their nations' difficulties with escalating petroleum prices, but because of the immediacy of their energy needs. Their overwhelming reliance on biomass for fuel - principally on firewood, crop residues, and dung - gives the diffusion of improved biomass-based technologies critical implications for alleviation of their energy problems.

Most rural people rely principally on human and animal muscle power in their work as subsistence farmers, herdsmen, fishermen, cash cropping smallholders, and plantation laborers. Clearing and plowing the land; planting, cultivating, and harvesting; and threshing, pounding, grinding, and storing are all done largely by hand, with some help from draft animals and a few simple tools. Most crops are transported from field to household and to the local market on foot or animals. Firewood, used mainly for cooking, is the principal fuel.

Technology in Context (p. 30-33)

Successful diffusion of biomass energy technologies in developing countries depends upon understanding how the poor are accustomed to organizing their productive activities, regulating their social relationships, keeping order, and maintaining the normative beliefs that are essential to social stability everywhere. It is into this sociocultural context that new biomass energy technologies must be introduced. If [p. 31:] they do not fit, they will not be diffused, regardless of their technological promise.

Many of the rural poor meet most of their needs, including their need for fuel, outside the money economy. Often patterns of exchange operate within the context of the kin group, through associations, or through other community structures to allocate rights to land and tools, to organize work, and to structure the distribution of the products of work.

However, money and markets are becoming more important. Cash is required to meet a growing number of subsistence needs, including fuel. For people accustomed to having most of their material wants satisfied through cooperative work with their kinsmen and neighbors, who do not customarily trade their labor for cash and who would never think of selling their lands, this new requirement for money is frequently hard to meet. For unskilled migrants from rural areas where fuelwood is still free, the need to purchase fuel for cooking and heating is often an unexpectedly harsh requirement. Nevertheless, the commercialization of energy eases the diffusion of technology to solve supply problems.

Many productive relationships among rural people in developing countries are still structured by kinship. The introduction of innovations designed to utilize biomass energy more effectively must take this into account. Rights and obligations derived from position in the family remain a major organizing principle in the life of the individual and community. Ties of kinship based on marriage or descent are often crosscut by associational links - membership in age grades, voluntary associations, and mutual aid societies - which lend added strength to the fabric of traditional society and determine the organization of most economic activities. Among the poor in urbanizing areas, such associational ties often serve as a valued alternative to familial relationships that are hard to sustain in an urban setting.

Still other factors affect the structure of the economic order. Age and gender play a major part in determining both the division of labor and the right to make economic decisions. In stratified social systems, class or caste position usually determines the worker's prerogative to control the products of his work and his place in the overall system by which economic rights are determined and benefits distributed.

The political organization generally derives its structure from the kinship-based social system that must be understood if community decision makers are to be effectively mobilized. This is particularly characteristic of Africa and Asia, though rural communities are increasingly being absorbed into national bureaucratic structures. Typically, village elders and other community leaders are selected from among the eldest responsible male members of the community's leading families. The poor in most countries play only a peripheral role in politics and are frequently excluded almost entirely from participating in those decisions - including decisions on technology and on the **[p. 32:]** definition of their own economic best interest - that most affect the work they do and how it is rewarded.

The system of relationships that characterizes this sociocultural setting is invariably sanctioned by the prevailing system of beliefs and practices that defines right and wrong, states social norms, and generally justifies the existing order, usually on the basis of religion. Natural events often are perceived as the manifestation of religious or magical forces, sometimes leading to a fatalism that may lessen enthusiasm for innovations that promise to correct problems seen as beyond human control. This belief in supernaturally based systems of cause and effect can critically influence the outcome of energy interventions that fail to take these perspectives into account.

In most developing nations, these traditional societal structures are overlaid by new governmental institutions, which vary in the particulars of their form but are almost universally marked by weakness and instability. Generally these institutions lack both the sustained financial and human resources, especially the managerial and technical labor power, necessary to plan and maintain complex, capital-intensive, long-term development programs. Too much time and effort is necessarily absorbed in simply keeping up with current operations and forestalling economic and political collapse. Inefficiency and corruption lead to lack of inputs and marketing failures. Reliance on external economic support is almost invariable.

National administrations are generally dominated by males drawn largely from the elite. Politically, their powers are often democratic in principle, but authoritarian in practice. Outside major population centers, they frequently lack the personnel and material support necessary to maintain even routine administrative control. Their capacity to supervise and support development projects is generally even more limited. Because of this institutional weakness, assessment of national resources, including critical energy resources, is often very difficult. The situation is paradoxical. For, as Dickinson candidly puts it, "Developing countries, even though they are poorer than we [the developed countries] and cannot support our institutions, want to obtain for themselves the apparent result of our institutions" (Dickinson, 1977).

Sensitivity to efforts to export "appropriate" (perceived as second-rate) technologies can be keen. It is important to ensure a more accurate view of the problem. For, as Singer writes, "critics of the concept (of appropriate technology) sometimes argue that it in effect establishes two different standards and will therefore create and perpetuate a technological gap. This is a misconception. The gap exists in the fact that some countries are poor while other countries are rich. The task is to reduce or eliminate this gap - the economic gap. Different technologies will serve to reduce the economic gap and hence, ultimately, to eliminate the need for different technologies... If we misdefine the problem by declaring that the gap is a technological gap and then try (disregarding the economic gap) to apply exactly the **[p. 33:]**

same technology to the two groups of countries, the real economic gap will widen further instead of narrowing" (Singer, 1977).

The Issue of Equity (p. 33)

The rural and urban poor in developing countries do not have equal access to their societies' available fuel resources. However, in rural areas where society is less stratified and the majority of people are engaged in subsistence farming, inequality of access to cooking fuels is less marked.

New fuelwood projects imply changes in land use and, often, controlled access. Plantations to supply urban fuel can compete with supplies from the landless poor and jeopardize their livelihood.

(p. 34) In some countries whole sectors of the population, members of different ethnic or tribal groups, may be excluded from participating equally in development programs of political regimes that are either indifferent or hostile to their interests. Regions such as the Senegal River Valley in Mauritania, West Irian, The Brazilian Northeast, and the territories of tribal or "national" minorities in India and China may fit this category. Such populations are often among the poorest in their nation, and their energy needs are frequently most severe and least likely to be met.

References (p. 35)

Dickinson, H. 1977. Transfer of knowledge and adoption of technologies. In: Introduction to Appropriate Technology, edited by R.J. Congdon. Rodale Press, Emmaus, Pennsylvania, USA.

Singer, H. 1977. Technologies for Basic Needs. International Labour Office, Geneva, Switzerland.

Factors that Promote Acceptability (p. 45-46)

From an analysis of the literature and the results of a number of project-sponsored site visits, the following six factors appear to **[p. 46:]** enhance chances for technical and economic acceptability of biomass-based renewable energy innovations in developing countries:

1. Structural simplicity and scale

2. Use of familiar materials

3. Employment of familiar techniques

4. Functional discreteness

5. Integration with existing technology

6. Ability to meet locally perceived technical and/or economic needs within a locally acceptable time

This list has several characteristics important to its use as a framework for assessing the likely acceptance of innovation:

The characteristics related particularly to innovation at the level of the poor individual or community.

The importance of the six basic factors varies according to situation or location, particularly with respect to knowledge or skill levels and in relation to current perceptions.

Interactions among the six factors, or their mix in a given setting, may be more significant than any one or all taken separately.

The factors are all dependent on the degree to which local control, or participation in the selection, of the technologies is organized.

6 CULTURAL AND ECONOMIC ACCEPTABILITY (p. 52)

The traits of a society - its patterns of adaptation to the environment and its economic organization, social and political institutions, and beliefs system - will all affect the acceptance and diffusion of biomass-based energy technologies. The influence of these variables will have to be assessed in the context of each local culture into which a technology is to be introduced. However, some generalizations can be proposed about those aspects of society and culture that play an important role everywhere in determining a biomass energy technology's acceptance or rejection.

The following conditions appear to increase chances for acceptance:

1. Adjustment to the system for allocating productive goods

2. Compatibility with the existing work organization

3. Adaptation to existing patterns of distribution

4. Integration with the social structure

5. Accommodation to authority

6. Harmony with prevailing values and ideology

As with the six main indicators of technical feasibility, judging the effects of diffusion from any one of these cultural variables will lead to oversimplification. The interaction of these factors with each other is extremely complex.

Diffusion of Information (p. 92)

Although the focus of this report is on the diffusion of renewable energy technologies for the benefit of the poor, analysis of the factors affecting this process indicates that decisions are made at all levels of society (and indeed outside of the society, by international development technical assistance agencies and multinational corporations) that affect diffusion in many ways.

At the highest level, policymakers and planners may require evidence that any type of biomass-based technology is practical and economically feasible. Successful diffusion almost always involves a national commitment.

Development-assistance and funding agencies cannot independently institute or support energy technology diffusion projects where there is little or no national receptivity. Where a national commitment exists, the agencies also must be convinced of the economic justification of the project and its relative importance.

Private and voluntary organizations and government extension agencies have related roles to play in the diffusion process, since both are in direct contact with the intended recipients. However, they may have different strengths; private organizations usually are more attuned to local perceptions and sensitivities, but may have limited technical knowledge and resources, while government agencies may have adequate information and resources but limited sensitivity.

A principal conclusion, therefore, concerns the manner in which information about the technologies is compiled and conveyed to planners and policymakers, government and private agencies, and funding organizations.

Extension Agencies (p. 94-95)

Operation guidelines for government agencies and private and voluntary organizations should stress the following points:

> A survey of locally perceived energy needs should be among the first steps in planning.

Representatives of the local population, the donor agency, and the implementing group should collaborate in planning and implementation.

Planning and implementation should allow for regular monitoring and the early identification of problems.

The probable sociocultural consequences of biomass-based energy technologies should be studied.

Demonstration in a neutral context should precede wide dissemination.

The social status of initial innovators may be critical to successful diffusion.

Subsidies or short-term incentives should be provided when the benefits of a technology are deferred.

In many cases, energy technologies may have to be labor-intensive and require minimal local capital investment. Tasks should be structured in accordance with local patterns of work organization, capitalizing on existing technical skills and ingenuity.

Existing management structures - rather than imposed organizational models - should be employed, so long as equity and efficiency are not jeopardized.

Women should be explicitly assured of equal participation in the benefits of these projects whenever possible.

The need to minimize costs may justify acceptance of lower levels of efficiency.

[p. 95:] Existing systems for the allocation of land should be analyzed for possible impediments to technology diffusion.

Information on renewable energy projects must flow from extension agencies to their funding sponsors, and also among these agencies themselves. Technical journals are excellent for this purpose, but slow; newsletters are particularly helpful. The use of audiovisual aids, particularly videotapes, may be justified to circumvent language barriers, as well as to communicate excitement and enthusiasm along with the technical information.

We now look into more depth into the adoption strategies of one particular region: Latin America. What emerges from this particular perspective, is the critical role that government and government policies play in the adoption of technology systems.

Szekely, F. (ed.). 1983. Energy Alternatives in Latin America. A study sponsored by the United Nations Development Programme, the United Nations Environment Programme, and the Latin American Energy Organization. Tycooly International Publishing Limited, Dublin, Ireland. 85 p.

CHAPTER 1 - INTRODUCTION (p. 1)

Over the past few decades, however, increasing attention has been given to the possible use of alternative sources of energy. In the developed countries, studies have intensified on the use of nuclear fission and fusion energy, magneto-hydrodynamics and renewable sources of energy (for example, solar, wind, geothermal, tidal and biomass).

Due to the effects of the 1973 'energy crisis', interest in renewable sources of energy in the developing countries has grown, especially in decentralized systems and their applications. At present, the need to study the potential of these energy sources in Latin American countries has become necessary in view of the substantial increase in oil prices; the danger of exhausting oil reserves over the next few decades; the fact that only six countries of the Latin American region are self-sufficient in oil production; the fact that the style of development adopted in the region has deprived a large majority of the population from sharing its benefits, since third levels of energy consumption place them below minimum levels for satisfying basic needs; and the fact that the prevailing model of development, in addition to making existing economic and social problems more acute, has given rise to other problems, such as deterioration of the environment due to the exhaustion of certain resources and to the unleashing of pollution processes that have proved difficult to control.

(p. 2) Consequently, this study is limited to the assessment of the region's potential for using the following sources of energy: direct solar, wind, plant material, biogas and small waterfalls and water flows. In view of the impossibility of studying all Latin American countries, the following were selected: Argentina, Brazil, Chile, Columbia, Costa Rica, Guatemala, Mexico, Peru, Trinidad and Tobago. They were considered to be representative of the region's efforts which are being realized in this field.

(p. 2-3) The study is concerned essentially with the rural sector, since a reasonable increase in the availability of energy could play an important role in improving the **[p. 3:]** quality of life of rural inhabitants and in affecting agricultural productivity. It is in this sector that the greatest deficit of energy is found in Latin America and it is here that decentralized energy systems could be widely used to complement conventional sources of energy.

<u>Factors Determining the Penetration Process</u> (p. 63-68)

The penetration process of technologies using renewable sources of energy is determined by diverse factors that variously influence these different kinds of technology. The following discussion presents a list of these factors, which, for presentation purposes, are classified as technological, economic, social, cultural and political. In practice, all are closely interrelated.

[p. 64:] Technological Factors

Design: An important aspect of the design of equipment is its simplicity of use and maintenance, since such equipment is normally used by people of relatively low educational level and in isolated places where technical services do not exist for supervising the functioning of the equipment or making any required repairs. Since users value convenience, equipment must satisfy the need for energy with the least effort and concern on the part of the user. This is precisely one of the reasons consumers prefer electric power, although the cost per kilowatt hour is higher than that of other energy sources. The convenience element, for example, has led to solar collectors often being manufactured with automatic equipment to operate electrically when the temperature drops below a certain point. Manufacturers who have not included this feature have lost a certain amount of competitiveness. [Footnote: This is the reason why a certain portion of the public in Mexico continues to buy solar collectors imported from the United States despite the fact that they are also manufactured domestically.]

Related to simplicity of design is the autonomy of the equipment, its capability of being used independently of other forms of energy. This is an important factor for certain uses. In some cases, design should consider specific characteristics of the places in which the equipment is to be used. Such is the case of solar collectors in areas with very hard water where it may be necessary to use different materials.

Quality: The quality, maintenance and reliability of equipment greatly influence its degree of acceptance by potential users. Cases have been known of unscrupulous manufacturers who have sold equipment of poor quality, insufficient duration and deficient operation to the detriment of the penetration of such equipment. Strict quality control is therefore extremely important. In some countries, considerable importance is being given to this aspect: for example in Argentina, the Argentine Solar Energy Association (ASADES) plans to set up a testing bank; in Brazil, quality guarantee certificates accompany such equipment. In most cases, the question of useful life and economic viability of equipment is a problem of materials technology that obliges countries either to import materials or to expend considerable research efforts to improve domestic materials.

Availability of the Resource: Certain factors limit either the degree of penetration inherent in the resource itself or in its technological development. Obviously, one of these factors is the intermittency of the resource, which makes it necessary to find economical methods for its accumulation or to limit its use to those who do not require constant availability of energy.

Level of Technological Development: In other cases, limitation derives from the fact that technology has not progressed sufficiently to make the manufacture of **[p. 65:]** equipment commercially viable. This is the case, for example, with regard to solar energy to produce high temperatures of 250 C or more.

It may also happen that manufacturers have not made efforts to make changes in their equipment that would definitely increase their penetration. For example, wind-chargers could have a relatively larger market if it were possible to increase their power, which does not appear to be too difficult from a technical standpoint [Footnote: Interview with Mr. Pablo Brosens, partner of the SRL agro-industrial firm in Buenos Aires].

Unfortunately, with regard to research in Latin America, scientists are usually reluctant to perform research on soft technology, preferring to devote their efforts to more complex and sophisticated problems associated with concerns of the scientific community in the industrialized countries. This is compounded by a lack of contact between universities and the production sector, which means that research is rarely directed toward solving concrete problems - in this case the energy problems - of large sectors of the population [Footnote: Interview with a salesman from the Leopard, SA firm, manufacturers of windmills].

Economic Factors

It has been stated previously that the economic viability of equipment is a necessary, although not sufficient, condition for penetration of a technology.

We will now analyze the factors that contribute towards increasing the economic viability of equipment.

Production Cost: The determining factor here appears to be the production cost of equipment, although some researchers interviewed felt that this was a secondary factor, since substantial support is required from government to be able to introduce such equipment on the market. However, this argument is not valid since subsidies or any other kind of incentives are ultimately paid for by the entire community; consequently, if mass consumption is desired, the equipment must be produced at the lowest possible price.

Economy of Scale: It is important to bear in mind that a kind of vicious circle exists with regard to cost since one of the important variables determining the cost of a specific piece of equipment is the volume of production, which in turn is determined by the degree of penetration of the technology, further influenced by the production cost of equipment that uses the technology. Overcoming this vicious circle requires clear-cut policies to support the development of the energy sector.

Operation Cost: The economic viability of equipment and consequently the penetration of a technology are strongly influenced by the operation cost of alternative equipment, which is principally determined by the cost of conventional [p. 66:] energy. The cost of energy for users is a political variable that depends essentially on the rate policies of the government concerned. If gas or electricity are inexpensive - as is the case in Trinidad - it is highly unlikely that equipment using renewable sources of energy will be competitive - except, of course, in areas of the country that are not well supplied with conventional energy [Footnote: A manufacturer of solar collectors in Argentina said his firm had decided not to attempt to introduce this equipment in the city of Buenos Aires since it was difficult to compete with gas heaters because the city was well supplied with relatively cheap and efficiently distributed gas]. Such dependence of the price of energy on political factors makes it possible for the situation to change suddenly, so that equipment that is competitive today may cease to be so tomorrow and vice versa.

Cost of Transfer of Technology: The cost of equipment using renewable sources of energy manufactured under licence requiring the payment of royalties or patents may be higher in accordance with the arrangements made for the transfer of the technology in question. In countries with balance of payments problems, the situation may be aggravated by the scarcity of foreign exchange.

Intensity of Use of Equipment: Another factor that often makes it difficult for equipment to be economically viable is inadequate use. Such is the case with cereal driers which are only used for a few months in the year. An example of this may be found in the Salta region of Argentina, where an attempt has been made to manufacture solar tobacco driers. However, in order to encourage farmers to use them, some alternative use must be found that will make it possible to use them for longer periods; otherwise, an inordinate amount of time is required to amortize their cost.

