ESCAP ASIA-PACIFIC APCTT **TECH MONITOR**

TECHNOLOGY ATLAS

AN INTERIM REPORT

ASIAN AND PACIFIC CENTRE FOR TRANSFER OF TECHNOLOGY
OF THE ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

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Interim Report on Technology Atlas

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BACKGROUND

Events Leading to this Project

1. "Technology for Development" was the theme of the 40th Annual Session of the Economic and Social Commission for Asia and the Pacific (ESCAP), held in Tokyo in April 1984. At this meeting, an ESCAP Plan of Action was adopted which called for the preparation of a "Technology Atlas for Asia and the Pacific".

2. The First Expert Group Meeting which was held in December 1984, to discuss the scope and objectives of a Technology Atlas, suggested a desk study to determine the contents.

3. The Second Expert Group Meeting which was held in October 1985, deliberated on the desk study outlining the possible contents of the Technology Atlas and finalized the guidelines for the preparation of a project document for a two-year first phase.

4. The project document was finalized in April 1986 and submitted to the Government of Japan for funding.

5. During 1985 and 1986, under the UNDP-funded project RAS/84/025, APCTT undertook the preparation of twelve country studies on status of technology policies and planning in Bangladesh, China, India, Indonesia, Japan, Repubic of Korea, Malaysia, Nepal, Pakistan, the Philippines, Sri Lanka and Thailand.

6. The Technology Atlas project was approved in June 1986 for funding by the Government of Japan with an estimated input of US$1,229,000 for the first two years.

Project Adviser

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5. Dr. K. Ramanathan, Technology Management Specialist (17 August 1986)
6. Dr. M.N. Sharif, Team Leader, (Director of APCTT)

Purpose of the Interim Report

The purpose of this Interim Report is to highlight the methodologies that are likely to be presented in the Technology Atlas. The methodologies are illustrated with examples using the limited data available at APCTT. This presentation indicates the nature of the excercises that are currently being undertaken with a view to get as many suggestions and comments from potential users so that, in the coming months, some of these conceptual methodologies can be refined. After collecting necessary data from at least ten selected ESCAP countries and in five areas of technology, the Atlas representing the assessment of technological capabilities, gaps and levels of development, will be published.

This report is published without formal editing.

Part I
Why a Technology Atlas

1. The Imperatives of Technology-based National Development

• A distinctive feature of human activity is making and using many kinds of physical tools for the amplification of muscle and brain power. By expanding the individual as well as collective physical and mental strengths, technology has enabled humans to depart from a purely biological evaluation to an intellectual phase of evolution. Thus, over the years, the relationship between technology and the process of social change has become very intricate, mutually reinforcing and all-pervasive.

Technology and Social Change

• The most primitive of all societies were the "hunter-gatherer" societies. In these societies humans occupied a very low position in the natural system. As the population was extremely small compared to the naturally available resources, food and other requirements could be met directly from nature; and collecting food was the major activity.

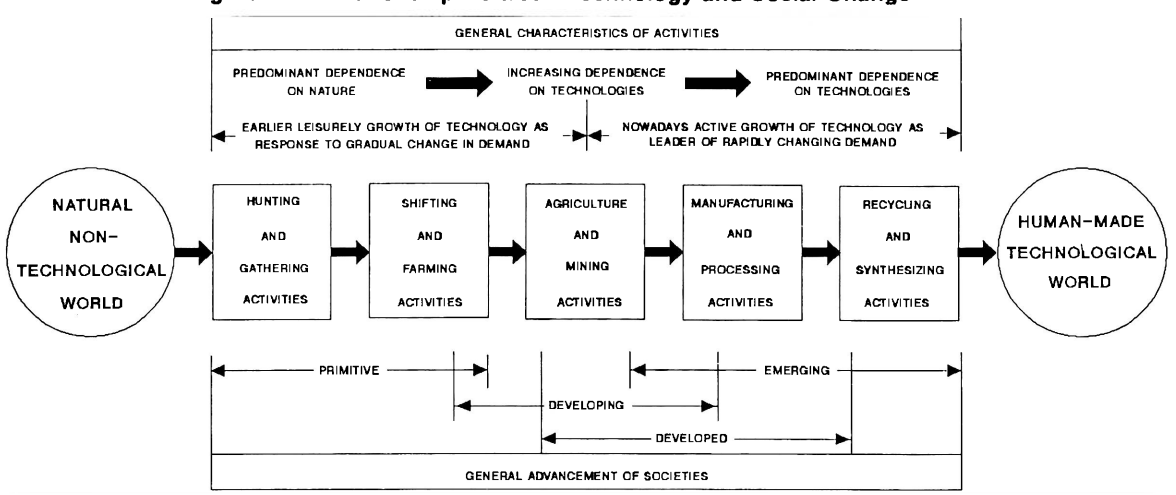
• With a slight increase in population and due to the adventurous nature of some people, a new human culture, in which natural food sources were supplemented by slash-and-burn farming, evolved. Small portions of forests were cleared by cutting and burning; the ashes were distributed over the cleared area for growing simple crops for a period of two to three years. As the soil became less fertile and when the forest reclaimed the cleared land, the society moved on to the next site. This availability of farmed food, led to the "shifting and farming" societies laying the basis for an increase in population.