Marketing Network: Another factor having an influence on the penetration of such equipment is the need for an adequate marketing network that will make it possible to inform rural inhabitants of the possibilities offered by the use of non-conventional sources of energy and to have them observe how such equipment functions without the need to travel to urban centres. An adequate marketing network would also make it possible to provide appropriate technical servicing to the users of such equipment.

Distribution of Income: The distribution of income in a given country is another factor that influences the prospects for the penetration of such equipment since, in addition to other factors, the size of the market is also important. On several occasions during the course of the interviews, it was noted that solar collectors at present can only be acquired by middle- and high-income sectors.

Existence of Support Infrastructure: The use of certain non-conventional sources of energy requires support infrastructure to facilitate the work of the user. For example, the development of a programme of alcohol fuel would not be viable if it did not include provisions for supply stations that would fulfil the function of the [p. 67:] gasoline stations presently supplying spent fuels. Establishment of such an infrastructure would probably require heavy investment and, therefore, support from the state is essential.

Social Factors

Resistance to Innovations in the Rural Sector: Technological innovations in the industrial sector usually encounter little resistance since, within the framework of economies of scale, their essential objective is to increase profits, which is relatively easy to achieve. In the rural sector, however, the situation is different since it is much more difficult to perceive the relationship between the innovation involved and the increase in production or improvement in the quality of life that may be obtained. In addition, a general lack of confidence exists with regard to innovations.

Resistance to Innovations in the Public Sector: Resistance to new technologies also exists in the public sector. Certain government officials regard the use of renewable sources of energy with great scepticism, since such innovations are not to be found within the framework of technological pluralism and are consequently considered almost second-class technologies to which countries seeking development cannot assign great importance.

Structural Factors: Land tenure structures and the degree of organizations of small farmers are other factors that influence the penetration of these technologies. Landless campesinos or small landowners have no energy alternative other than human or animal energy or that of depredating the soil. Obviously in such cases, the possibility of using other energy sources arouses great interest. Certain equipment using renewable sources of energy are commercially justified if they can produce an amount of energy larger than the requirements of a single family. For this reason, a certain degree of campesino organization is essential in order to be able to use some of this equipment jointly [Footnote: Experience has been accumulated in India regarding the use of individual or collective biogas plants. Many of the difficulties encountered are not of a technical nature but rather are derived from lack of community organization].

Examples of Cultural Factors

Cooking and Eating Habits of Users: This factor should also be considered in designing solar energy equipment, particularly solar kitchens. An example of how the failure to consider this aspect has been detrimental to the penetration of solar kitchens - one that is often criticized in the literature on this subject - is the case of a design for kitchens to be installed in the open air that was not accepted by the [p. 68:] community because housewives were accustomed to cooking inside their homes. The case also exists of kitchens using biogas, which were also rejected because the food cooked in them bore a taste to which the users were unaccustomed.

External Status Symbols: In some communities the possession of certain equipment or implements associated with urban domestic life may constitute status symbols, for example gas or electric stoves instead of wood-burning stoves, or conventional water heaters. This situation may constitute an additional difficulty for the penetration of certain equipment in some communities.

Political Factors

Government Attitudes: The penetration of this equipment is substantially determined by governmental policies. To date, the development of renewable sources of energy has generally been looked upon with little interest by governments since these sources will produce only long-term results and governments are under heavy pressure to deal with short-term problems.

A determining factor in government attitudes is their development concepts. Governments that include among their principal development objectives that of attempting to satisfy the basic needs of the population more likely will give much greater priority to renewable sources of energy than those whose main objective is to increase the per capita income growth rate.

Attitudes of Certain Groups: At times, economic interests among certain groups of society may encourage them to frustrate the development of renewable sources of energy. During the Seminar on Energy in Guaruja, Brazil, the instance was mentioned of certain agricultural co-operatives that had opposed the introduction of solar soybean driers since it was felt that they would provide greater negotiating power to campesinos who would no longer feel pressured to sell this product [Footnote: Address by Professor Meyer of the University of Campinas].

Attitudes of Large Corporations: During the same seminar, several participants were of the opinion that in some cases opposition from large transnational corporations operating in the field also existed, since the multiplication of decentralized systems would diminish the great power they yield at present.

Policies Directed Towards Increasing the Level of Penetration (p. 72, 74-76)

Almost all of the studies that have been made on the possibility of increasing the use of renewable sources of energy agree that an essential requisite in so doing is Government support that can be translated into implementing the politics formulated for this purpose. This opinion was repeated on many occasions by people interviewed during the present study.

The support the State must provide for the development of these energy sources cannot be indiscriminate. It must be centred on sources that use the natural resources possessed by the country in question and are most adaptable to its social and economic realities. Feasibility studies must be carried out in order to select those technologies with the most potential for producing a positive impact on the economy [Footnote: In this regard, awareness is being created on both national and international levels. For example, the Agency for International Development (AID) plans to initiate a support programme for extensive feasibility studies to determine future lines of renewable sources of energy].

Projects related to the development of renewable sources of energy cannot be evaluated simply on a private cost basis since the positive effects of such projects benefit the community as a whole. Consequently, project evaluation methods should be used that take into consideration the social, environmental and other effects such projects may bring about - methods such as cost-benefit analysis and the methodology recently developed by Technology Assessment. Cost-benefit analysis offers the advantage of not considering private costs or benefits but rather social ones, which are reflected in their opportunity cost.

It is interesting to note the conclusions of an evaluation of biogas plants using this methodology (Barnett, 1976). These conclusions may be applied to other renewable sources of energy. The principal conclusion is that biogas plants are most feasible in the following situations: (1) when diverse inputs have a low opportunity cost, that is when they have practically no alternate use; (2) when the [p. 74:] efficiency of plant operation is inadequate and (3) when the alternatives to the products manufactured have a high opportunity cost.

These conclusions are also applicable to other renewable sources of energy, and consequently the State should support their development in situations when this is most feasible.

With respect to the first situation, an analysis is needed of what alternative uses there are of capital, labour, natural resources and other inputs that are employed to produce energy from renewable sources. Normally, natural resources (sun, wind, organic wastes) have no alternative uses; however, in some cases they do. One instance that demands careful study is the production of alcohol fuel from agricultural products, principally from sugar cane. In this case, the problem arises whether one can justify using land resources to produce energy instead of food.

In the second situation, it should be noted that the study of plant efficiency is essentially technical. In some cases, efficiency may be increased by using hybrid systems, such as fossil fuels plus solar energy. For example, using solar collectors as fuel 'economizers' may be much more attractive than using complete systems based on this kind of energy.

Lastly, the third situation depends on the opportunity cost of conventional energy. Here, it is important not to consider the price of the fuel which may be subsidized, but rather its opportunity cost - the real cost in resources of having that fuel available for the country in question.

Once it has been determined which technologies using renewable sources of energy would have the most positive effects by being developed, the State should assume responsibility for carrying out whatever policies are necessary to foment such development - in other words, to increase penetration. Policies oriented towards increasing penetration may be of diverse types and, for the purpose of study, may be classified according to the objectives they aim to fulfil.

Policies Directed Towards Promoting Technological Development of Equipment Using Renewable Sources of Energy

The State may make a decisive contribution to the development of technologies concerning renewable sources of energy by assisting in financing research and encouraging such research to solve problems of a practical nature. This may be accomplished within the general framework of governmental scientific and technological policy. Governments must attempt to establish some kind of control over the quality of equipment to ensure that it complies satisfactorily with the function for which it is designed. Current levels of technological knowledge are relatively high and it consequently appears more appropriate to devote greater efforts to seeking practical applications of already-known technology than to develop new technologies. Efforts should be concentrated on improving certain technological parameters - such as windmill power or obtaining higher temperatures by means of solar energy - which would make it possible to increase the market for such equipment.

[p. 75:] Policies Directed Towards Increasing the Economic Viability of Equipment Using Renewable Sources of energy

In this respect, several parallel tactics may be adopted as a means of achieving, inter alia, the following objectives:

(a) diminishing the cost of production of equipment: this may be achieved by means of furnishing technical and economic support to producers either by assisting them in acquiring inputs or by co-operating in their efforts to increase productivity;

(b) expanding the market: a few measures that may contribute to achieving this objective are:

- purchase of equipment by the public sector;
- financial support to users to assist them in making the initial investment;
- elimination of legal restrictions that in some countries prevent the free use of renewable sources of energy.

(c) increasing the intensity of use of the equipment: this will make it possible to reduce the amortization period;

(d) co-operating in the organization of a marketing network;

(e) increasing the competitiveness of equipment using renewable sources of energy: this may be achieved by means of exemptions or incentives designed to reduce the operating cost of new equipment, although this may be difficult since this cost normally is in itself quite low. Another possibility is to attempt to maintain the price of renewable energy as close as possible to its opportunity cost, which generally means increasing its price. A more drastic alternative consists of directly restricting the use of conventional energy by limiting the sale of fuel or in some way establishing strict environmental controls.

Policies Directed Towards Diminishing Resistance to Innovation

An important role may be played by campaigns oriented towards obtaining greater acceptance of innovations by both users in rural areas and government officials on various levels.

Generally speaking, there is a lack of information available concerning the real advantages and limitations of the use of renewable sources of energy as compared with the use of conventional sources. This lack of information, which must be remedied, limits penetration.

Existing agricultural extension services may be useful during information campaigns. Other instruments may also be used, such as the construction of pilot plants or equipment as a means to demonstrate the advantage offered by the use of renewable sources of energy.

[p. 76:] Policies Directed Towards Considering Cultural Factors

It is most important for the technicians - who are responsible for designing equipment to use renewable sources of energy - to understand cultural limitations clearly and to adapt the characteristics of such equipment to cultural realities. Often the problem is presented improperly by attempting to see how the cultural patterns of eventual users may be modified so that they will accept the technology in question. In reality, the matter should be dealt with by attempting to determine how cultural factors may be considered in designing such equipment. These policies may only be implemented insofar as governments fully assume the role they can play in the development of renewable sources of energy.

References

Barnett, Andrew (1976), Social and Economic Evaluation of Biogas Plants. University of Sussex.

Energy, Energy Policy and Renewable Sources of Energy
(p. 78)

The development of renewable sources of energy demands singular awareness and concern on the part of those who make decisions in the energy sector in order to translate such decisions into well-defined policies. It is important that explicit policies - those laid down officially for the sector - should not contradict implicit policies - those defined by other sectors that impinge upon the energy sector. It may happen, for example, that the explicit policy calls for reducing the consumption of fossil fuels; however, such a policy will have little chance of success if, at the same time, implicit policies exist that contradict this objective, such as a policy entailing artificially low fuel prices or a transportation policy based fundamentally on the development of highway transportation. For such concordance between energy and the policies promoted by other sectors to exist, some kind of high-level machinery must also exist with genuine authority to enforce established policies and resolve any differences that may arise with other sectors.

(p. 78-79) In almost all the countries visited, organizations exist with functions related to the production or the consumption of energy. There are electric power companies responsible for the development of electrical systems and mining, energy and hydrocarbons departments or ministries responsible for exploring and exploiting oil or natural gas deposits and for the commercialization and distribution of fuels. In addition, there are transportation and industry [p. 80:] departments or ministries that supervise activities that consume fuel and, lastly, organizations that are concerned with agricultural and rural developments, for which an adequate supply of energy is important. The multiplicity of organizations engaged in one aspect or another of the energy problem makes it essential to establish some kind of institutional machinery at the national level to co-ordinate the activities of such institutions and to assist in formulating energy policy criteria that consider the problem in its totality.

Science, Technology and Institutional Machinery (p. 81)

Institutional machinery to provide support to the scientific and technological sector may be of great importance in the development of renewable sources of energy. Consequently, detailed knowledge of the technologies for using these sources is an essential prerequisite either for transferring the most appropriate technologies to local realities or for developing new technologies. The problems involved in scientific and technological development are intimately linked with general problems of development and are relatively similar in any given field of research, such as housing, agriculture or energy. Generally speaking, one may say that analysis of scientific and technological systems may be carried out by considering three subsystems: information, education and transfer of technology.

Information

One of the recurring topics in the interviews with researchers in the field of renewable sources of energy was the need for more information on research being performed on this subject both within the region and in the industrialized countries. At present, such information may be obtained from scientific publications or by attending congresses or seminars on this topic; however, in both cases the information is obtained with a certain delay that prevents researchers from using it to improve the orientation of their own research.

Education

The sine qua non condition for the success of any line of research is the existence of a 'critical mass' of researchers working in a single area. One of the first tasks to be carried out by countries interested in the development of renewable sources of energy is to form a basic nucleus of people specialized in the various sources involved. Scientists must be encouraged by appropriate incentives to choose renewable sources of energy as their main interest area. In view of the diverse aspects involved in the development and introduction of such sources of energy into the rural sector, which demand consideration of the social, cultural and economic characteristics of the potential users, it is necessary to organize interdisciplinary research groups that take these factors into account.

Transfer of Technology (p. 82)

One of the factors that has contributed to the inability of developing countries to respond appropriately to the challenge of technology has been the conditions under which the technology developed in the industrialized countries has been transferred to them. In recent years, thanks to the efforts of UNCTAD and other United Nations organizations, much greater awareness has been created with respect to the problems associated with the transfer of technology, such as the cost of such transfer, the various clauses that are generally included in transfer contracts and that prevent the developing countries from obtaining significant benefits and the negative long-term effects resulting from the purchase of inappropriate technologies and the ensuing inhibition of national technological development. These problems will emerge again in the transfer of technology to the use of renewable sources of energy if steps are not taken to develop national technological capacity.

The problem is all the more serious in view of the large amounts of resources the industrialized countries have been allocating for some time to the development of renewable sources of energy, such as solar energy programmes or projects for constructing high-powered windmills to be hooked-up to power grids.

(p. 83) In order to minimize the problems associated with the transfer of technology using renewable sources of energy, various Latin American countries have begun to establish instruments for controlling such transfers. In this respect, it is interesting to note the Brazilian experience in this area and Mexico's National Registry of the Transfer of Technology, which is empowered to review all contracts for the transfer of technology subscribed to by Mexican entrepreneurs with foreign companies. So far, these countries have not registered any transfer contracts for equipment using renewable sources of energy, an indication that the same is probably true for the entire region.

Manufacture, Marketing and Distribution of Equipment Using Renewable Sources of Energy (p. 83-85)

The development of renewable sources of energy in Latin America demands that its countries be able to design and manufacture equipment to transform such sources into thermal, mechanical or electrical energy. The industrial capacity to produce such equipment exists in most of the countries in the region, albeit in varying degrees. Obviously, it will require much greater effort to increase quality as well as reduce costs, which in reality means increasing the capacity of local engineering to improve the design of this equipment. If this is not accomplished within a few years the region will see the introduction of mass-produced equipment in the industrialized countries, probably in kit form.

In certain cases - for example, with regard to solar equipment - the problem consists not so much of a lack of knowledge about solar technology per se, as of improving materials technology to increase the useful life of such equipment. Thus, although capacity exists in these countries, an enormous amount of ground still remains to be covered in order to perfect equipment using renewable sources of energy. This problem has obvious institutional implications insofar as it will be necessary to secure much closer collaboration between researchers and the universities on the one hand, and the manufacturers of equipment on the other, in order to solve existing design and materials problems jointly.

The existence of factories for the manufacture of equipment using renewable sources of energy in large urban centres does not ensure its distribution and marketing in rural sectors, precisely the area in which such equipment is most necessary. In the case of almost any commercial product, demand normally becomes the incentive for setting up distribution points throughout the national territory, without the need for institutional support to create such a network. However, the situation is different in this case, in which it would be in the interest of the State to publicize and promote the installation of equipment using renewable sources of energy, since the advantages of their use are perhaps not **[p. 84:]** fully realized by potential users. This situation makes closer collaboration necessary between government organizations responsible for rural development and manufacturers or researchers desiring greater distribution of the equipment they are producing, whether on a commercial or experimental level. If it is hoped to promote greater use of this equipment, a marketing strategy must be formulated either by using already existing channels, such as agricultural banks and extension services, or by creating entirely new channels specifically for this purpose.

Another aspect related to distribution is the legal situation prevailing in a given country with respect to the use of some of the sources of energy discussed in this study. For example, in Brazil, the use of small waterfalls is controlled by the government; farmers wishing to use them must request a concession. Limitations of this kind may also exist in other countries.

Means of Communication and Responsible Institutions

An essential factor in the capacity of countries for developing renewable sources of energy is the belief by all sectors of the population - especially rural sectors - in the prospects and advantages offered by such sources. This requires intensive efforts in which both public and private means of communication should play an important role. For this purpose, high-level organization of a commission responsible for designing and implementing a publicity campaign on the advantages of renewable sources of energy may prove to be effective. Researchers working in this field should strive to translate the results of their efforts into ordinary language easily understood by people with little education so that the advantages and savings that may be obtained through the use of such equipment will be readily grasped. Certain organizations already existing in almost all countries, such as agricultural extension services with experience in introducing new agricultural technologies, could be instrumental in carrying out this activity. The development of pilot projects as demonstrations may also help to awaken interest in this equipment.

Institutional Machinery and Financing

All the institutional mechanisms mentioned require substantial financial support. Consequently, all the elements constituting the chain of development of equipment using renewable sources of energy - researchers, manufacturers, distributors and users - would benefit from access to financing that would assist them in researching, manufacturing, selling or buying this kind of equipment. The State should investigate special financing methods and mechanisms to develop this equipment since, although private investment in its development may not be highly advantageous, the social benefits to be derived are quite evident. Also, the principal problem involved in installing such equipment may be more a financial **[p. 85:]** than an economic one since, although the savings achieved may be great, the users may not possess funds to make the required investment.

The various problems outlined here demonstrate that development of renewable sources of energy requires creating or improving diverse institutional machinery, so that formulating and implementing the policies required to achieve this objective will be more feasible.

Lastly, one more reference should be listed for completion:

Agarwal, B. Diffusion of rural innovations : some analytical issues and the case of wood burning stoves, World development Oxford : v. 11, no. 4 p. 359-376 1983

Based on larger study titled The woodfuel problem and the diffusion of rural innovations done for SPRU. Provides good review of development innovation literature. Offers a simple model whereby the effectiveness of a particular approach in the diffusion of an innovation depends on the technical, the economic and the social characteristics of the innovation.

6. THE CASE OF MARKETING POLICY RESEARCH TO DECISION-MAKERS

An important output of research carried out in developing countries has a significant policy component to it. Policy research in the social sciences is generally targeted to decision-makers and policy-makers in government, and to community and political leaders. Packaging the results of several years of research in a way that will make sense to decision makers requires an appreciation of the context within which they operate. This process of communicating the results of policy research to decision-makers represents a special case of the utilization process, which has yet to be studied thouroughly. We present here some bibliographic references which could throw some light on the process, though none of the the references specifically address the question of "selling" to decision-makers. This should be a fruitful area of research in itself.

COMMONWEALTH SECRETARIAT, **Decision-Making in the Public Service for Choice of Technology: Report of a Workshop of Senior Officials i Kuala Lumpur, Commonwealth Programme for Applied Studies in Government, London, 1981.**

This workshop report was part of a programme begun in 1980 to help public administrators to improve their understanding and control of technological aspects of development. This report includes a summary record of the workshop and incorporates the papers reviewed by the participants.

The workshop record has sections which introduce the nature of the workshop; summarize the participants' recommendations (action at national and international levels and with special attention to the needs of small nations). Four special foci were isolated: "policy and infrastructures for technology decision-making"; "technology information systems"; "use of consultants"; and "training needs specific to technology choice"; and summarized the deliberations of the participants.

There are four background papers, each of which takes a particular issue (institutional structures, information acquisition and use, external consultants and training for decision-makers), and draws out the conclusions of four major country case studies (Fiji-Kiribati, India, Nigeria and the UK). The first three of these case studies have been published individually and are annotated elsewhere in this bibliography.

The background papers in the workshop report are very short and it is advisable to refer to the case studies if the reader is particularly interested. (DH - 26)

BHATT, V., Decision-Making in the Public Sector: The Case of the Swaraj Tractor, World Bank Reprint Series, No. 96, 1978.

An excellent detailed study of the process of decision-making and implementation of a new 20 horsepower tractor (for small to medium Indian farms) using entirely indigenous technology and inputs - i.e. designed from the start by Indians for existing local conditions.

Initially the proposed project (in great detail) was not accepted by central government because of a lack of confidence in local technology especially in the face of existing tried and tested imports. The author also suggests an important interpersonal rivalry between the chief technical planner and the central government decision-makers. But it was taken up by the Punjab government with great difficulties in financing from the national development bank.

The project was rigorously tested in terms of its economic and technical feasibility but no social analysis of its impact was undertaken (i.e. it was simply a response to an existing demand). Very good back-up services were built-in to the project which eventually produced tractors at a profit and was highly regarded by the users. (DH - 175)

JAMES, J., Bureaucratic, Engineering and Economic Men: Decision-Making for Technology in Tanzania's State-Owned Enterprises, ILO, World Employment Programme, Technology and Employment Project, Working Paper No. 125, Geneva, 1983.

James refutes the idea that decision-makers in such enterprizes aim to maximize social welfare. He sees more fruit in conceptualizing such decision-makers as "bureaucratic men" i.e. lacking incentives to minimize costs (cost - plus pricing - no financial rewards for low costs) thus having other goals - such as initiating projects, (possibly aid-related and high prestige but involving low effort-levels from the state enterprize). This leads to easy and "impressive" technology choices; therefore few considerations of its aptness are made. The "engineering-man" hypothesis is also tested and found to have some relevance. Thus, instead of "economic-man" decisions the "engineering-man" decision would lead to "high product quality" choices, "a desire to manage machines not men" and a "preference for using sophisticated machinery which appeals to his sense of aesthetics".

Some policy conclusions include: encouragement of pressures to reduce costs yet maintain production targets (would lead to more technological calculatedness); a technology unit of state departments to prepare handbooks and put pressure on state enterprizes; better training including in-house for managers; the promotion of products requiring less capital intensive production technology; and the promotion of the image of small-scale production techniques while recognizing the vested interests against this. (DH - 182)

JAMES, J., The Choice of Technology in Public Enterprise: A Comparative Study of Manufacturing Industry in Kenya and Tanzania, in Macro Policies for Appropriate Technology, edited by F. Stewart, Westview, Boulder, Colorado, 1987.

Despite the substantial differences in the political structure of these 2 countries the evidence on technology choice by their industrial public enterprizes shows a remarkable similarity of technological [p. 99:] behaviour. Furthermore, the outcome of this behavioural pattern "appears to diverge from many of the most important national development goals of both countries". He concludes that these decisions are made with a single objective which is also most unimpeded by countervailing pressures from either the macro-environment or from other agencies of government. This "objective predisposes managers to search for investment projects in which, through various mechanisms and with varying degrees of directness, developed country patterns of scale, factor intensity and product characteristics are invariably closely reproduced". Factors such as pandering to "easy" options of foreign aid (including technological implications), poor training of managers (e.g. awareness of benefits of appropriate technology (AT)), weak measures to control managers of parastatals (finance, specification of AT target objectives etc.), the weakness of government bodies and policies to enhance the macro-environment for small-scale operations. (DH - 183)

7. THE CASE OF AGRICULTURE AND RURAL DEVELOPMENT:

Given that over half of the research carried out in developing countries is in the agricultural area, it is not surprising that a great deal of interest has been shown in how that research is being disseminated. Agricultural innovation, in fact, has been the mainstay of such scholars as Rogers. A key vector for disseminating agricultural innovations has been the extension system, first instituted in the US at the turn of the century. A great deal has been written about extension, and there is even a journal that publishes regularly on the topic. We will review one work here, a World Bank evaluation of over 120 projects in the extension and technology transfer areas. Extensive excerpts will be reproduced, because this evaluation goes beyond just the 120 World Bank projects, but reviews the underlying principles of any extension system. It may well be, according to the Bank, that there is nothing wrong intrinsically with an agricultural extension system, but the financial and centralized management resources required to operate it effectively are so high, that few developing countries can afford to run one.

The World Bank. 1985. Agricultural Research and Extension: An Evaluation of the World Bank's Experience. The World Bank, Washington, DC, USA. 110 p.

PREFACE (p. vii)

The conclusions in this study are based on a review of the World Bank's support for agricultural research and extension (R&E) in 128 projects in ten member countries over the period 1974-80.

The projects reviewed include agricultural projects with research or extension components or both, and freestanding research or extension projects. At the time of the study most of the former had been completed and the majority of the latter were beyond the midpoint of their implementation period. The 128 projects reviewed represented 35 percent of the total number of projects that received the Bank's support for research and extension; the freestanding national research or extension projects reviewed accounted for 55 percent of the projects supported by the Bank.

The ten countries included in the review were Brazil, India, Indonesia, Kenya, Mali, Morocco, Nigeria, Sudan, Thailand, and Turkey. The countries were selected to permit coverage of (1) the various approaches the Bank has followed in providing support for research and extension; (2) all geographical regions as defined by the Bank for internal administration; (3) major agroecological zones; and (4) countries in which the Bank has supported research and extension for a period long enough to permit an analysis of the experience.

MAJOR FINDINGS AND RECOMMENDATIONS (p. 3)

The World Bank's efforts in support of research and extension (R&E) were significant and worthwhile, even though the efficacy of the approaches followed in various countries to address specific needs differed. This study proceeded from the premise that research and extension were related functions and examined the Bank's initiatives in this light. The study found that the Bank's support for R&E, which is still evolving, has helped highlight the importance of strengthening these two functions.

(p. 4-5) The review found that, regardless of the approach followed in the ten countries studied, the level of R&E services needed to achieve the countries' development targets far exceeded the level of services provided. This gap was a result of the fact that the countries' development objectives were not fully related to the means available for achieving them and of the fact that R&E services were generally provided in a fragmented manner.

The Bank's efforts to support the development of R&E functions were often hindered by the limited response it received from [p. 5:] policy-makers with regard to formulating and implementing the necessary actions. This limited response had two origins. First, the limited capability in some countries to effectively identify, prepare, and appraise R&E components and projects meant that they did not fully appreciate the urgent need for policy actions. Second, the Bank's suggestions for policy actions in support of R&E sometimes failed to reflect realistically existing political, institutional, and financial constraints in the countries.

The study found inadequacies in resource allocation to an between research and extension; this reflected weaknesses in planning and monitoring processes in the countries. Frequently, development plans and project documents showed more concern with the quantity of resources allocated for R&E than with the effectiveness and impact of their use. The Bank attempted to help countries make better use of R&E resources in several ways: through its broad-based direct support to R&E systems, through its cooperation with other outside agencies financing activities in support of R&E, and through its policy dialogue with members. In some countries these efforts were successful; in others they were less so. Broad-based support for R&E has created additional demands for scarce budgetary resources, which some countries are unable to sustain. On the whole, the experience with cofinancing for R&E has been positive, although the amounts involved have been limited. In the policy dialogue, the Bank has effectively used R&E components in agricultural and rural development projects in several countries as the precursor to freestanding R&E projects.

(p. 6-7) In extension components, the Bank's support has been worthwhile. The support has helped meet the urgent and realistic needs of developing member countries and has increased their awareness of the potential benefits of technology transfer. These extension components, however, have tended to stress the technology supply and service aspects of the extension function, often at the expense of its education aspect. This emphasis has been a result of limited correlation between the scope and substance of extension components and the state of the research function in the country; it is also a reflection of limited emphasis on proper resource management.

The major strength of Bank-supported extension through agricultural projects was its ability to increase the access of groups of farmers, particularly small farmers, to an integrated package of technology. The package, which included physical inputs, credit, [p. 7:] technical advice, and other services, proved especially useful for farmers involved in the production of a variety of crops and livestock. Technology could be transferred to these farmers under conditions of limited or unskilled manpower and weak national research. During the implementation of many extension components, however, the provision of inputs and services tended to prevail over the actual extension either because there was no need for actual extension, owing to the simplicity of the technology used and the farmers' prior familiarity with it, or, where extension really was needed, because of the lack of suitably trained extension personnel.

The full-scale extension projects supported by the Bank covered a wider area and a larger number of farmers than did the extension components in agricultural and rural development projects. The full-scale projects sought to introduce organizational change and to improve the performance of extension workers. This approach appeared to suit countries with large numbers of small farmers at a low level of technological development and with abundant but poorly trained and inadequately used extension staff. These projects, however, often made unrealistic assumptions about the availability and quality of technical and extension specialists. As a result, limited effort was made to significantly upgrade the competence of specialized personnel and to expand their availability.

(p. 10) The more successful extension organizations displayed a combination of some of the following characteristics:

> Flexible extension methodology to fit the nature of the technology being extended, clients' needs, and the means available to the country

Close coordination of the extension function with other technology transfer functions

Active participation by extension personnel (subject matter specialists), along with researchers, in translating research results into recommendations for users

A formal feedback mechanism that directly reflects clients' points of view rather than observers' opinions of what those points of view are or should be (this may require training clients to work together in articulating their demands more clearly to research and extension staff)

Clearly defined job descriptions for extension personnel, who are supervised and evaluated on the basis of these job specifications

Adequate attention to both the technical skills and the communication or pedagogical skills needed by extension personnel in view of the technology to be extended and the clients to be served

Extension projects should emphasize (p. 12-13):

Formal training for higher-level extension personnel in technical agricultural subjects as well as in communications

Job descriptions for extension personnel that are consistent with the country's administrative procedures and the existing reward system

Training that relates to (1) the country's demand for skilled manpower, its training capacity, and its budgetary limitations both during and after the project's completion, (2) the differences in the levels of technology being used by various groups of farmers, and (3) the potential for tradeoffs between the use of human resources and the communication media for extension

Formal professional links between research and extension

[p. 13:] The establishment of channels through which farmers, especially the less privileged among them, can influence the form and substance of extension being provided.

(p. 30-31) In Indonesia, Sudan, and Thailand, the early stages of development of R&E systems reflected the historical orientation of the organized section of their production systems to supply raw agricultural materials (such as rubber, cotton, and other commercial crops) to industries outside these countries. Policymakers in these countries had to go (or are still going) through a process of trial and error to expand and adjust their old systems to serve the needs of the entire agriculture sector. Repeated changes in he organization of R&E in Kenya, Morocco, Nigeria, and Turkey were indicative of the awareness of policymakers that their systems had not been adequately responsive to national needs. One observation, common to these countries and others, was that attempts to reorganize the R&E system were not comprehensive because they did not address the major factors (such as manpower, operating funds, allocation of responsibilities, authority, and staff motivation) that accounted for the weakness of the existing organization. In addition, policy decisions related to organizational reforms often addressed the consequence of the problems (such as ineffective organization) rather than the problems themselves (for example, limited manpower capability and limited policy priority given to R&E).

The persistence of weaknesses in the national R&E systems of these countries allowed a demand for technology to grow unsatisfied. As a result, some R&E clients sought services outside the national system (these included agencies responsible for the implementation of rural development programs) or produced their own services, often independently of the national system (the research on fruits and vegetables in Morocco, for example). Because of such reactions by the users of R&E services, there has been an increase in the awareness of policymakers of the usefulness of R&E, of the inadequacy of national R&E organizations, and of the [p. 31:] need to rethink their approach to building a permanent national R&E capability. There is evidence of that rethinking in the nature of actions taken by policymakers: a progressive change in favor of planned and integrated interventions in some countries (Brazil, India, Indonesia, Sudan, and Thailand, for example).

<u>Research Organization</u> (p. 47-48)

Judging from the case studies, efficiency in the organization of research systems was not easy to achieve in smaller countries with simple administrative structures. In fact, it was the larger countries in the sample that seemed to have more efficient organizations. Six factors emerged as common features of the more successful research organizations reviewed:

> A strong central organization with overall responsibility for most aspects of national research and with funds to carry out its responsibility
>
> Some degree of autonomy from the routine bureaucratic structure of the Ministry of Agriculture
>
> Good links to the national planners and policymakers despite the organization's semiautonomous of autonomous structure

Service units - either directly part of, or closely related to, the central research organization - that perform important planning, monitoring, and evaluation functions

[p. 48:] A planned decentralization of regional research

Active participation in translating research results into recommendations communicable to users.

Although there was no single formula appropriate to all circumstances, it was clear that any coordinating mechanism must ensure that sound links exist among national policymakers, research planners, and clients. If there is an umbrella management organization for research (which seemed valuable for larger countries), it must have control over research funds and be provided with adequate supporting services for planning, monitoring, evaluation, economic and statistical analysis, and financial management. It was the absence of these factors that rendered coordinating institutions impotent and defeated efforts to establish effective national research organizations. It is important that the coordination function not be confused with that of top-down central control. The latter may be as ineffective as fragmentation.

(p. 57-58) Internal Linkages and Transfer of Research Results. The picture in this area is bleak. For instance, the Indian Agricultural Research Institute has not produced a comprehensive report of its scientific activities since 1977. In Sudan, many researchers in the national research organization did not even recognize the need to be accountable for their results or to be responsible for transmitting the results to potential users. Horizontal communications among research institutions were inadequate in most countries because of the fragmentation of responsibilities. Weaknesses in the mechanisms for communication of research results to farmers were evident, even in countries where the Bank supported national extension projects. These weaknesses resulted mainly from inadequate communication between research workers and extension agents. In several countries, both research and extension services transmitted technical information independently and separately to farmers. Examples of duplication, and even of conflicting recommendations, were found in Indonesia, Thailand, and Turkey.

The quality of both the information and the means of its transmission was often poor. In Brazil, communication was specifically recognized as vital to the success of research, and an attempt was made to train staff and to establish units killed in the reception and transmission of information; this was very much an exception. The importance of communications as an essential element in solving linkage problems was not well recognized by national agencies or, at times, by the Bank. This lack of recognition [p. 58:]

was evident from the fact that the supervision reports made no mention of the failure of research and extension training centers to utilize adequate and up-to-date equipment, mass media, and teaching methods, even where these were financed by the Bank.

<u>Status of Extension Personnel</u> (p. 61)

Agricultural extension has historically been perceived as a function of low status performed by poorly qualified and poorly equipped persons who deal with poor and, frequently, illiterate farmers in remote rural areas. This perception has been supported by facts: low salaries, unclear job description, poor supervision of performance, and poor quality of work by extension personnel.

Lack of an Adequate Reward System. Salary scale and allowances were set by the civil service. The provision for improving salaries across the board or on the basis of merit was limited. Prior to the Bank's involvement, there was no indication in the countries visited that any type of reward system had ever been considered - let alone established.

(p. 62) Job Description for Extension Personnel. A common feature within national extension systems has been the excessive involvement of field-level extension personnel in the noneducation aspect of technology transfer. For example, in India, prior to the Bank's involvement, village extension workers had multipurpose assignments within the Community Development Program; they spent only a limited amount of their time on agricultural programs and even less time on agricultural extension. In Kenya, Nigeria, and Turkey, agricultural extension workers helped run production campaigns that were heavily involved in the provision of inputs and other services. In Brazil, Morocco, and Thailand, administrative responsibilities diluted the role of extension personnel.

The Bank's approach to this problem, particularly in the full-scale extension projects it has supported in Asia, has been to insist that extension personnel work full time on the knowledge transfer component of technology transfer.

(p. 64) Supervision of Extension Personnel. A common problem associated with unstructured, multipurpose job assignments for extension personnel in the field has been poor supervision of their work. Where it was difficult to define the agents' assignments, it was equally difficult to establish criteria to evaluate their performances.

(p. 64-65) Quality of Extension Personnel. The poor quality of field-level staff was a problem common to all countries. There was general agreement among the countries visited that the poorly educated and poorly trained extension staff were not fully [p. 65:] equipped to disseminate improved technology to farmers effectively.

Resource Allocation, Development, and Management (p. 66-67)

The allocation of available resources among various elements of the technology transfer system within countries was affected by [p. 67:] several factors. First, the extension (knowledge transfer) element tended, historically, to be combined at the operational level with other technology transfer functions. This confusion was partly a result of the fact that organized extension was an alien concept in most developing countries; not enough time had elapsed for them to recognize the importance of, and need for, an effective extension service. Second, the extension function depended on the availability of knowledge worth transferring. The development of such knowledge was slow in most countries. The extension element thus had no basis for acquiring recognition as a function. Third, the transfer of technology from more advanced countries had created needs for the supply and the distribution of marketed inputs and for accompanying services at a time when the physical and institutional means available in various countries were not sufficient to meet them. Consequently, the extension function, which was less tangible and more difficult to perform, was often sacrificed in favor of other technology transfer functions. Fourth, various technology transfer functions were considered separately for purposes of the allocation of resources, particularly of those resources originating outside the country. These functions thus competed with one another for resources.