• As human population grew, the ready supply of food from the wilderness gradually depleted. This ecological pressure on the growing human population made domestication of plants and animals necessary for survival. Thus, in many parts of the world where the climate was conducive, stable agriculture came into existence. However, due to seasonal changes in the weather, stable agriculture had to work within time constraints. Higher productivity of labour became a necessity and this was achieved through the use of stone and metallic hand-tools. These "agriculture and mining" societies laid the foundation for the increasing use of technology. A consequence of this was a further increase in population. The efficiency of food production associated with stable agriculture (plant, animal and fish) heralded a new era of human civilization. Due to the availability of surplus food, part of the population could also be freed for pursuits other than food production. Thus, some members of these societies started to seek knowledge and soon discovered many new resources for the benefit of mankind.

• With the discovery of coal as a concentrated source of energy, human civilization entered the threshold of industrialism. Initially coal, and later oil and gas, fueled the Industrial Revolution. Human labour was partly replaced by machines. Large segments of human population in many parts of the world moved away from the farm and formed the "manufacturing and processing" societies. Industrialization advanced at an accelerated rate with the increasing use of technology. This resulted in enormous productivity gains, and thus allowed a larger part of the population to move into what we now call the "service sector" (such as transportation, communication, health, etc.).

• However, with the increasing demand from an already large and still growing population, the non-renewable energy and other resources of the world are being depleted at an alarming rate. The present world is no longer big enough to support the human population without substantially increasing the use of technology. Technologies have already been developed for stabilizing the human population. Efforts are underway for producing synthetic foods, recycling of non-renewable resources and satisfying the varied demands from renewable resources. Thus, we are now witnessing the emergence of a "recycling and synthesizing" society.

Figure 1.1: Relationship Between Technology and Social Change



Changing Role of Technology

- The need for technology came from human inquisitiveness in problem solving. Ever since the Stone Age (which perhaps marked the beginning of the use of technology), the history of mankind is one of human societies built on successive technological advancements. We now live in what is often called "the technological society"; yet there is so much controversy about technology throughout the world!

- Technology is viewed differently by different people. Some view technology as the source of wealth, well-being, and above all, the instrument of power to dominate nature and societies. Others view technology as something that has enslaved human beings, and destroyed jobs, environment and social values. On the one hand, there is considerable concern that the use and abuse of technology is leading our societies towards disaster; on the other, there is considerable agreement that further development of human society is possible only through the application of technology.

- There is concern over too-much technology in the developed countries, while in the developing countries the dissatisfaction is about having too-little technology. There is also a tendency among some to blame technology for the evils of society. However, considering the record of past successes, it is not surprising that many people have faith that technology could solve our current problems.

- Technology is not an independent and autonomous force; it is merely an instrument for problem solving. It is up to us to determine what problems we solve, and how we solve them. If we can master its use, technology can be the "key" to a propsperous society for all human beings - including the poorest of the poor!

Technology is a Commodity

- Technologies are being continuously produced and improved to meet the ever-increasing demand of contemporary societies. Technology is a marketable commodity, specifically generated for war, prestige, economic competition and social welfare. Industrial technology is generally produced under patent rights, mostly for commercial benefits.

- It has been observed that while the prices in the international market of the high-technology products have been increasing steadily, the prices of primary goods have been fluctuating widely, in many cases even dropping considerably.