(p. 70-71) The lesson to be learned from these examples is that an imbalance in resource allocation does not have to be corrected by creating an imbalance elsewhere, nor does it have to be corrected overnight. Because extension was neglected in favor of supply and service functions, countries need to balance their support to various functions in such a way that these functions remain useful and [p. 71:] complementary to one another. Each country should be able to afford to provide these services to its farmers; this requires, first, careful planning and sequencing of project inputs (recognizing the country's limitations) and, second, proper management of existing resources and selective development of new resources.

Extension Methodology (p. 71-72)

At one end of the spectrum, agricultural extension is a communications task: transferring information about new farm practices from research to potential users and getting feedback from users to researchers. This is all that would be needed if the technological practices being introduced did not require major changes in the existing production process. Farmers could simply substitute the new practice for an old one and expect a higher output. For example, a crop variety could be rendered more efficient (that is, provide a higher yield) by the application of fertilizer or other inputs.

At the other end of the spectrum, agricultural extension can be seen as an education task consisting of both the communications task and the added task of helping farmers adapt their production process to take full advantage of the technological practice suggested. This role would apply whenever the technological practice being introduced led to major changes in the existing production process and required farmers to relearn how to combine their factors of production optimally.

The Bank's support for agricultural extension in national projects has favored heavy reliance on demonstrations, small group meetings, and farm visits [This applied particularly to India, Indonesia, and Thailand, where the training and visit technique of extension was utilized. Appendix 5 provides a further explanation of extension methodology.] To be properly implemented, this approach had to be labor-intensive. But because extension workers were often poorly educated, their task consisted, for the most part, in transmitting a technical message at regular periods to farmers. Therefore, the extension agent became more of a person-to-person communicator than an extension agent. This approach appears to have worked in two cases: those in which the objective was to [p. 72:] assist farmers in acquiring technological elements that did not substantially alter existing production processes and those in which the emphasis in the extension agent's job was more on transfer of information than on education.

(p. 73-74) The preceding discussion suggests that extension (communication and education) should be regarded as a <u>tool</u> of technology transfer, which can be adjusted to serve that <u>end</u> (transfer of technology) under varying <u>circumstances</u> (depending on the nature of technology and the characteristics of clients). It is the circumstances that determine the extent and the nature of adjustment (mix between communication and education) and, consequently, the nature and intensity of the extension effort required. The extension methodology should be selected to fit the circumstances [p. 74:] under which it is to be applied. The opposite approach of attempting to change the circumstances to fit the methodology may work under certain conditions, but it cannot be viable in the long term.

<u>Linkages</u> (p. 79-80)

As part of the technology development and transfer system, an extension organization has to (1) be knowledgeable of, and responsive to, the needs of its clients; (2) have a source of knowledge to rely on for answering client's questions; and (3) have established channels to supply inputs and services that complement extension. The linkages between extension and these three elements are reviewed in the remainder of this section.

Extension-Research Linkages. Bridging the gap between research and extension has probably been the most serious institutional problem in developing an effective R&E system; this is particularly so in countries in which these two functions are carried out by different organizations. Historically, attempts at linking R&E have been through individual initiative, through formal meetings organized for research and other agricultural technical staff, or though coordinating or technical committees. India was the first among developing countries to try to establish a formal link based on the system of land grant universities in the United [p. 80:] States. More recently, attempts at linking extension and research were centered on that portion of the R&E continuum consisting of technology testing and demonstration. The agricultural technical specialist, who has been referred to as the subject matter specialist in the extension literature, became the key actor in establishing a bridge between extension and research.

(p. 82-83) Extension-Client Linkages. Concern over the linkages between extension services and their clients stems from the need for feedback to (1) determine the usefulness of technologies being extended to clients; and (2) ensure that extension approaches are adapted to the specific needs of various groups of farmers.

Extension organizations in the countries visited were traditionally top-down institutions; they operated on the assumption that R&E personnel knew farmers' problems and goals. Attempts at correcting this misconception were concentrated on encouraging the establishment of internal feedback channels within extension services through regular contacts between extension workers and farmers. This mechanism, although an important step in the right direction, still left farmers at the mercy of the extension agent's willingness and capability to comprehend their problems and transmit them to researchers. The extension organization in such a case lost touch with clients and took on its own objectives, which included its survival. More positive steps have been taken in some cases. In the dairy project in India, farmers' cooperatives at the village level were set up and their memberships taught to look after their own interests, including their interests in the development and [p. 83:] transfer of technology. These farmers' organizations took an active interest in the relevance and quality of the services provided to their members.

The Bank's support for extension stressed the need for feedback from farmers. However, only a few projects in the countries visited had concrete proposals and funds for establishing formal structures through which farmers could participate in the planning and programming of R&E. In most extension projects, the Bank supported reliance on feedback through field-level extension agents, but most of the extension organizations visited lacked the capability to check on the quality of such feedback.

The example of dairy farmers in India illustrated the need to provide channels through which the less privileged groups could express their points of view and, thus, make the technology transfer function more useful. Numerous case studies have indicated that small farmers, in general, and women, in particular, had the least say on either the form or the substance of extension.

Because small farmers were more vulnerable to risk than large farmers, the former were often perceived as being more resistant to change. Extension workers were naturally drawn to those farmers who were likely to find their information useful and to appreciate their help; these were, very often, farmers with large landholdings. Such actions of extension workers had implications on the types of problems fed back to the research system for the development of future technology. Moreover, because the extension function was often tied closely to the supply of inputs and services, those farmers who had their own means or were qualified for credit gained more access to inputs and technical assistance. Therefore, if the supply of inputs and services was limited, extension agents paid more attention to farmers with more economic and political power; these generally were not the small farmers.

Given this rather broad critique of the extension system, let us examine some alternatives that are being proposed. There are many such systems and projects being proposed throughout the world, it should be noted, and this represents an area of research in itself.

CHAMBERS, R., and GHILDYAL, B., Agricultural Research for Resource-Poor Farmers: The Farmers-First-and-Last Model, IDS (Sussex) Discussion Paper No. 203, 1985.

The normal transfer-of-technology (TOT) model for agricultural research has built-in biases which favour resource-rich farmers whose conditions resemble those of research stations. "A second emerging model is farmer-first-and-last (FFL). This starts and ends with the farm family and the farming system. It begins with a holistic and interdisciplinary appraisal of farm families' resources, needs and problems and continues with on-farm and with-farmer research and development, with scientists, experiment stations and laboratories in a consultancy and referral role". The authors make the case that FFL suits poor farmers better than TOT, but that there are major obstacles to its development and introduction. They go on to make suggestions as to how these could be overcome by illucidating four specific proposals for FFL systems and analysing their likely strengths and weaknesses. From this they stress methodological innovation; interdisciplinarity; resources; rewards structures; and training. (DH - 136)

HERATH, H., Role of Rural Institutions in the Diffusion of Agricultural Innovations in Sri Lanka, ILO, World Employment Programme, Technology and Employment Project, Working Paper No. 109, 1983.

This paper is the fourth in a series of papers on the role of institutional factors in the generation and diffusion of agricultural innovations. It draws on the conceptual paper by Ruttan (Working Paper No. 67), and follows two case studies (Kenya, Working paper No. 95, and North Vietnam Working Paper No. 98). This study is somewhat narrower than the others in that it concentrates on one particular example of technology; namely high yielding varieties of rice, (the others deal with a range of technologies). It also is the result of detailed empirical investigation.

As in all ILO WPs on technology and employment, the focus is primarily on employment connotations.

The study was based on two villages (one in a wet zone the other a dry zone) and attempted to isolate the effects of institutional factors (farm size, land tenure, demographic variables, etc) and formal technology institutions (extension services etc). The author found that with respect to the latter, informal mechanisms such as word of mouth were more important. He also drew out interesting relationships between the former institutional factors and the demand for, and ability to receive, new technologies. (DH - 145)

MAXWELL, S., The Role of Case Studies in Farming Systems Research, Agricultural Administration, Vol. 21, No. 3, 1986.

This paper discusses the case study method as a useful and cost effective addition to the range of research tools used in multi-disciplinary farming systems research (FSR). The author argues that the case study as a tool in FSR is in danger of being ignored. He provides general arguments for a case study approach as well as those specific to FSR. With respect to the latter he argues that the case study method provides information that would be hard to obtain by other means, as well as an opportunity for close collaboration between social scientists, natural scientists and farmers. (DH - 148)

CLARK, N., and CLAY, E., The Dryland Research Project at Indore 1974-80 - An International Innovation in Rural Technology Transfer, IDS (Sussex) Discussion Paper, No. 222, 1986.

This paper analyzes an alternative to the conventional model of agricultural research and extension (i.e. scientists in research stations establish "principles" which are subsequently spread by the relationship of extension workers and farmers) by assessing the Indore Dryland Research Project. In this project, "scientists from different disciplines work directly with farmers in a concerted effort to raise yields in a catchment area of around 2,300 hectares". Extension agencies played more of a service function.

This paper, first, describes the structure and activities of the project, then assesses the main effects. There was a rapid (especially in the first three years) growth of productivity due to increased yields per crop per acre and changes in the cropping pattern. These were centrally dependent on improved soil and water management. The authors also note a slowing down in progress after the initial phase in part due to changes in personnel, but also due to the comparative ease of early progress. The overall positive picture was also qualified by the recognition of a possible "glass house effect" i.e. an intensive concentration of activity by scientists in a limited area.

The authors nonetheless found the experiment to have had largely positive effects and they therefore attempt to place the concept within the overall field of science policy analysis. They thus trace the development of thinking on appropriate technology to an increasing interest in the dynamics of technical change in developing countries. Clearly the role of agricultural research and extension is closely linked to the processes of technical change. The relevance of the Indore project, apart from the local impact, is that it shows that more organic models of rural technology transfer can be successful. In essence, the authors argue that "the project is consistent with a view of the process of technological change which is essentially evolutionary and holistic".

The paper also includes a bibliography which is a useful guide to recent literature on agricultural technology change and the role therein of institutions.(DH - 138)

RANIS, G., STEWART, F., Rural Linkages in the Philippines and Taiwan, in Macro Policies for Appropriate Technology, edited by F. Stewart, Westview, Boulder, Colorado, 1987.

The authors make the general case that rural industries tend to be appropriate in that they are more labour intensive and produce more appropriate products using a higher proportion of local resources e.g. furniture is usually simple, low-cost and uses local materials. Given this and the strong links between agricultural and rural industrial prosperity they argue for policies which enhance these links and thus stimulate more and "better" growth in a "virtuous circle". Using the cases of Taiwan and the Philippines they show that despite similarly impressive agricultural production growth rates the growth of rural industries has been much less impressive in the Philippines. A vast array of policies such as: land distribution, prices, credit, research and development, industrial and trade policies are shown to influence consumption and production (backward and forward) linkages. Most importantly they point out that agricultural growth has a very strong off-farm local employment effect (in the Philippines a 1% agricultural output increase led to over 1% increase in non-agricultural employment). Thus, reversing the decline in agriculture in much of Africa "is the single most important aspect of promoting appropriate technology in the rural areas". (DH - 152)

AGARWAL, B., Cold Hearths and Barren Slopes: The Woodfuel Crisis in the Third World, London, Zed Books, 1986.

This book looks at the scale, causes and possible solutions to the woodfuel crisis in the Third World drawing on the experiences of East and West Africa, Asia and parts of Latin America. The woodfuel crisis is related to social and political inequality from the international to the household level. The remainder of the book is concerned with solutions to the crisis. The main technical aspects of woodfuel innovations - tree planting schemes and improved wood burning stoves - are examined. This is followed by an analysis of diffusion of rural innovations (Chapter 3 to Chapter 5). Chapter 3 constructs an analytical typology of rural innovations according to their technical, economic and social characteristics. Chapters 4 and 5 evaluate factors that lead to success or failure in diffusion of improved wood burning stoves, and social forestry and other tree planting schemes respectively. An appendix examines the diffusion of improved charcoal kilns.

With respect to wood burning stoves the author concludes that a crucial factor in successful diffusion "is the importance of adapting the stove to the users' needs and of involving the potential beneficiaries as closely as possible in the designing and building of the stoves".

For tree planting crucial factors are whether the scheme is "top down", access to and control over land and the nature of the implementing agent (government/community or private management).

The final chapter (Chapter 6) examines how to evaluate woodfuel diffusion programmes. Ex post and ex ante evaluations are discussed but it is argued that in either case effectiveness will depend on the approach by which evaluation is carried out ("top-down") or participatory), by whom (local people or outside evaluators) and the method of data collection (questionnaires, group discussions etc.). No single method is advanced as universally correct and it is argued that the crucial consideration is who does the evaluation.

This book also has a useful and substantial bibliography. (DH - 156)

HERRERA, A., The Generation of Technologies in Rural Areas, in World Development, Vol. 9, pp. 21-35, 1981.

The author first criticizes the weakness of attempts to generate and diffuse appropriate technologies (AT) due in his mind to the lack of a coherent concept of development as a reference point and the assumptions or paradigms emanating from rich countries which underlay current attempts.

He then proposes an interactive research and development procedure with a premium on communication with rural dwellers and more emphasis on traditional technologies at least as contributors to new solutions to social problems or objectives. He also stresses the need to understand the dynamic socio-economic elements in which a technological problem is always immersed. (DH - 171)

8. THE CASE OF NEW STRATEGIC TECHNOLOGIES

A lot has been written about the importance of strategic technologies in the industrialised countries: microelectronics, artificial intelligence, advanced materials, biotechnology. Less has been written about these new technologies for developing countries. Here is a selection of citations on the topic.

BHALLA, A., JAMES, D., and STEVENS, Y. (eds), "Blending of New and Traditional Technologies: Case Studies", ILO (Monograph), Tycooley, Dublin, 1984.

This book attempts to elucidate an emerging trend whereby advanced technologies (specifically microelectronics, biotechnology, space satellites, new materials technology and solar energy) are being blended with more traditional technologies. Blending implies the specific integration of new and old technologies in the same production process. The book draws on 19 case studies from developed and developing countries to highlight the actual blending processes. These include: 1. a review of "off-line uses of microcomputers in selected developing countries" - 4 case studies of microcomputer application in statistical compilation, development projects, financial management and engineering research; 2. "The use of numerically controlled machines on traditional lathes in the Brazilian capital goods industry" - which very briefly traces the diffusion and economic impacts of a particular numerically-controlled lathe; 3. "Electronic lead-controlled mini-hydroelectric projects: experiences from Columbia, Sri Lanka and Thailand" - examines the application and effects of an electronic device which controls the load on hydroelectric plan alternators in the 3 countries; 4. "The application of biotechnology to metal extraction: the case of the Andean countries" - bacterial leaching of metals from ores or concentrates can reduce the cost of mining [p. 3:] low-grade metals and prolong activity in small and large operations; 5. "Cloning of palm oil trees in Malaysia" - traces effects of large-scale application of new technology; 6. "Technological change in palm oil in Costa Rica" - again traces a large scale corporation application of new biotechnology; 7. "Bio-technology application to some African fermented foods" - Kaffir corn (sorghum) beer, Nigerian ogi (pap), Gari and Mahewu are all processes requiring fermentation, this article assesses the application of effects of new biotechnologies in their preparation; 8. "Use of satellite remote-censing techniques in West Africa" - two case studies: one of rice production forecasting in Mali and Guinea and the other a hydrogeological investigation in Niger (to trace water supplies); 9. "India's rural educational television broadcasting via satellites" - essentially notes the weaknesses of a series of educational projects by these means, especially the commercialization of the television programme; 10. "New construction materials for developing countries" - this briefly outlines the idea of fibre reinforced concrete which adds flexibility and strength to cement as well as having a lower density, better thermal insulation and absorption characteristics than more conventional steel or asbestos reinforcements; 11. "Photovoltaic solar-powered pump irrigation in Pakistan" - solar-powered units can provide irrigation for very small farmers who often benefit little from more conventional tubewells - this paper review the application of 20 photovoltaic solar-powered irrigation pumps in 1981; 12. "Photovoltaic power supply to a village in Upper Volta" - examines the use of solar cells as a power source for common village tasks with special emphasis on womens' tasks.

This book also contains a select bibliography devoted to the topic of blending new and traditional technologies. (DH - 3)

Here is a later publication by the same authors:

Bhalla, A.S., James, D. 1988. New Technologies and Development: Experiences in "Technology Blending". A study prepared for the International Labour Office within the framework of the World Employment Programme. Lynne Rienner, Boulder, CO, USA. 336 p.

PREFACE (p. ix)

Can the developing countries exploit the tremendous potential of new technologies in the interests of the bulk of their poor populations, or will the poor of the Third World continue to be bypassed by the discoveries of technical progress? This question deserves to be at the heart of the current debate about the potentials and pitfalls of the new technological revolution. This volume poses this question, inter alia, and tries to marshal empirical evidence in support of the assertion that, through conscious policies and governmental efforts, the new technologies like microelectronics, new biotechnologies, telecommunications, remote sensing, photovoltaics, and laser technologies can be harnessed for the benefit of the majority of Third World populations. This can be done particularly if ways are found to combine the utilization of new technologies with the traditional activities and methods of production which characterize the urban and rural poor in these countries.

INTRODUCTION (p. 1)

The new technological revolution based on microelectronics, new materials and biotechnologies, remote sensing, and communications satellites is here to stay, and it is likely to change the economic, social, and perhaps political spheres of life. Although this revolution has originated in the advanced countries (like its precursor, the Industrial Revolution) it is clear that developing countries cannot remain disinterested spectators. The implications of new frontier technologies are all-pervasive and they are going to affect (and indeed, in many cases, they are already affecting both the South and the North. Therefore, this one-world opportunity (and at times, problem) needs to be well managed and harnessed so that its potential can be fully exploited.

We maintain that the developing countries are most likely to benefit from the new technological revolution if frontier technologies are channeled consciously and primarily for the satisfaction of essential human needs like food, shelter, health, and education.

I. New Technologies and Blending (p. 1-2)

The newly emerging technologies are being applied in different sectors of economic activity (e.g., agriculture, industry, and services like banking, [p. 2:] insurance, and transport and communications). The emergence of these technologies has widened the scope of technology choice but notwithstanding this, it is clear that in many cases, these technologies will exist side by side with the conventional and traditional technologies for the foreseeable future.

The diffusion and application of new technologies in developing countries at present remains isolated and limited. The knowledge about and documentation on the experiences of applications are not easily available. For example, data on the diffusion of microelectronics-based innovations in the agricultural sectors are hard to find even for the advanced countries, not to speak of the developing countries where this sector is predominant. Also, the diffusion pattern across sectors is quite uneven. Therefore, generalizations become extremely difficult if not impossible.

Technology Blending (p. 3)

The term 'technology blending' in a narrow sense refers to the possibility of physically combining elements of new and traditional technologies. Defined in this sense of retrofitting, (as is also done, inter alia, in Chapter 1 and in micro cases of Como silk industry and French footwear industry in Chapters 5 and 6) it is not a new concept. In the history of technical progress, there have been many examples of this type of blending. On the other hand, in a more general sense, it attempts to focus mainly but not exclusively on the applications of new technologies to predominantly traditional, small-scale activities. In this wider context, this focus on small-scale or traditional activities is a recent phenomenon. Thus, the concept is distinct from that of the use of frontier technologies which completely replace traditionally economic activities in which large populations are engaged.

Thus, technology blending may be characterized by (1) applications of new technologies in traditional activities, (2) technology adoptions by small-scale producers or agencies applying them for the overall benefit of small-scale sectors, and (3) use of new technologies for the production and delivery of basic needs type of goods and services. For example, let us take the case of small-scale producers. Many developing economies (particularly in Asia) are moving toward more liberalized economic regimes, which implies an increase in competition particularly for small-scale producers. It is therefore becoming more important than before to explore whether new technologies offer these producers an opportunity to improve quality of their products, to reduce their prices, and, in general, to respond more easily and quickly to changing patterns in demand. In this respect, the experience of developing countries is very patchy. It is for this reason, inter alia, that we have included in the volume case studies of French and Italian small enterprises (Chapters 5 and 6) besides examining the experience of developing countries (Chapters 4 and 7).

1 NEW TECHNOLOGIES AND OLD DEBATES (P. 13-14)
N. Rosenberg

It is now widely accepted that the prospects for a substantial improvement in economic welfare in developing countries depend upon the successful incorporation and exploitation of more effective technologies than are presently available in those countries. Thus, critical issues with respect to the economic future of developing countries are now perceived to turn upon their ability to select more efficient technologies for introduction into their economies and the conditions that determine the successful outcome of such undertakings.

It is not difficult to see why the transfer of technologies from advanced [p. 14:] countries to developing countries should currently be receiving so much attention. There is, first of all, a widespread perception that the rate of technological change is very rapid in industrialized countries. There is, moreover, substantial evidence that new and improved technologies are being transferred more rapidly than ever before from one industry to another within the major industrialized countries, and also that new technologies are being transferred between industrialized countries with greater speed than previously. In addition, it is widely believed that we are in the midst of an industrial revolution - a revolution that will transform the nature and the productivity of the economy as much as the steam engine, electrification, and the internal combustion engine did in earlier generations. The present, ongoing revolution is electronics-based, with computers and microprocessors becoming truly ubiquitous [See the long list of microprocessor applications by industrial sector in A.S. Bhalla et al. (eds): Blending of New and Traditional Technologies: Case Studies, Dublin, Tycooly International Publishing, 1984, pp. 5-9], but we are also in a much earlier stage of a biotechnological revolution that began with the discovery of DNA in the 1950s, with profound implications for areas such as medical care and food production. In addition, further technological revolutions may also be in the offing in such fields as new materials and photovoltaics.

Thus, the present situation is one of dramatic, ongoing technological changes in the industrial world, and a rapid diffusion there of the benefits of these technologies. But it is precisely the failure of these technologies to exercise a major impact in the poorer countries of the world that has called attention to the possibilities for technology blending.

(p. 16) Thus a central conclusion of the technological dualism view is that the advanced technologies that have been developed by the industrialized countries include a bundle of economic characteristics that were generated in response to the economic conditions of industrialized economies. Precisely for this reason, they generally have little relevance or utility in labor-abundant, capital-scarce, low-income economies. In spite of drastic oversimplification, including the neglect of the immense variation in economic conditions among developing countries, the stylized picture captured by the technological dualism hypothesis contains considerable validity. The critical questions, of course, are "How much validity?" and "What constructive measures can be taken to deal with such a reality?"

II. Requirements for Successful Technology Blending (p. 16-17)

A critical but promising feature of this approach is that it attempts to identify the conditions that will permit poor countries to derive some of the benefits from the newly emerging technologies without having first to undergo certain fundamental economic and social transformations. It does not compile useless and discouragingly long lists of unlikely "preconditions" for successful development. Instead, it poses the question: assuming that traditional societies will remain essentially wedded to [p. 17:] their traditional technologies for the foreseeable future, are there nevertheless significant opportunities for making selective use of more sophisticated, science-based technologies? Thus, the central thrust of the blending approach is to determine how newly emerging, R-&-D-intensive technologies can raise the performance of traditional technologies without seriously disrupting them. An approach that indicates directions of progress that does not require, as a precondition for success, numerous other complementary changes, is one that is inherently more likely to succeed.

(p. 26) To conclude, developing countries can derive some economic benefits from new technologies available from the advanced countries. In world of internationally traded goods there are a number of other avenues for deriving benefits from new technologies. On the one hand, it is possible for developing countries to identify components of sophisticated high technology products and to produce these components for assembly abroad. Alternatively, there are many advanced products that possess labor-intensive assembly stages (such as electronic components) in which developing countries could easily specialize. Such possibilities are particularly numerous for product lines in which transport costs are not very significant, or where a developing country is advantageously located close to an advanced economy (as in the case of Mexico). Finally, if one approaches the problem in terms of product life cycles, it is obvious that many technologically sophisticated products offer an expanding set of opportunities to developing countries as they approach maturity.

2 SOME CONCEPTUAL AND POLICY ISSUES (p. 28-29)
A.S. Bhalla, D. James

[p. 29:] For a number of years now, work on the development and promotion of intermediate technology has been aimed at improvement of traditional technology. The development of superior building blocks and panels from pressed bagasse and slaked lime in Latin America [W.P. Strassmann: "The Development of Alternative Construction Technologies in Latin America," in J.H. Street and D. James (eds.): Technological Progress in Latin America: The Prospects for Overcoming Dependency, Boulder, Colorado, Westview Press, 1979, pp. 247-257.], an improved design for a small-scale reciprocal coal feeder in India [M. Carr: Developing Small-Scale Industries in India: An Integrated Approach, London, Intermediate Technology Publications, 1981.], and the application of a spiral-shaped radiation concentrator for more efficient solar cookers used in Africa are illustrative. In his early formulation of the concept of intermediate technology, Schumacher [E.F. Schumacher: Small is Beautiful: A Study of Economics as if People Mattered, London, Abacus, 1974.] put forward the propositions that new workplaces would be created with low investment costs, production methods would make modest demands on skills, and local production of the technologies would be possible.

(p. 30) The applications of new technologies to traditional activities will typically involve capital costs far exceeding those envisaged by proponents of intermediate or appropriate technology. While intermediate technology can be developed with local knowledge/technology/ materials, with few exceptions, blending must rely on the importation of new technologies from advanced countries in the foreseeable future. Furthermore, the application of new technologies to traditional activities, say in rural areas, is also likely to raise the dependence of the latter on urban industrial networks in the same way as did the Green Revolution. The high-yield variety (HYV) technology made the rural producers dependent on the urban industrial sector to purchase fertilizers, machinery, and fuel and "to sort out, decode and evaluate the scientific and economic messages that reach them from bureaucracies, banks and experimental stations." [A. Pearse: Seeds of Plenty, Seeds of Want - Social and Economic Implications of the Green Revolution, Oxford, Clarendon Press, 1980, p. 159.] This factor is also likely to distinguish technology blending from intermediate technology. The latter is generally based on local or national self-reliance, which may be eroded with the application of new technologies, particularly in the least developed countries which do not possess the capability to develop new technologies on their own.

However, there is one sense in which a parallel may exist between the concepts of intermediate technology and technology blending. In a continuum of technological change, blending represents an intermediate state between the conventional and the newly emerging technologies just as intermediate technology was conceived as a stage in between traditional and modern conventional innovations.

II. Some Policy Issues and Options (p. 33-34)

It is generally argued that the new technology applications will exercise tremendous influence on the developing countries. Latecomer developing countries can take advantage of new technologies to leapfrog without necessarily having to go through all stages experienced by the present advanced countries. For example, developing countries could move away from manual methods directly to flexible manufacturing system without first having to introduce fixed automation. Several reasons in support of this argument are presented. [L. Soete: "International Diffusion of Technology, Industrial Development and Technological Leapfrogging," in World Development, March 1985.] First, competition in the international technology market for microelectronics is so keen that prices are falling rapidly. This is likely to make access of developing countries to the technology much easier. Second, in view of the rapidly changing character of the technology, it is difficult to appropriate its benefits through patents - this factor should in principle make possible its easier diffusion. Third, one of the unique characteristics of the electronics technology is that it is both capital saving [p. 34:] and labor saving. To the extent that it is capital saving it should be attractive for developing countries suffering from a chronic capital shortage. Fourth, the technology is mainly science-based and requires less learning-by-doing and experience (which are scarce inputs in many developing countries) and more scientific and technical education (which many developing countries, especially NICs, possess). Thus its diffusion may not be unnecessarily hindered in the Third World.

The above argument in support of leapfrogging is based on a number of assumptions which may not be valid for many developing countries, particularly those at low levels of industrialization. First, it presupposes the existence of organizational capacity for producing new products through the use of high technology. Second, it assumes that in developing countries existing technological capability is already at a level at which "high" technology can be assimilated and efficiently utilized.

In most developing countries, except a few NICs, the above preconditions are unlikely to prevail. It is for this reason that in these countries the diffusion of "high" technology is at present very limited. Although the cost of many "high" technologies is going down, it is still quite high relative to the national per capita incomes and foreign exchange availability in most developing countries. As long as the infrastructure and software requirements in these countries are not met, the "high" technology hardware will remain too sophisticated to be used efficiently and at full capacity. This is shown in Chapter 9, which focuses on the use of computers in education. Although in principle new technologies can (1) raise efficiency of the traditional educational system and (2) permit training outside the school system (through self-learning), their potential cannot be easily exploited because of the lack of adequate software programs. Thus the capacity of non-NICs (mainly the least developed countries) to absorb "high" technology and leapfrog may remain limited in he foreseeable future.

(p. 35) The experience of the Green Revolution also suggests that the demand for newly emerging technologies may have to be consciously stimulated by policy interventions. That is precisely what was done by way of introducing technology in the agricultural sectors of developing countries. Government financial support, dissemination of information, and various training efforts go a long way in explaining the remarkable rapidity with which the new technology spread in many regions. The experience of the Green Revolution therefore highlights the importance of the government's role, direct as well as indirect, in ensuring the application of new technologies in different environments and among poor producers who by themselves cannot afford to own or utilize the technology to raise their productivity and living standards. A conscious effort was made by policy makers and administrators to plan and provide for the integration of different components of the new technology into a single comprehensive package. The implementation of this package resulted in important changes in traditional methods of growing rice and other foodgrains as well as in irrigation, planting, and weeding practices. When introducing new technologies into nonagricultural traditional production, similar changes are likely to occur (see Chapter 20).

16 SATELLITE REMOTE SENSING IN DEVELOPING COUNTRIES; THE EXPERIENCE OF WEST AFRICA (p. 223)
N. Jasentuliyana, R. Chipman

Remote-sensing satellites have been used for surveying natural resources on a large scale since 1972, and the technology can now be considered operational, although it will certainly continue to evolve. Applications of satellite data, however, have been slow to develop to an operational stage, especially in developing countries, despite the apparent potential for promoting resource development and management.

Satellite remote sensing offers a basically new capability in the economic systems of most developing countries which have previously not attempted to monitor or manage natural resources on a national scale. Therefore, it does not replace traditional technologies and cannot slip into an existing niche in the economic structure. In this case the problem of blending new and traditional technologies becomes the problem of establishing connections between advanced technology and traditional agricultural practices, taking agriculture in the wide sense to include forestry and water resources, as well as crops and soil. Remote sensing also has applications to mineral development, urban planning, oceanography, and other fields, but these will not be considered here. [For a general description and analysis of remote sensing in the Third World, see C.O. Justice, J.G.R. Townshend, B.N. Holben, and C.J. Tucker: "Analysis of the Phenology of Global Vegetation Using Meteorological Satellite Data," in International Journal of Remote Sensing, vol. 6, no. 8, 1985, pp. 1271-1318.]

V. Conclusions (p. 238-239)

The management of agricultural resources in many developing countries, using the term management in its broadest sense, is primarily carried out by millions of rural farmers living in small villages, mostly without electricity, paved roads, telephones, or other means of access to modern development tools. Most of the decisions that affect agriculture, forestry, or water resources are made by these people. Only if remote sensing results have a meaningful influence on the multitude of decisions made in the traditional sectors can one say that a technology blend has taken place.

The social and economic implications of remote sensing are largely indirect. It is only as part of an extensive system of resource management and development that it will affect significant numbers of people. As an integral part of national planning of natural resources including agriculture, forestry, water resources, and fisheries, however, the effect may be extremely important. Since most West African countries have limited mineral resources and limited industry, the economies of the countries and the incomes of the great majority of the populations depend on agricultural production, both commercial and subsistence. Development, at least for the near future, will depend on increasing agricultural production, which can be promoted by agricultural extension services based on a knowledge of soil types, land use patterns, and other features which can be mapped and monitored by remote sensing. The rural standard of living also depends strongly on availability of firewood and access to clear water, the development of which will depend on governmental programs of reforestation, afforestation, well digging, and environmental protection, which can also be assisted through remote sensing.

Rural extension services and economic incentives are therefore the necessary links between modern remote-sensing technology and the traditional systems of resource management. Clearly, the relationship between modern technology, traditional technologies, and extension services is a very complex one. While the notion of development implies modification of traditional practices, forced changes can be counter-productive as well as [p. 239:] morally offensive. Major efforts must therefore go into ensuring that the modern technologies, generally imported, and the extension services, generally provided by educated urbanites, are adapted to the needs of the producers, generally rural people. Developing such a system is a long, slow, and often painful process with a certain amount of inevitable misunderstanding and conflict between the technical staff, the extension agents, and the rural people.

The problems of integrating modern economic planning with traditional rural practices are, of course, not unique to remote-sensing programs and are widely considered to be the central problems of promoting development, especially in the least developed countries. Since remote sensing is only one input, and a very modest one at the moment, it will not be a determining factor in attempts to solve these problems.

However, of relevance here is the perennial argument between the proponents of centrally planned development with active government involvement in large-scale projects, such as large dams for power and irrigation, and the proponents of government incentives to promote individual and local initiative, in particular higher prices for agricultural products. While satellite remote sensing can be used in both approaches to development, the technology will be a centralized government operation for the foreseeable future and will tend to have a more important role in large, centrally planned projects. The major dam projects underway on the Senegal river and its tributaries will require repetitive surveys of large areas to plan the use of the resulting irrigable areas and to monitor the resulting environmental changes. Since the economic justification for remote sensing in development to date has generally been problematic, it might be best to concentrate remote-sensing efforts and technical assistance from international agencies on such large projects where central planning is a major part of the scheme. Where a grass-roots development policy is adopted, remote-sensing programs may well not be cost effective, at least at the present stage of development of the technology and applications.

20 CONCLUSIONS AND LESSONS (p. 287)
A.S. Bhalla, D. James

In Section I, we describe specific social and economic: cost effectiveness, levels of employment, and distributional impacts (and some conceptual and methodological gaps in analyses) that should be considered for assessing the impact of new technology applications. There follows in Section II an attempt to identify policy needs in terms of skills and training requirements. Priority areas and the government role in focusing on new technology applications in traditional sectors are discussed in Section III. Finally, Section IV briefly describes the potential of technology blending in the future.

II. Educational and Training Implications (p. 297-298)

The successful utilization of new technology implies the need for complementary changes in human knowledge, abilities, and capabilities. Taking an extreme case, once a technician sets up the system, laser-guided land levelling requires such simple skills that anyone who can drive a tractor can accomplish the task. Yet, even here there is a need for widespread knowledge of the existence of the technology, how to obtain it, and what net benefits can be expected from using it. At the other extreme, there are new technology applications, typified by remote-sensing techniques (both for producing images and using them properly) and RISDA-like regional agricultural planning (both for planners and using farmers), for which more extensive and formalized training efforts are essential. At the present stage of our knowledge, it is not very clear whether training for technology blends [p. 298:] should be different from that for cases of straightforward applications of new technologies in advanced sectors.

Government Role (p. 301-302)

As we noted in Chapters 2 and 3, governments have a general responsibility for providing an environment that is favorable to the promotion of technology blending. In more specific terms, governments can stimulate it in at least four ways. First, a state agency may either acquire the new technology and make it available to users on a shared basis or encourage other institutional arrangements for sharing (e.g., cooperatives and subcontracting). Second, governments can also play a key role in promoting suitable educational and training strategies, policies, and programs. As noted in the earlier section, the use of new technologies calls for flexible types of education and training policies that facilitate quick anticipation of new types of education/training/requirements. Third, technology blending has been conceived as part of an experimental program, which implies the need for research, development, and trials. Governments can promote relatively inexpensive trials of the application of newly emerging technologies in cases where the scientific and technological problems have already been solved. This may be done in several ways - e.g., through assistance in undertaking feasibility studies, partial financing of costs of experimental trials, or direct subsidies to firms taking new initiatives. Fourth, governments will need to provide appropriate communications infrastructure to facilitate decentralized production through the use of new technologies.

Apart from reorientation of existing production structures, it may also be essential for the governments to provide for development and adaptation of new technologies. This could be achieved through national research and development policies and programs that would in some cases imply essentially a modification of imported technologies rather than their local [p. 302:] manufacture, which might be too costly and unfeasible for limited markets and productive capacity. One difficulty is that most new technologies, with few exceptions, are almost exclusively developed in the advanced countries, which prevents the developing countries from capturing learning effects that could be obtained if some research were undertaken within the latter countries.

(p. 303) Finally, as suggested by the case study of PV street lighting in India (Chapter 13), a major challenge for policy concerning implementation of such systems is the way government agencies can mobilize action to solve organizational problems in distribution of electricity and benefits. This is not a feature of PV systems alone but, rather, of community projects in general. One approach often argued, for the cultural and socio-political conditions of India's rural areas, is that such problems should be solved through mobilization of local participation. Another approach may argue, however, that this view of local participation often ignores the fact that villages have an imperfect distribution of power among castes and income groups so that benefits tend to be tilted to the more powerful groups where local participation is high in designing and implementing village projects.

BUTTEL, F., KENNEY, M., and KLOPPENBURG, J., From the Green Revolution to Biorevolution: Some Observations on the Changing Technological Bases of Economic Transformation in the Third World, in Economic Development and Cultural Change, Vol. 34, No. 1, 1985.