- International trade statistics indicate that the developing countries mainly export primary goods (agricultural products and industrial raw materials, which are of low technology content) to the developed countries, while they import mostly manufactured goods (appliances and machine-tools, which are of high technology content) from the developed countries.

Table 1.1: Examples of Changing Value of Technology in Trade

Year	Indonesia	Pakistan	Year	Indonesia	Pakistan
	Tonnes of palmoil needed to buy one car	Tonnes of rice needed for buying a car		Tonnes of palmoil needed to buy one car	Tonnes of rice needed for buying a car
1971	5.83	-	1978	7.12	6.10
1972	8.26	-	1979	6.40	4.44
1973	6.20	-	1980	7.99	8.72
1974	3.20	5.51	1981	8.05	8.85
1975	7.06	4.38	1982	11.98	8.92
1976	8.40	8.26	1983	15.41	10.47
1977	8.26	8.24	1984	16.03	-

Technology and Development

- Developing countries are technologically less developed. Even though most of the poor countries are quite rich in natural resources, culture, etc., they have three basic problems: (i) they have a relatively large population base, which is expanding very rapidly; (ii) their technological base is very small and ineffective; and (iii) their natural

resource base is being depleted due to inefficient use and indiscriminate export.

• To realize their inherent richness, these countries should try to: (i) control the growth of their population base; (ii) develop their technological base; and (iii) conserve and efficiently use their resource base. As population control and optimal resource utilization require the application of technology, expanding the technological base is the most crucial task for the developing countries.

Technology is the "master key" for development.

2. Issues in Achieving Technology-induced Progress

• Technology has emerged as the crucial strategic variable for rapid socio-economic development in today's increasingly competitive international environment. Therefore, even in the developing countries, there is a visible attempt to integrate technological considerations in the development planning process. The APCTT country studies on technology policies and planning (published during 1986) indicate the existence of a myriad of problems and constraints. This section briefly lists some of these and also presents some of the opportunities available to the late developers.

Problems

• The Asia-Pacific region consists of countries of enormous diversity. The problems faced by each of these countries in their attempt to establish a technology-based development programme are generally varied and numerous. Only some of the most common problems faced by a fair majority of the developing countries of the region are listed here. It should, however be noted that the entire set is not necessarily applicable to any particular country.

• The first set of problems may be categorized as problems in understanding the unique characteristics and related aspects of technology. For example:

- technology is not just a physical production tool, but really a complex combination of both the tool and the know-how associated with the tool;
- technologies as embodiments of such complex combinations, are marketable and have both economic and political values;
- the world is becoming increasingly interdependent due to technological specialization; and
- technological advancement could be considered as a good measure of national development.

• The second set of problems arises due to the existence of a widely varied number of preferences and perceptions, such as:

- the general population's preference for imported technologies rather than locally generated technologies;
- the unrealistic expectation regarding technology transfer as a by-product of foreign investment;
- the common perception of self-reliance as being equivalent to self-sufficiency in technology for economic growth;
- defining technological appropriateness only with respect to labour-intensiveness; and
- following the bandwagon, without selectivity, in building local technological capabilities.

• The third set of problems is associated with the organizational infrastructure and prevailing management practices, which include:

- ineffective public sector research and development institutions;
- knowing science (knowledge) being given operational command over doing science (application), the successful use of which reflects a nations ability to use technology for development;
- missing or weak linkages between users and suppliers of generated and imported technologies;
- the absence of any sort of institutionalized attempt at monitoring, forecasting and assessment of technology;
- the compartmentalization of technology by institutional design in government organizations (ministry/division/department);
- the ineffective coordination by ex-officio committee members who have other pressing concerns; and
- choices of technology being generally considered only at the lowest level of planning heirarchy.

• The fourth set of problems refers to the level of commitment to technological considerations and leadership behaviour, such as;

- statements of policy-makers not getting sufficient financial, fiscal and legal support;
- technologists and scientists not being exposed to management and socio-economic development concepts;
- politicians and planners displaying their own biases or inclinations without a visible compromising approach; and
- attempting unprecedented and revolutionary changes with outdated administrative procedures.

• The fifth set of problems may be referred to as the problems of climate represented by the attitudes and preoccupations of the people, such as:

- attention of top leadership being devoted mostly to crisis-management, whether warranted or not;
- high-level policy decisions being made in response to immediate political and economic pressures, while questions of long-term sustainability and the implications for the less powerful actors in the development process get overridden;
- scarcity of time, as intellectual priorities are clogged with trivia and ceremonial duties; and
- finding fault with others, and using the excuse of uniqueness to avoid necessary action.