This excellent article summarizes the new technologies involved in what it calls the new "biorevolution" and attempts to conceptualize the influences this will have on developing countries. The effects of new technologies such as genetic engineering (where for example, plants or animals can be given useful characteristics of other plants or animals or micro-organisms can be programmed to manufacture desirable quantities of chemical substances), plant cell fusion (hybrid formation), tissue culturing (regenerating plants from cells) etc. can be felt through "chemical and pharmaceutical production, pollution and waste management, energy generation, food processing and animal and plant breeding".

The pursuit of these new technologies has especially been taken up by multinational corporations (MNCs) despite the efforts of some larger developing countries (India and the Philippines) and proposals for intergovernmental research by UNIDO. Their control, including increasing use of patents, and the ability of developing country government bodies to get access to new information will be a major issue. So too will the social consequences (as in the "Green Revolution") of the dissemination of these technologies and the ability of governments to manipulate this. (DH - 83)

COMMONWEALTH SECRETARIAT, **Technological Change: Enhancing the Benefits, 2 volumes, Report by Commonwealth Working Group, London, 1985.**

These volumes concentrate on the main socio-economic and policy issues thrown up by the rapid diffusion of new technologies (microelectronics, biotechnology, new materials technologies, renewable energy technologies etc), in recent years. The second volume concentrates on detailed empirical analysis of each of the new technology sectors noted above. Thus, for example, in the area of biotechnology, a divide between new (e.g. gene cloning) and traditional (e.g. fermentation organisms in beer-making) technologies exists, and that recent innovations are tending to widen the technological gap. Many of the new technologies are seen as highly inappropriate (capital intensive and requiring advanced forms of production organization) but appropriate research bodies, both international and national, could adopt many of the new innovations - as has already happened in some cases - e.g. International Maize and Wheat Improvement Centre in Mexico. Furthermore, the strength of multinational corporations (MNCs), due to the enormous research budgets, will have to be tackled directly - perhaps by agencies of the UN.

The first volume concentrates on the policy issues arising from this array of advanced technological developments. Suggestions regarding research and development, labour relations, control of technology, imports, etc. are propounded. The emphasis is on the necessity to be aware of the trade and production location effects of the new technologies and the need for active policy responses to avoid the worst aspects of the widening technological gap. (DH - 84)

HOFFMAN, K., Managing Technological Change: The Impact and Policy Implications of Microelectronics, Report submitted to the Commonwealth Secretariat Working Group on the Management of Technological Change, London, 1984.

This is a highly recommended, comprehensive review of the issues and trends in new microelectronic-based innovations (MRIs), their diffusion, their social impacts and existing and potential policy responses. MRIs create new products (computer-based machines, electronic goods etc.), alter the nature, especially the quality, of existing products and change numerous production processes. The debate as to the balance of social effects is far from decided. On the one hand the optimists see increased leisure time, reduction of dangerous jobs, new jobs, increased productivity and wealth, better quality goods, etc. while on the other hand the pessimists stress labour displacement, labour unrest, relocation of investments, the falling behind, and thus loss of markets, of countries less able to compete (a widening technological gap), etc.

Hoffman goes into great detail to describe the major trends of diffusion of these new technologies in electronics, industry and services and draws on numerous empirical case studies. However, the literature is notably undecided as to the balance of effects in the Third World. He stresses that the electronics sector is and will be the main carrier of MRIs and will adopt a role similar to that attributed to the capital goods sector (i.e. the driving force of technical change). He stresses in particular the need for developing countries to develop their software capacity to adapt imported technologies to local needs. He notes the uneven diffusion of a vast array of MRIs (take cars versus clothing for example), especially in developed countries and relates these to labour implications (displacement, job creation in electronics and services, the nature of the labour process etc.) market implications for developing countries etc.

Chapter 4 reviews the present state of policy towards MRIs, and finds a huge gap between developed countries, newly industrialized countries and poorer developing countries. (DH - 85)

JUNNE, G., New Technologies and Third World Development, in Vierteljahresberichte, No. 103, March 1986.

In this introduction to a highly recommended special edition of this journal on new technologies and Third World development, the editor describes the two main "new technology" areas and proposes a conceptual framework to assess the potential effects of these on developing countries. Thus, microelectronics, which includes mostly computers and telecommunications equipment (sometimes merged and called information technology) affects mostly advanced industrial and services production. Biotechnology (techniques which use living organisms in production processes - e.g. breeding plants with certain characteristics (drought or pest resistance, yields, homogeneity of outputs, nitrogen fixing); animal reproduction (artificial insemination, twinning etc.); biomass development (e.g. energy from sugar); pharmaceuticals; flavouring, etc.) is as yet not so well analyzed but many observers expect it to have at least as many influences in the Third World as the "green revolution".

Junne divides the areas of potential impact into four: 1. the impact of new technology application in developed countries on devel-oping countries - e.g. relocation of production in developed countries - although there is little empirical evidence yet. In fact some newly industrialized countries are receiving increased foreign investment due to their ability to apply new technologies; 2. the degree to which developing countries are able to apply new technologies themselves in order to overcome the threat to their comparative advantage based on cheap labour. It appears that the ability of even the most advanced newly industrialized countries to do so, is questionable, but there is no question of the increasing technological gap of the poorer developing countries. Nonetheless, there are numerous cases where new tech-nologies are also appropriate technologies and can be implemented. Some of its benefits could include energy efficiency, less skilled operatives, less maintenance, smaller scales and higher quality; 3. the degree to which developing countries can participate in the development of new technologies in order to avoid increasing technological depen-dence. Only very few large newly industrialized countries can get involved in the risky business of developing their own "hightech" capacity so most developing countries depend on relations with multinational corporations. New deals and mechanisms of control will be necessary to make the best of this; 4. the impact of new technologies applied within developing countries on developing countries. New technologies rarely directly displace labour in developing countries as they are mostly new investments while on the other hand the employment creation effects of new technologies (i.e. the production of the new technologies) are rarely felt in developing countries (most equipment is imported). Similar arguments attach to the issue of "deskilling". Higher wages could be expected in any event. (DH - 88)

9. ORGANISING FOR UTILIZATION AND DISSEMINATION: MAKING IT HAPPEN!

This section attempts to bring together a broad range of experiences and cases on how to make utilization happen. Because the word "utilization" is not a searchable word in most of the databases used in this project, other terms had to be substituted, such as technology transfer, commercialization, and diffusion. To some extent, some of the literature presented here overlaps with that presented in the section on "RESEARCH AND UTILIZATION AS A MANAGEMENT PROCESS". Yet because of its emphasis on practicality, it was thought to deserve a separate and concluding section. To styart with, here are some substantive excerpts from a classic, which recounts a the proceedings of a conference on Technology Transfer in the seventies:

Frank Bradbury, Paul Jervis, Ron Johnston, Alan Pearson Technical Processes in Technical Change, Sijthoof & Noordhoff 1978, The Netherlands.

(p 4) Common definition of technology transfer: "the process by which a technology is applied to a purpose other than the one for which it was originally intended," or in other words, "technology transfer is putting technology in a different context". This view reflects the origins of the term "technology transfer" in the United States where since 1940 the federal government has been responsible for the direction of a steadily increasing share of National R&D resources, primarily for achieving military, space, and atomic energy goals.

... Quotation from Harvey Brooks (in "National Science Policy and Technology Transfer" in Proceedings of a Conference on Technology Transfer and Innovation NSF 67-5, Washington D.C. 1966)

> "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 technology transfer. This can be either transfer from more basic scientific knowledge into technology, or an adaptation of an existing technology to a 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 operations of some kind.

(P.22) Models of innovation have customarily been represented graphically by boxes interconnected by arrows. This is, of course, partly a device used because it is convenient for the draughtsman. However, this representation is itself a model, commonly used in such diverse fields as cybernetics, communication theory and organisational design, which has its origins in electrical circuit diagrams. Adoption of this model entails the assumption that phenomena can be divided up into events or processes which can be conveniently be considered as relatively self-contained activities (the boxes), receiving inputs or stimuli, operating on them, and providing outputs directed towards other boxes. The inputs and outputs are the arrows.

Boxes can be a number of types. They may denote events, such as "need or opportunity recognition" or "idea formulation", and they may refer to activities like "research" or "development".

The compartmentalization into boxes provides a convenient way to describe the system which is being investigated, the boxes representing a division of the system into what appears to be its component parts....

But the division into boxes causes problems, in two ways. Firstly, the activity based division into boxes may not reflect the organizational skill-based compartmentalization which occurs in real life. Thus in the process of technological innovation the activity called "research" may, and in fact usually does, involve scientists and technologists in universities, others in research organizations established and maintained by industry, and yet more in the production and engineering departments. Secondly the box arrangement assumes that the output from one box is in a form suitable for the input to the next -- but this does not always happen. A parallel in domestic electronics is that one cannot use any loudspeaker with any amplifier -- it is necessary to match the impedance of the speaker with the output impedance of the amplifier.

In the past most attention has been focused on the boxes in the box-and-arrow models, with the assumption that if the components within a box operate properly the output will automatically be accepted by the next box. People have concentrated on the box and ignored the arrows, whereas our focus on transfer <u>processes</u> throws stress on the importance of the arrows though we do not suggest that boxes are unimportant. Our attention on the arrows, however, leads us to ask questions such as "what are they?" -- in other words what medium carries the output from one box to another; is the analogue of the wire between speaker and ear more appropriate or "ether" between speaker and ear more appropriate? What are the obstacles which may prevent the arrows reaching their targets -- are there barriers of one sort or another in the way?

(p. 25) Where does diffusion fit within our concept of transfer processes in technical change, and how do models of diffusion relate to descriptions of transfer processes?

We suggest that diffusion must be seen as a special case of the broad category of transfer processes in technical change. The models of Rogers (Diffusion of Innovation), Mansfield ("Technical Change and the Rate of Imitation" in N.Rosenberg The Economics of Technological Change, Penguin, Harmondsworth, 1971), and others have the common feature of describing the spreading of the usage of a technology within a population of users, usually within a group characterized by some common element of productive activity such as farming or mining. The lateral shift of technology transfer implies a shift of technology from one population or group of users to another, say, from farming to mining.

(p. 27)... we see diffusion as one of the numerous transfer processes within technical change, but we distinguish it from lateral shift transfer which is another special category of transfer processes in which there is a contextual shift of technology from one user to another.

...technology developed and applied in one context cannot be applied in another without some adaptation or modification. To apply technology in a new context demands the reworking of at least some of the later stages of the innovation process.

(p. 28)... [Jervis in particular built on this concept by suggesting that] early attempts by Government laboratories at this horizontal transfer had relied on a two stage process, a transfer from the laboratory to a manufacturer or supplier who would then be responsible for all dealings with the eventual user. This approach had proved to be unsatisfactory and a three-cornered relationship with the originating laboratory, end user and manufacturer had been found necessary. In terms of our discussion of context the reason that this triangular is needed is easy to see. Transfer to the user requires the adaptation of the technology, but that adaptation can only be done if the context of the technology is understood. It is much easier for the creators of a technology to adapt it to a new use than it is for the intermediary. And when the intermediary, the supplier or manufacturer , is selected both ability to handle the technology and possession of suitable links with potential users (in marketing terms things such as sales force, distribution channels, after-sales service capability, and credibility with potential customers) are important criteria.

(p. 29-30)... [Bell and Hill comment that] ...most models of innovation and technology transfer are inappropriate to the developing country situation, and that one of the primary reasons for this is that they ignore the need for a continuous interchange with a diversely located "technological stock", a body of knowledge and know-how. ...all innovation and transfer processes need to draw on this stock of knowledge but in industrialised countries its existence can be, and in practise is, automatically assumed....In the context of less developed countries, this stock of knowledge does not exist. It is not merely that the receiving countries do not have the necessary scientific and technological infra-structure but that, if the technology being transferred has been chosen with due regard to all aspects of user needs and constraints, the necessary infra-structure may not exist even in the industrialized countries. This is because the technology appropriate to the developing country may have passed out of use in the industrialized countries so long ago that, to all intents and purposes it is no longer available. (LDCs need technology "which is not at the leading edge but some way behind the trailing edge of practice in industrialised countries. If it is no longer in use it is difficult to identify and retrieve information about it."

(p. 31) Time and time again, in different ways, participants stressed that the fundamental concern in transfer processes was the understanding of the environment, attitudes, needs and skill of the receiver....At every step in the transfer process there must be dialogue between those who would transfer and those who would adopt; dialogue between concerning design detail, specification detail, user need detail -- contextual mapping to use the jargon of the morphological analysts....It is only by the iterative process of information exchange culminating in direct verbal discussion with repeated readjustments of understanding and rephrasing of questions that a sufficient knowledge of context and specifications can be achieved.

(p. 60) [Johnson has shown how].. the barriers around knowledge areas are necessary for their rapid development, but [that] transfer of information across these barriers is consequently hindered. Effective transmission will occur through personal contact where, once again, the transferor with his contexed knowledge and the receiver can effect the exchanges necessary to translate the information or process transferred into the receiver's work conditions.

...we must recognise that individuals can fulfil both informal and informal roles. By formal agents we mean people such as liaison or transfer officers whose major function is to promote transfer and who operate at the interface between their own organization or department or that of a contractor, and the potential receiver organization. This category would also include the research scientist who after developing a product has his responsibility extended to transferring it out of the laboratory and possibly further, out of the innovating organization. A much wider range of actors can be grouped under the heading of informal agents. They include the university inventor or scientists in a government laboratory who feels motivated to ensure that industry takes up his ideas, and devotes time and energy to championing his product although this does not form part of his official duties.Schon (2) has commented that such "product champions" also occur in industry, and can have a powerful effect in lowering or removing barriers to innovations. Other examples of informal agents include sales service personnel who may act as transfer agents in serving small customer companies; or staff who move from one department to another or one organization to another. When discussing transfer processes in technical change we recognise that there are two classes – those that will happen, in any case (unplanned) and others which people actively seek to promote (planned)....many organizations are trying to embody lessons from unplanned transfers in their planning, and one aspect of this involves formalising the roles of agents.

The employment of formal liaison or transfer agents is considered to have been started with the U.S.Agricultural Extension Service, which is a late 19th century conception. The role of this Service in the promotion and diffusion of agricultural innovations has been widely studied (see Rogers). The use of formal agents has usually bee patterned directly on the model successfully established in the agricultural field, with the agent developing close and regular contacts with a limited number of potential customers and having a strong back-up providing information about new developments and technical support. The allocation of potential customers to agents was done on a geographical basis, each agent having a "parish" within which to work. Just as the extension service located its agents in agricultural colleges, so geographical allocation of resources located at teaching or research organisations has been adopted in many later transfer programmes.

(p.65) We conclude therefore, that formal agents can be used as a mechanism to encourage and facilitate transfer processes, but that the success they will have will depend on their ability to act as an interface between sources of technical assistance and possible customers. A liaison agent can act as a catalyst for information flow, but wrongly chosen, or operating in an inappropriate way, he may become a barrier to the dialogue which is needed in the contextual mapping of technology on to use-system is to be achieved. The choice of mechanism for communicating between the source of the technology and the potential user is one of the main decision points for those involved in managing transfer programmes...there is no one "right" answer.

(p. 97) The conclusions we have drawn can be summarized in seven statements:

1. both technology and the processes by which it can be transferred are functions of their environments or contexts;
2. there is no single best way to transfer technology. A multiplicity of transfer processes is available, only a few of which will be appropriate for a given situation;

3. a major determinant of success in transfer will be the degree to which the technology establishes a contextual fit in its new environment. Many factors will influence this goodness of fit;
4. if transfer is to be encouraged then care must be taken to ensure that both the technology and the mechanism to be employed for transfer are appropriate within the contexts of provider and receiver. In addition sufficient modification of the technology to fit the receiver's context must be ensured;
5. existing methodologies for studying transfer processes are inadequate and definitional problems inhibit the development of a relevant body of knowledge. New methodologies are needed, designed for the task in hand and departing as necessary from those appropriate to physical sciences;
6. the study of technical change should now progress by the examination of these transfer processes, rather than by the investigation of those parts of the activity which can conveniently be compartmentalised within institutional or disciplinary boundaries;
7. in studying transfer processes more stress must be placed than hitherto on concepts such as ownership and motivation. A greater focus on behavioral aspects of the process is needed.

(from paper by F. R. Bradbury, Technology Transfer) p. 107

Quote from New Scientist 1973, 5 July, p.26:

> Definitions of technology transfer:
>
> - the multi-lateral flow of information and techniques across the boundaries of science, technology, and the practical world;
>
> - transferring research results to operators;
>
> - 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 programmes;
>
> - getting knowledge out of the academic area and into the hands of those who apply it.

These definitions describe innovation if they describe anything... preferred definitions would include:

- the process by which a technology is applied to a purpose other than the one for which it was originally intended; and

- technology transfer is putting technology into a different context.

p.108...technology transfer is more than innovation and diffusion of innovation in that it implies a transverse shift, from the original trajectory of the innovation to another, aimed at another target.

p 110....SAPPHO ... has put before us a limited number of maxims for success in innovation. The five principal rules:
1. study user needs;
2. pay attention to promotion and marketing;
3. do thorough development;
4. use relevant extramural information;
5. have sufficient authoritative leadership.
...In particular the importance of studying user needs is something which bears much weight in the technology transfer analysis.

p 130 R.D. Johnston in "Theories of Technology Transfer, or Models, Images, and Myths revisited"
quoting Tom Burns to a 1966 MIT Conference on the Human Factors in the Transfer of Technology (T.Burns "Models, Images, and Myths" in W.Gruber and D.G. Marquis (eds) Factors in the Transfer of Technology The MIT Press, Cambridge, Mass. 1969, p11).

Burns' article can be considered to be have marked a watershed in studies of technology transfer. His conclusion that "the mechanism of technology transfer is one of agents, not agencies; of the movement of people among establishments, rather than the routing of information through communication systems," marked a considerable step in understanding of technology transfer processes.

p.139..Paul Jervis "Innovation and Technology Transfer -- a Note on the Findings of Project SAPPHO"

Project SAPPHO was a study of success and failures in industrial innovation, and the analytical results have been published widely (Success and Failure in Industrial Innovation, Centre for the Study of Industrial Innovation, London, 1972) During the project 71 case studies of innovation were carried out, 36 in the chemical industry and 35 in the instrument industry, and the data gathered was used to detect differences between commercially successful and unsuccessful innovations. Much more data was gathered than has been discussed in the published reports, and if the success/failure comparison is abandoned, and the material considered as a set of detailed case studies, a number of additional analyses can be carried out.