Constraints

- Most of the problems listed in the previous section are internal rather than external; and can be resolved with strong determination and wholehearted commitment at all levels. However, there are many other problems which are more external than internal. These are listed here as general constraints:

- The first set of constraints is basically due to the dependence of many developing countries on external assistance, such as:

  — decisions with respect to the selection of development projects being conditioned by the funding source;
  — the mode of operation of international institutions inadvertently reinforcing dependence;
  — assistance being conditioned by considerations other than the developmental needs of the recipient; and
  — non-relevant research activities being undertaken with easily available seed-money from abroad.

- The second set of constraints is primarily due to the demonstration effect caused by the communication revolution, resulting in:

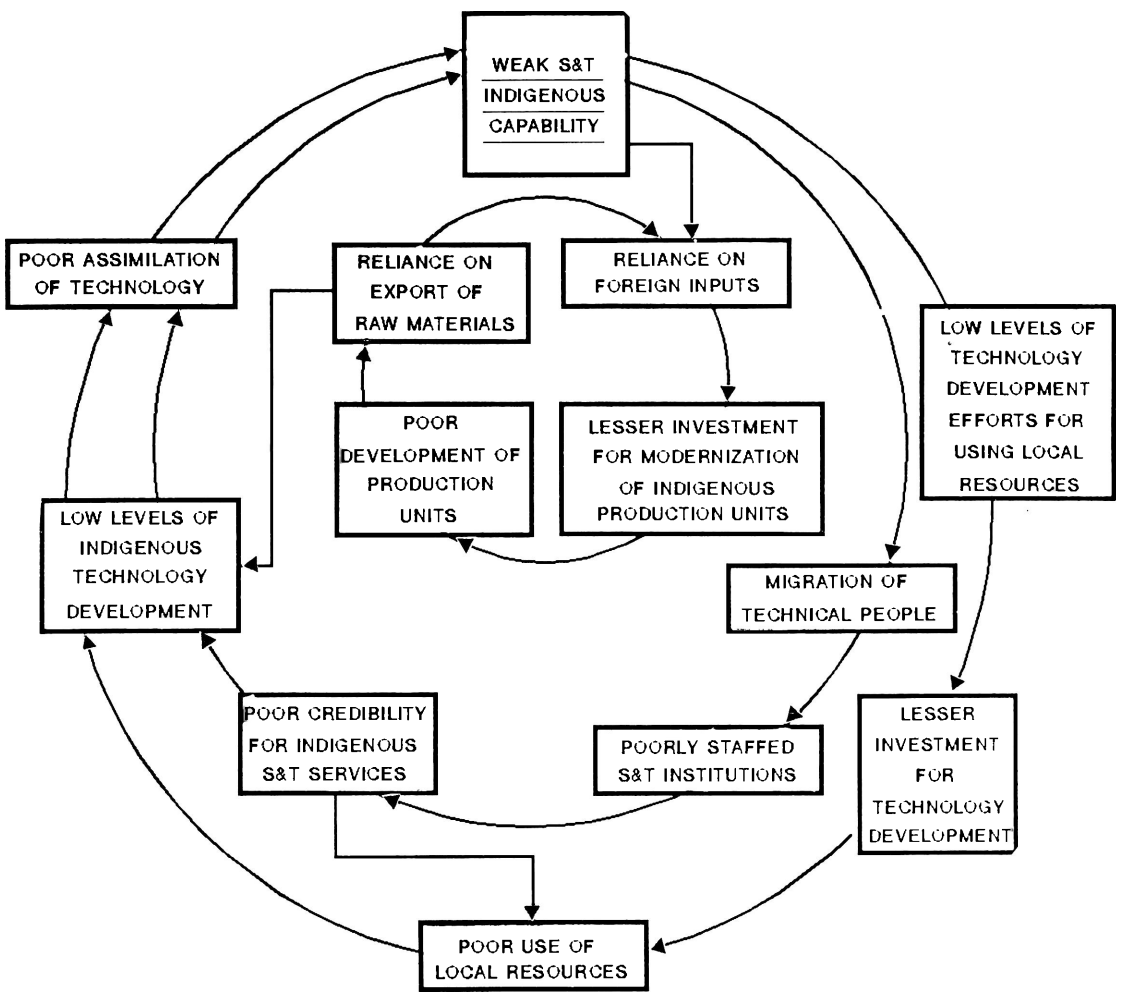
  — aspirations being raised to frustratingly high levels by ever-increasing coverage in the mass-media;
  — illusions of achieving in a few decades what the developed countries achieved in centuries; and
  — the widespread use of the power of collective indiscipline for non-developmental expenditures.