R.M.Bell and S.C.Hill "Research on Technology Transfer and Innovation"

Quoting Tom Burns (same source) in reference to the USA space programme to foster industrial application of government research:

> "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."

Project Hindsight...(K.Kreilkamp, "Hindsight and the real world of science policy", Science Studies 1, (1971) 43-66) based on a twenty year time scale and on a somewhat questionable methodology ... suggested that only 0.3% of research "events", which were relevant to a set of defense technology applications came from basic research funded by the Defence Department. Predictably, this demonstration of a possible chink in the armour of the conventional view was seen as threatening by both government and scientific establishments. The threat was quite explicit. Following the earliest publication of the Hindsight results, the Journal "Science" published an article and later an editorial, both of which questioned the utility of academic research. However relief was on hand to restore peace of mind to the faithful. It was no coincidence that at this time the US National Science Foundation commissioned "Project Traces", (S.Globe, G.W.Levy, and C.M.Schwartz, Science, technology, and Innovation Report prepared for the National Science Foundation, NSF-0667, Columbus, Ohio, Battelle, 1973), the terms of reference of which allowed a much greater chance of fundamental research being shown as relevant. This study essentially replicated Project Hindsight, but on a longer time scale (50 years) and using a methodology relying on a more circumspect selection of cases and armchair reminiscence. From Project Traces it was demonstrated, not unexpectedly, that 70% of inputs to innovation ultimately came from fundamental research. Science was now able to publish an article which stated "Basic research was of overwhelming importance in five recent technological innovations of wide value" .

(p.254) One striking feature of the industrialized societies is that the industrial production system operates very close to the universal frontier of advancing technology...

(The following is based on research in Thailand)

(p. 255)...In a society like Thailand many parts of the leading edge of economic advance rest on technology that is far behind the leading edge of current advance, and on techniques which have long since "stabilised" and ceased to change in significant ways. In many cases it is so far behind that it is close to, or behind the <u>trailing edge</u> of technology -- the historical phase boundary at which technology passes out of use in the industrialised societies.

(p. 262)...the production-oriented structures in the "typical DC firm" may be rich in "change" resources. Such resources may seldom be institutionalized in a way which sets change as their primary objective, but nonetheless they are in fact frequently involved in technical change.

The contrast in the LDCs is stark. The "typical LDC firm" is poverty stricken with respect to those resources. in the mass of firms in the small-scale sector (employing less than fifty workers) it is hard to find those resources...(also absent in larger firms)

Plant managers and production engineers often have very little of the deep technological experience which allows effective technical decision-making. Even when such experience does exist, one finds two types of constraints on its use for these types of change. First there is a very limited degree of division and specialization of labour. Often the manufacturing manager has management responsibility also for personnel and engineering (perhaps also for sales and finance). Beneath him in the organization one may drop straight to production foremen. Secondly, and partly in consequence of the limited specialization of function, the problems of day-to-day management seem to occupy a high proportion of available time of those who might be change-oriented. Attention to change, even if all other factors are favourable, just has to be put off.

Engineering and maintenance facilities again tend to be "thin" on experience, "light" in staff, and heavily involved in day-to-day demands. Quality control facilities, if they exist, very often add up to little more than on-line "checking" capabilities. Product design or product improvement departments or sections hardly ever exist. Where they do, for example, in some electronics firms, their concern is almost exclusively with the "art" aspects rather than the technical aspects of design (for example, in designing next year's cabinet for the unchanged, technical "guts" of the portable radio). Production supervisors and foremen often have very limited technical experience. They and the production operatives seem totally oriented to basic operation. Again and again questions we asked management about the objectives of training at these levels induce response about operation -- and in detail about basic operation -- of the plant. Any "atmosphere" of change, of "stretching" the system or even optimising seems to be absent -- or at best rather "thin".

In general then we suggest that in the LDCs this whole intra-firm "sub-culture" of technical change capabilities and attitudes hardly exists. We suggest that in DCs not only does it exist, but it plays key roles in the innovation process.

This reference is very rich indeed, and offers not only some useful definitions, but also goes into some of the more problematic issues of managing technology transfer iin the context of a particular third world coutry -- Thailand.

It is useful now to examine what some organizations have done to transfer technology from their own research organizations. The case of India's Council of Scientific and Industrial Research (CSIR) is examined first. This large complex of government-owned laboratories has adopted a fairly innovative way of financing from the government, based to a large extent on a new formula that would recognize the performance of various laboratories in commercializing technologies. The formula which has been recently adopted, could prove to be a powerful incentive to government researchers to become more commercial minded.

Bhojwani, H.R. 1989. Commercialisation of Research Results: Experience of Council of Scientific and Industrial Research. Paper presented at Workshop on Commercialisation and Evaluation of Research Results, Nigeria, 24-28 April 1989. 7 p.

(p. 1) CSIR has 40 research institutions which cover areas of science and technology such as Molecular Biology, Ocean Development, Geophysics etc. and industries such as Chemicals, Drugs, Food, Mining, Electronics Leather etc. Besides it has five Regional Research Laboratories covering both scientific and industrial on multidisciplinary and multi-product basis. Thus the research results of CSIR laboratories are of value to different sectors of the economy such as agriculture, health, public utility systems, rural development, defence besides industry per se.

... <u>New Approach</u> (p. 4)

The direct government financial support to CSIR till date was based on an informal appreciation of the needs of CSIR and a loose evaluation of its performance. However CSIR suggested to the government that the government support to it be based on its performance to commercialise research results and the productivity and efficiency of its R&D activities. Its performance in commercialising research results was to be measured in terms of external funds it could obtain from Contract Research, Consultancy, Technical Services and from Licensing of Technology; where as its R&D

productivity was to be measured in terms of 'net surplus' it could generate. Accordingly the government grant to CSIR would now be on the basis of an agreed formula with quantifiable parameters as indicated:

$$G_t = \underbrace{G_o(1+r)^t+Q}_{\text{CORE GRANT}} + \underbrace{{}^{k}F_{t-1}}_{\text{MATCHING GRANT}} + \underbrace{{}^{a}R_{t-1}}_{\text{INCENTIVE GRANT}}$$

CORE GRANT	:	MAINTAIN THE INFRASTRUCTURE
MATCHING GRANT	:	LINKED TO CUSTOMER CREDIBILITY
INCENTIVE GRANT	:	LINKED TO PRODUCTIVITY
Q	:	ADHOC LIABILITY
F	:	EXTERNAL CASH INFLOW
R	:	R&D RECEIPTS (NET)

(p. 5) Hitherto there was no pressure on CSIR to commercialise its research results or in more wider terms it entire knowledge base. But now not only would the government grant' be linked to external cash flow; but CSIR has further been directed to generate at least 33.3 percent of its R&D expenditure through external cash-flow by 1992-93.

Thus, the importance of enhancing the external cash-flow through commercialisation of the entire base of research results has assumed paramount importance.

Cash Inflow

As indicated CSIR's performance in commercialisation research results is to be evaluated in terms of the credibility it has established with its customers. This can be measured by the cashflow it can generate from sources other than he government grant. There are broadly four S&T based sources of cash-inflow viz. Contract Research, Consultancy, Technology Sale, Technical Services. Table 3 [Not included here] indicates the progress of these in time.

It is evident that cash-inflow due to technology sale is presently about one order of magnitude lower than that due to consultancy and two orders of magnitude lower than that due to contract research.

A similar experiment was also tried in New Zealand, as reported in the next article, which also includes some reflections on the longer-term consequence of performance funding, or more precisely in this case, user-pay funding.

Palmer, C.M. 1989. Commercialisation of R&D: The New Zealand Experience. Paper presented at Workshop on Commercialisation and Evaluation of Research and Development, Lagos, Nigeria, 24-28 April 1989. 6 p.

Government Policy (p. 1-3)

Government policies in recent years have been aimed at decreasing public expenditure and Government involvement in operations of all kinds. This sharper focus on control of government expenditure and on means for improving the efficiency with which the Government uses its resources, has seen the introduction of a variety of techniques, including a shift of attention from inputs towards outputs. The policies have not shown much selectivity and science and technology have been included. In early years the changes came through the use of control techniques such as across the board expenditure cuts, staff ceiling controls and the requirement that, unless Cabinet made an express exception, new policies could be funded only by an **[p. 2:]** equivalent reduction in expenditure on existing policies. However in recent years more imaginative measures have been emerging. Provision has been made for most government departments to operate under a revolving fund system under which certain of the Government's activities could be restructured on a commercial or quasi-commercial basis. Departments were encouraged to specify output objectives and carefully define their corporate plans so as to assist the process of Government looking for means by which different spending activities could be ranked one against the other.

Thus the decrease in public finance to science and technology has been part of a systematic withdrawal by Government of assistance and support to all sectors of the economy to create so-called neutral market conditions. This must be seen alongside the efforts, particularly by the present Government, to deregulate the economy through inter alia removing such regulatory mechanisms as import tariffs and quotas, stopping interventions such as agricultural subsidies, deregulating the finance market and floating the dollar, and the establishment of State Owned Enterprises (commercial companies which have taken over previously public funded activities such as electricity supply, coal resources, state forests, rail and shipping, etc.).

This process of evolution and more transparent accountability for the operation of government agencies has included the introduction of the "user pays" concept. [p. 3:] The user pays policy as it affects government-funded science agencies is such that the direct users of science are now being billed for investigations, advice and service which was previously provided in the main free of charge. An important incentive under the user pays regime has been for funds so earned to return to the departments rather than, as was the case in earlier years, being paid into a central Government consolidated fund. There has been little question that Government should continue to fund long term basic or strategic research, but the groundrules have not been made clear and the definitions of such things as "public good" or "appropriable" research remain unclear. This has made it very difficult for science managers to operate effectively under the new regime.

There have undoubtedly been major changes in the management attitudes and style of the traditionally government-funded science agencies. But many of the difficulties have been attitudinal rather than technical. Many scientists seeing or believing that funding for their particular specialty was at risk under new government policies, concluded that the Government no longer believed in the importance of science and technology. This has caused major morale problems within the science community and needs to be addressed. Another concept which is difficult for many with more ideological views on the social responsibilities of Governments, is that the policies introduced in New Zealand are a major swing away from Government as a provider of a service t that of purchasing the services it requires, often on a contractual basis, from those best able to provide those services. The organisation of the health and education systems is also following this principle.

Likewise those users and beneficiaries of what was previously a free service, not faced with being charged at commercial rates, equally have difficulties accepting the new regime.

It is important to recognise therefore, that any major changes towards a more commercial, client-oriented and contractual approach by Governments to science and technology (or any other activity), raises major philosophical and attitudinal issues which must be given careful attention. Clear definition of new or changing policies must be given and regrettably we have fallen short in this area. Low priority has been attached by the Government to developing and communicating a clear policy on science and technology under the new regime.

<u>Organisational and Structural Implications</u> (p. 3-4)

In the New Zealand context, the changes have raised questions as to whether the current organisation and structure of what has been predominantly a government-funded R&D process is the most appropriate to cope with the new regime. The mechanisms by which Government receives S&T policy advice under the new and changing regime; makes strategic decisions on where its S&T funds should be spent, and the kinds of agencies to which it should direct this investment, remain key questions. It is not simply a matter of making the [p. 4:] user pay. So-called commercialisation is a much more complex issue than this and involves taking a holistic view of the whole process of science and technology. It involves, for example, the relationship with the private and commercial sector, and also requires a re-assessment of the role of the higher education system in research, education and training. With operational R&D institutions in effect looking increasingly at a range of contracts to undertake their science, be it from Government or other clients, the question as to whether these same agencies should be involved in policy advice to Government, in view of possible conflicts of interest, is another critical issue. New mechanisms will be required to meet these changing demands, and management of technological change.

(p. 4) Operating R&D agencies have to "sell" their experiences and skills to Government in order to receive a contract for government-funded R&D. Long-term strategic research therefore under this scenario is as much a commercial deal, given that it implies a choice by Government as to who it is going to fund and under what regime. Government R&D agencies will in turn contract out their services for other government departments. In New Zealand for example, the forensic work for the Police and Transport Departments is contracted out to DSIR. Similarly, major contracts with the Health Department are arranged for things like chemical quality advice in foods, water and pharmaceuticals. The continuation of these contracts will depend very much on the continuing need of the client department and the performance of the agency providing the services. Outside of the government sector of course the next step is selling services to the commercial, industry and service sectors, be it a chemical analysis, a geological survey, or a social or environmental assessment. Public relations and marketing skills are becoming an important feature of the R&D scene.

We nefinally present a number of other examples , by no means exhaustive, of other mechanisms or initiatives taken to commercialize or utilize technology. The number of case studies and documented experiences is so large, that the whole area deserves to be a designated a research topic on its own. What would be required is a systematic search of all case studies, and a method for assessing them say against a particular framework, in order to derive some managerially-oriented genertalities.

SMILLIE, IAN, No Condition Permanent: Pump-Priming Ghana's Industrial Revolution, Intermediate Technology Publications, London, 1986.

This study of the development of the Technology Consultancy Centre (TCC) in Ghana provides a thoughtful analysis of successful and unsuccessful technology selection and development in a number of small industry areas. "The book is about the hard-won lessons that emerged from a long and sometimes painful search both for appropriate hardware and for a workable technique for applying it in the cause of human development." TCC projects recounted include nut and bolt manufacture, soap making, glue making, weaving, foundries, cotton spinning, and agricultural equipment manufacture. The book demonstrates clearly the dynamic nature of technology choice, and the importance of on-going learning to the success of small industry ventures. (DH - 124)

DE WILDE, T., Use of Technology: Rural Industrialisation, Sarvodaya Press, Sri Lanka, 1980.

This is a study of the problems of applying technology in rural Sri Lanka. The analysis is carried out at three levels. Firstly, it looks at the evolution of the organisation of technology in Sri Lanka over a very long historical period (480 BC to 1970s). Secondly, it carries out a macro-analysis of industrial production units established under the government Divisional Development Council Scheme (DDCS) in 1972-77. Thirdly, this is supplemented by a micro-analysis of nine strawboard factories set up under the DDCS. At this level the author focuses on three sets of variables: organizational (e.g. standardization); socio-psychological variables (management ideology, workers' maturation); and economic variables (e.g. raw material use, production costs).

The author argues that there has been a deterioration over time in the protection of village production units. With respect to the DDCS the author declares that it failed due to its concentration on production rather than an integrated system approach. In addition the political interference was found to be prevalent and harmful, and an alternative approach of basing industrial production units on community participation at the village level was advanced. (DH - 104)

CARR, M., Developing Small-Scale Industries in India: An Integrated Approach: The Experience of the Birla Institute of Technology's Small Industry Scheme, ITDG, London, 1981.

This book describes the nature and impact of a successful institute in developing and promoting small-scale industries. The Birla Institute of Technology started in 1960 to "develop an awareness of the needs of industry among technical students through work on projects of practical use to neighbouring industries". From this it attracted the interest of the state government and other institutions.

The report concentrates on three aspects of this case: replicability, integration and entrepreneurial development. It stresses the impact of [p. 60:] a small group of committed teachers in the implementation of a workable model of small industry promotion. Similarly it stresses the integration of several, usually disparate, features (e.g. testing facilities, favourable banking arrangements, entrepreneurial training) under the direction of a single working group. The author argues that the scheme "is concerned as much with the development of entrepreneur-ship as it is with that of small industries". The study includes seven short case studies as well as a comparison with the performance of other centres in India. (DH - 100)

The following excerpt is revealing in that it provides the essence of the results of a recent workshop of business and government officials to discuss commercialization of technology, and comparing the experience of several Asian countries.

APO (Asian Productivity Organization). 1986. Proceedings of the Symposium on the Commercialization of Indigenous Technology. Asian Productivity Organization, New Delhi, October 7-11, 1985. (Compiled and edited by volunteers in Technical Assistance.) 214 p.

(p. 2) The above presentations included several interesting cases, such as the commercialization experiences of the Korea Technology Advancement Corporation (K-TAC), the Research Development Corporation of Japan (JRDC), The Bank Pembangunan Malaysia Berhad, the Volunteers in Technical Assistance, USA (VITA), and the Bharat Heavy Electricals in India. Other studies related to the commercialization process of Shirasu Porous Glass (SPG) in Japan using volcanic ash, and exploitation of some developments in India in the field of energy and in rural areas. Analysis of the salient features of these presentations and ensuing discussions are given below.

Criteria for Project Selection and Review (p. 2-3)

National development is dependent on a wide spectrum and quantum of technologies. Particularly during the early stages of economic development, the major focus of developing countries has to be on how to import required technologies intelligently and aggressively. Indigenous efforts in the context [p. 3:] of limited technical and financial resources may have to concentrate largely on innovations. Absorption, assimilation, and adaptation of imported technologies would pave the way towards building up indigenous technological capabilities. More often than not, a number of R&D institutes in developing countries are required to do too many things such as testing, standardization, and research all at once, and thus fritter away their energy. This results in the need for priority setting.

In fact, most of the R&D institutes in developing countries initially aim toward academic excellence and then vaguely hope for the research results to be disseminated through some unknown form of osmosis, which hardly ever occurs. Commercialization cannot be a mere post R&D phenomenon but must be taken into account right from the stage of project selection and throughout different phases of R&D progress. As revealed by the experiences of JRDC and K-TAC, utmost care has to be exercised to select research projects of promise. Interestingly, Bharat Heavy Electricals (India), which manufactures a wide variety of power equipment and has one of the largest R&D facilities among the Indian industries, has recently opened a marketing and commercial division within the research wing itself.

(...)

In this context, the three major criteria that were considered in the Shirasu (volcanic ash) based product development in Japan in Miyazaki Prefecture may be of interest:

> the project must have a strong local flavor;
>
> it must have a favorable impact on local industries;
>
> it must aim for new material development applicable in advanced technology areas, such as biotechnology and medical science, which are of particular interest to the Miyazaki Prefecture in its development of Technopolis.

Management of R&D (p. 5)

Successful commercialization of results would very much depend on the R&D capabilities and the management of the R&D functions. Multi-disciplinary team approaches, flexibility, industrial experience of R&D personnel, linkage with industry, and linkage of education with practical research were some of the important factors brought forth during discussions. R&D at any stage is a risky business and strong leadership plays a key role to boost the morale and enthusiasm of researchers. (...)

(p. 6) As revealed by some of the experiences from the United States, problems in commercialization of R&D are not confined to the developing countries. The crucial issue in technology commercialization does not lie in the lack of scientific knowledge, but in the organization of that knowledge into a useful form, so that it can be adopted to local conditions and form a basis for technological development. The successful exploitation of the U.S. transfer of technology by the Japanese is a typical example. The U.S. firms face problems in effecting a smooth transfer from basic research to prototype to production model, an area in which the Japanese excel.

Several of the country papers cited a number of negative factors in R&D management that stand in the way of successful commercialization. These included: absence of demand-pull approach in project selection; search for technical excellence at the cost of commercial reality; mismatch of objectives and interests of R&D institutes and corporate objectives; technological gaps between R&D institutes and firms and time lags in transfer; lack or loss of creditability of R&D institutes with client industries and lack of sustained follow-up; transformation of overseas educated elite into desk managers of R&D; search for too quick results without sustained efforts; lack of an integrated approach; and the like.

Market and Dynamic Partner (p. 6-7)

Experiences reveal that successful commercialization depends upon market demand rather than on technology. This is amply demonstrated by the strategy of the Japanese Sony Corporation [p. 7:] in securing the license for transistors from Bell Laboratory and subsequently succeeding in capturing the international market for transistor radios. An analysis of the Korean experience also indicates that the most crucial factor for successful commercialization is demand-pull. Technology push without cognizance of market needs has largely met with failure.

(p. 8) Several country papers listed a number of measures taken by the government to promote successful exploitation. These included: stressing indigenous technology promotion as part of national planning strategy and programs; provision of social infrastructure like education and training; availability of risk capital and financial assistance on soft terms; promotion of transfer agents and design engineering as well as project engineering facilities; establishment of science parks to promote high-tech ventures; protection of genuine indigenous products from spurious imitations of low quality, and the like.

In short, successful commercialization will be influenced by the following factors: appropriate project identification and conduct of in-depth feasibility studies during the different phases of development; identification of dynamic business partners; solid financial resources; and continuous technology upgrading and effective government protection. In all these areas, government can play an effective catalytic or promotional role.

Syndicate Discussions (p. 8-11)

Towards the end of the Symposium, all the participants, resource persons, and observers divided themselves into two working groups to discuss aspects relating to "cooperation and linkage leading to successful commercialization of technology." The reports of the two groups were presented at the plenary session on the concluding day. Ensuing discussions led to the adoption of the following conclusions and recommendations.

Review and Selection of Topics

> Research topics can come from public research institutes, universities, and industries.
>
> There should be industrial participation from the very beginning of the review and selection process of research topics. The interested industry should finance a substantial part of the cost.
>
> Agencies utilizing outside consultants drawn from the universities and industrial experts can review and select the topics.
>
> [p. 9:] The candidate projects should be monitored on a continuous basis and reviewed periodically.
>
> R&D persons should have sufficient industrial experience so that they can cooperate freely with industrialists in a confident manner.

Bridging the Gap

The gap between the generators of technology and the prospective entrepreneur or existing enterprise could be bridged through the following means:

Making people aware of how a technology can improve the quality of life.

Informal contacts between generators and users of technology and among professionals.

Intermediaries, such as:

- consultants
- financial institutions
- promotional institutions
- non-governmental organizations
- universities
- consumer organizations
- trade associations
- chambers of commerce
- governmental organizations

Specialized news letters.

Governmental programs to generate confidence in domestic technology, which might include:

- demonstration projects
- technology fairs
- establishment of industrial standards applicable to both domestic and imported products
- follow-up of technologies domestically and after sales service by suppliers.

Marketing and Technology

Organizations responsible for R&D marketing must be functional and effective.

Marketing of technology can be effected through direct negotiation with appropriate industries by the government agency (e.g., JRDC). It can also be done through semi-government organization (e.g., K-TAC).

[p. 10:] The prefeasibility study is a fundamental prerequisite for marketing technology. This should provide information such as investments required, market potential and prospects, and profit generation potential.

The technology generator must play a role of assistance to the entrepreneur throughout the process of development and production to minimize the risk of the entrepreneur.

Role of Financing Agencies and Other Transfer Agents

There can be different types of financing and transfer agencies: government (e.g., JRDC), public R&D agencies (e.g., K-TAC), development banks (e.g., Malaysian Development Bank), and venture capital companies.

Their role is to facilitate the development and transfer of technology including new developments and the modification of existing ones.

Commercialization of technologies will be greatly facilitated by:

- Induction of development banks to give preferential treatment to loans for the exploitation of new technologies including low interest loans with long grace periods and long repayment schedules.

- Provision of revolving fund.

- Creation of capital investment guarantee agencies for R&D development by entrepreneurs without collateral.

- Extension of banking services to include technical and management assistance and other consultancies.

- Formation of venture capital resources.

Government Policies and Supporting Measures

Government should crate R&D institutes that can attract R&D personnel with industrial experience both from within the country and abroad.

Incentive measures and minimum protection should be given to industries that develop commercializable indigenous technologies for a limited period of time. The government should also provide incentives to industries that establish R&D facilities.

[p. 11:] The government should decentralize information dissemination networks throughout the country for easy access.

The government should establish a one-stop business service agency to facilitate investment activity.

As part of the above symposium, there was one presentation made by a representative from Technonet, a somewhat unique network for technology diffusion to small enterprises. It is reminiscent of the Canadian experience with CRIQ in Québec, and IRAP, at Ottawa's National Research Council.

COMMERCIALIZATION OF INDIGENOUS TECHNOLOGY: TECHNONET ASIA'S EXPERIENCE by Mr. Md. Shahabuddin Paruque (Industrial Development Officer, Technonet Asia, Singapore) (p. 197)

INTRODUCTION

(...) In brief, it is a cooperative grouping of 16 participating organizations that aims at upgrading the quality and efficiency of production in those countries' targeted enterprises. It does so by applying knowledge of known processes, methods, techniques, equipment modifications, and approaches to existing operations affected by the transfer of technical information, the provision of industrial extension services, the facilitation of technology sharing and its adaptation, and entrepreneurial development.

(p. 200-201) Technonet's approach to an effective transfer of technology either from local or foreign sources is very labor intensive. It can only be successfully implemented by people -- a cadre of well trained and creative technical information and industrial extension specialists, who are vital links between sources of technology and the entrepreneurs. They are in a better position for organizing and facilitating technological needs, obtaining solutions from appropriate sources and making the necessary adaptations. They also can make the technologies more comprehensible for the entrepreneur. To effect such a program is not an easy task. It will require the development of institutional capabilities and substantial investment in manpower development and other resources. Government has a key role to play in promoting the indigenous technology generation and adaptation that is consistent with their development goals. Depending on the development strategy in each country, various schemes are being implemented towards this end.

There are various ways that technology transfer is effected between a donor and receiver. For simplicity sake, we classify this mechanism into two areas according to structure. The first one is non-contractual: "technical information, [p. 201:] in-plant consultancy, special workshop training, study tour, research study, etc." The second is contractual: "joint venture, licensing, franchising, leasing, turn key project, etc." Technonet's activities are mainly concentrated in the non-contractual area of technology transfer and sharing, although we have a current limited scale program on a contractual technology transfer facilitation program for the Asian and Canadian SMI enterprises.

Let me expand on the activities that are performed by Technonet in accelerating technology transfer in the non-contractual area.

Technologies that are not generally complex in nature can also be transferred without any need for contracts. This is the case with conventional technology or basic technology transferred through published technical information, trade exhibits, etc. Institutionalized training is one of the main channels for technology transfer in the non-contractual area. The main aim of technology transfer in the non-contractual area is to develop and upgrade capabilities of human resources within the country to reach certain levels so that they can absorb/adapt technology and develop technologies in the future. There are many mechanisms to facilitate technology transfer in this area, such as technical training, seminars, demonstrations, exhibits, technical information services, extension services, consultancy services, and so on. However, these mechanisms can be grouped into three; namely, mass presentation, group presentation, and individual contacts and direct personal visits. For the mass presentation, the main mechanisms are providing technical information services, conducting conferences, holding exhibits, and using mass media (newspapers, television, radio, etc.) for disseminating scientific and technological knowledge. Group presentation covers training activities, demonstrations, seminars, group consultancy services, etc. Individual contacts and direct personal visits are the activities of extension services, inquiry-answer services, letters, advisory services, and so on.

Lastly, as a sobering thought, we present an analysis by Sagasti in which he essentially questions the North American Paradign that companies will innovate and adopt new technologies to become more competitive.

Francisco SAGASTI, MARKET STRUCTURE AND TECHNOLOGICAL BEHAVIOR IN DEVELOPING COUNTRIES, in Wad, A. (ed.). 1988. Science, Technology and Development. Westview Press, Inc., Boulder, CO, USA. 315 p.

<u>The Components of the Conceptual Model</u> (p. 150-151)

There are three sets of factors that ultimately influence technological behavior in a given industrial branch: (a) industrial organization and market structure; (b) type of technology and level of technological capabilities prevailing in the branch; and (c) characteristics of the leading firms in the branch. These three sets of factors have to be taken together. Regardless of which of them is taken as a starting point, in the end all three must be examined to provide an adequate understanding of the technological behavior of the branch.

The combined effect of these three sets of factors, together with the objectives of the firms, condition the behavior of individual firms of the branch. One of the key manifestations of this behavior is the form of competition prevailing in the branch and the set of competitive strategies adopted by the leading firms in it. Indeed, the competitive strategies mediate between the three sets of factors and other expressions of the behavior of firms in the branch, including technological behavior. In this context, it becomes necessary to examine the extent to which technological advantages play a clear and identifiable role in the patterns of competition observed in the branch and in the competitive strategies of the leading firms. The larger the role played by these technological advantages, the greater the pressures for innovation and for the development of technological capabilities.

(p. 150-151) The technological behavior of firms in the branch is manifested through the <u>choice of techniques</u> incorporated into the productive processes, which generally involves the introduction of major innovations, and also through the firms' <u>technology absorption efforts</u>, which encompass all [p. 151:] minor innovative activities. Outside the industrial branch, the technological behavior of firms generates a pattern of demand for technology, in which imports usually play the dominant role in relation to domestic supply. Within the branch, technical choices and technology absorption efforts determine the speed and direction of technical change, which in turn affect market structure and industrial organization, the type of technology and level of technological capabilities and the characteristics of leading firms. Each of these three main sets of factors - market structure, type of technology and characteristics of the leading firms - will be examined in turn, before focusing on competitive strategies and the role that technology plays in them.

(p. 151-153) For the purpose of the present essay the terms <u>market structure</u> and <u>industrial organization</u> encompass the characteristics that refer to the interactions, interrelations and relative market power of the firms concurring in a particular industrial branch. Following the approach proposed in the STPI methodological guidelines [**Footnote:** Francisco R. Sagasti and Alberto Arraoz, <u>Science and Technology for Development: Methodological Guidelines for the STPI Project</u>, Ottawa, International Development Research Center, 1976], an industrial branch is defined as the collection of firms engaged in the production of similar goods oriented towards a particular market, and includes also those productive and service units that provide inputs to these firms and are closely related to them.

According to the model proposed in this essay, the characteristics defining the market structure and industrial organization of a given branch are:

(i) Size of the market, (...)

(ii) [p. 152:] Degree of concentration, (...)

(iii) Vertical integration, (...)

(iv) Market segmentation, (...)

(v) [p. 153:] Barriers to entry, (...)

(vi) Nature and degree of government intervention, (...)

(p. 160) Nevertheless, however difficult the task may be, the design of policies to stimulate technological innovation in developing countries must be based on an understanding of the factors that condition the process of technical change in industry. For this reason, it is necessary to identify some interconnections between the three sets of factors that characterize the structure of an industrial branch and the diverse manifestations of technological innovation. One possible approach is to examine the ways in which forms of competition and competitive strategies mediate between the structural characteristics of the branch and its technological behavior.

(p. 161-162) The predominant forms of competition in a given branch will be conditioned by the structure of the market, the type of technology employed, and the characteristics of the leading firms; within this framework the competitive strategy of an individual firm will make use of different vehicles for competition.

In developing country markets, where oligopolistic structures and behavior prevail, there is a general tendency [p. 162:] to avoid price reductions and prefer other forms of competition in order to maintain and enlarge a firm's share of the market. This is because of the desire to keep profits above an acceptable level and increase them as far as possible, but without sacrificing risk aversion and the firm's preference for stability. In other words, NNPGs play a very important role in guiding firm behavior in developing country markets. Notice also that in oligopolistic market structures productivity gains and cost-reducing innovations usually do not result in lower prices for consumers, but rather in higher profit margins for the innovators. In some cases there may be limited forms of price competition, primarily through discounts and credit lines for wholesale distributors, but these are used rather infrequently and their impact is felt only at the level of commercial intermediaries, rather than at the consumer level.

Consequently, in the design of competitive strategies a tendency emerges to engage in other forms of competition - less threatening or destabilizing - before undertaking major price reduction, which is usually kept as a last resort. Furthermore, in developing country markets, where governments usually intervene to a larger extent than in those of developed countries, price controls and regulations often reinforce the trend to avoid price competition, as does the adoption of protectionist measures to shield local firms from the threat of imported products. In extreme cases, particularly when government controls appear to be excessive, firms will display "pseudo-competitive behavior," going through the motions of competition to appease government officials, but in fact acting in a concerted way.

The overall impact of the three factors examined in this section - market structure, type of technology and characteristics of leading forms - on the competitive strategies of developing country firms that pursue a combination of profit and NNPG objectives is likely to be in the direction of reducing competitive pressures, choosing forms of competition and strategies that do not disturb the "stability" of the branch, and limiting the extent to which price policies and technological innovation will be used as vehicles for competition.

<u>The Principle of the "Least Technological Efforts"</u> (p. 164-167)

The behavioral consequences of the conceptual model proposed in the preceding sections may be put forward in the form of a "General Principle" and four theses regarding the impact that market structures, types of technology, and characteristics of leading firms, as well as patterns of competition, have on technological behaviors of industrial branches in developing countries.

General Principle of the Least Technological Effort

The leading firms, and the branch as a whole, will avoid forms of competition that involve major technological innovations and will exhaust all other forms of competition first. There is a strong preference for patterns of competition that involve, directly or indirectly, the least technological effort.

First Thesis: Progression of Technological Activities

Firms will follow a progression from innovative activities that require lesser to those that require greater technological effort and risk. This takes the form of preferring the acquisition of well known rather than advanced techniques, of favoring incremental changes rather than replacing existing practices, and indicates a bias towards the performance of minor innovative activities. Only a departure from the "steady state" prevailing in the branch will force firms, and the leading ones in particular, to [p. 165:] proceed to higher levels of effort and risk in the performance of technological activities and the introduction of innovations.

Second Thesis: Socialization of Technological Risks

If and when it becomes inevitable to introduce major technological innovations, there will be a tendency to socialize risks by making all or most firms in the branch assume the same risks, by asking the government to bear a share of the risks (through subsidies, guaranteed purchases, preferential access to capital, etc.), or by influencing consumer behavior in a concerted way to accept the results of "experimental" production.

Third Thesis: Special Roles for Foreign and Local Technology Supply

When a firm introduces an innovation into the productive process for the first time, the demand for technology will be oriented towards foreign sources of supply. After the imported technology has been incorporated into the productive process, there emerges a demand for local technology absorption activities (adaptation of products to local conditions, cost-reducing improvements, capacity-stretching, and other minor innovations). Only under exceptional circumstances will there be a substitution of foreign technology for the results of local research, development and engineering efforts. This, coupled with advances at the technological frontier and the occasional need to keep up with them, leads to a pattern of long-term and sustained dependence on foreign sources of technology in which the incorporation of new and more advanced foreign technologies takes place sporadically.

Fourth Thesis: Irrelevance of "Pull" and "Push" Forces for Innovation

The traditional "market pull" and "science and technology push" forces that stimulate innovation and the domestic generation of technology in the developed countries are mostly irrelevant in the context of import substituting industries. The first because the set of conditions prevailing in developing countries allow the leading firms to [p. 166:] disregard market signals and consumer preferences to a large extent. The second because there are no local scientific and technological capabilities to generate advances that could induce major industrial innovations. In consequence, the main forces leading to innovative behavior emerge out of the combination of uncommon circumstances, pressures and opportunities affecting the leading firms that set the pace for the branch as a whole.

The "General Principle" and the four theses put forward in this section refer to industrial activities as a whole and should be particularized at the level of an individual branch. For this purpose, it is necessary to generate specific hypotheses regarding the impact that a combination of market structure, type of technology, and characteristics of leading firms - taken together with a given balance of profit of NNPB objectives - will have on the prevailing forms of competition in the branch, and on the technological behavior of the various firms and the branch as a whole.

There are two additional issues to be considered to complete the development of the conceptual framework. The first refers to the impact of the macroeconomic situation and of government policies on the three sets of factors, on the patterns of competition, and on technological behavior. For example, during a period of high economic growth when markets are expanding, there may be a recomposition of the market structure and industrial organization (entrance of new firms, increased vertical integration, etc.); new technologies are likely to be introduced through capital investments (altering the level of technological capabilities of the branch); and new firms may assume a leadership role. All of these will influence the forms of competition, the competitive pressures faced by the firms and, ultimately, their technological behavior. On the other hand, during a recession a very different picture can be expected. Similar remarks can be made with regard to the impact of government policies referring, for example, to the degree of protectionism: in a highly protected industrial branch the market structure, level of technology, and characteristics of leading firms are likely to be quite different from those that would prevail if a relatively more open market policy were implemented, with the consequent differential impacts on patterns of competition and on technological behavior.

The second issue refers to the feedback from technology choices and technology activities to market structure and industrial organization, type and level of technology, and characteristics of the leading firms. The lines of influence [p. 167:] are mostly in one direction, from the latter to the former, and only under exceptional circumstances will technological behavior affect the three sets of factors examined here. This unusual event could take place, for example, through the introduction of major technical innovation by a leading firm, or though the accumulation of technological advantages derived from technology absorption activities. In both cases, a firm or group of firms would acquire enough market power to alter the "steady state" prevailing in the branch and force a realignment of market structure, type and level of technology and characteristics of leading firms.

<u>Concluding Remarks</u> (p. 167)

This essay has examined the combined impact of a variety of sources of influence on technological behavior. Starting from an analysis of market structure, type of technology, and characteristics of the leading firms in a branch, it examined the interactions between these factors and the balance between profit and NNPB objectives prevailing in the branch, so as to derive their implications for the patterns of competition and for the competitive strategies adopted by individual firms.