- The third set of constraints may be attributed to the situational change faced by the late-starters, such as;

  — the ratio of naturally available resources to population being worse now for most developing countries;
  — a high propensity for suboptimization due to narrow specialization and professional isolation; and
  — the adverse skill-structure of the labour-force due to brain-drain and degradation of craftsmanship.

- The constraints listed above are not necessarily exhaustive but are the ones commonly experienced, and certainly these are not insurmountable. The negative influence of many of these constraints can be reduced in the long-run through visionary zeal and collective sacrifices.

Figure 2.1: The Vicious Circles of Technology and Underdevelopment



Opportunities

• The problems and constraints listed in page 8 should not lead one to believe that everything is hopeless in the developing countries. On the contrary, the developing countries also have many late-starter advantages. Listed below are some of these opportunities for exploitation by the developing countries.

• Developing countries do not need to reinvent the wheel. It is possible for them to tap accumulated technologies and knowledge in many ways:

- knowledge can be gained through formal and informal education, training and retraining;
- effective learning is possible from the experiences of both developed and other developing countries;
- many production technologies are available internationally, however mostly through transnational companies;
- information about technologies is available from public and private information centres; and
- expertise is available from local and foreign consultancy service firms.

However, it should be noted that the price of any technology depends on the relative bargaining positions of the seller and buyer.

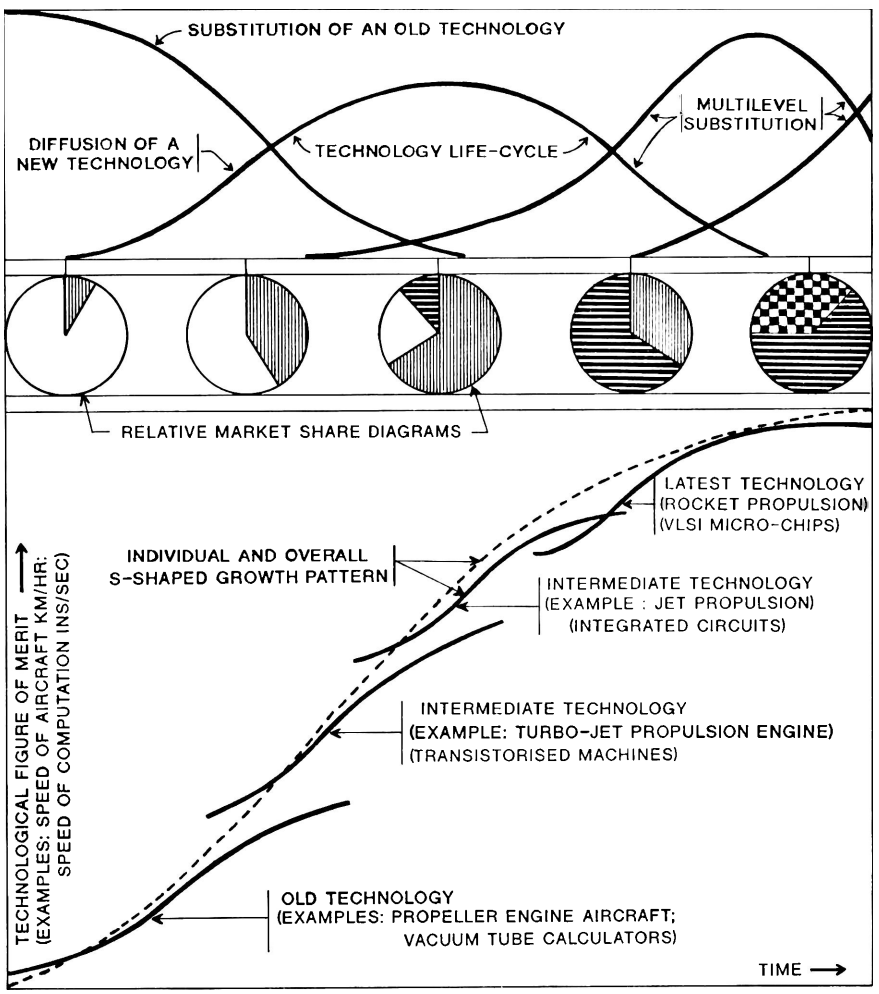
• Developing countries can greatly benefit from the judicious application of some of the emerging technologies because:

- some emerging technologies are multi-purpose and pervasive in nature (e.g. microelectronics);
- some emerging technologies are scale-neutral for production and use (e.g. biotechnology); and
- some emerging technologies are also situation-independent for application (e.g. computer aided design/manufacturing system).

• Developing countries can also take advantage of the inherent characteristics of the technological change process. Since technological change occurs through a series of successive substitution and diffusion process, there are two significant implications:

- eventual catch-up is possible due to the S-shaped growth pattern of any particular technology; and
- leap-frogging is possible sometimes by skipping the intermediate stages of technological change.

Figure 2.2: Sequential S-Shaped Technological Change Process



- Another advantage for late-starters is the opportunity for avoiding known pitfalls, through:
  - effective learning from the experiences of both developed and other developing countries;
  - preventing or minimizing the possible negative impacts of certain available technologies; and
  - carefully studying the success and failures of one's own past experience for determining future activities.

3. Need for Better Measures of Technology for Development

- Just as developing countries need to develop an indigenous capacity to screen, assess and modify the various foreign technological hardware they may wish to import, so too, do they need to develop an indigenous capacity to assess the performance of their own scientific and technological activities, both in relation to their own societal needs and in comparison with the world standards. Thus, national capabilities need to be built up to apply existing Science and Technology Indicators and also to develop new indicators for overcoming the current limitations in the measurement activities.

The Need for Science and Technology Measures

- The application of science and technology has greatly influenced the economic, social and physical welfare of countries and regions. Recognition of this correlation has led to a growing interest in measuring the progress and status of science and technology. The development of science and technology measures is a result of the intensification of this interest.

- While there is an increasing realization in the developing countries that technological considerations have to be incorporated into the traditional socio-economic planning process, this is often not possible due to lack of measures of technology. The development of measures of technology will facilitate this integrated planning exercise.

- There is increased awareness among national planners today that systematic technology measures, preferably quantified measures, are necessary whether one wants to influence practice and policy, or to understand the factors influencing technology development. This will help to strengthen current approaches which rely heavily on case studies, anecdotes and personal experiences.

- Technology measures can play an important role even from the point of descriptive purposes. Well defined technology measures can help in comparisons among countries from various angles. If such comparisons are carried out, critical issues can be brought to focus for public attention and for the consideration of national planners.

- Technology measures, if suitably devised, can also be used for analytical purposes which will help in the understanding of the economic consequences that result from carefully planned technology development activities. Thus, technology indicators can be an important aid to a better understanding of causal structures relating science and technology to the development system of a country.

Review of Available Science and Technology Measures

- Science and Technology (S&T) measurement activities are currently carried out at four levels as indicated below:

  Level 1 : Firm/department level analysis
  Level 2 : Inter-firm/inter-department comparisons
  Level 3 : Industry level/national analysis
  Level 4 : Regional/international comparisons

Table 3.1: Levels of Science and Technology Measurement Activities

Level	Scope and Purpose	Users
Level 1 : Firm/department level analysis	* Collection and publication of a variety of partial indicators for purposes of internal monitoring budgeting and planning	* Firm level managers * Academic researchers * Specialists in industry and national planning agencies
Level 2 : Inter-firm/inter-department comparisons	* Inter-firm comparisons supplemented by information collected specifically for each study * Can point to important conclusions for national policy making	* Academic researchers * Specialists in industry and national planning agencies * Business associations * Sectoral level policy makers * National level policy makers

Level 3 : Industry level/ national analysis	* Industry level/national statistical surveys carried out by government/private agencies * Requires use of standardized definitions and concepts * Can point to important conclusions for national policy making	* Academic researchers * Specialists in industry and national planning agencies * Business associations * National level policy makers
Level 4 : Regional/ international comparisons	* Carried out by regional/international agency * Requires harmonization of various national definitions and procedures * Useful only if activities are innovative and catalytic which leads to dissemination of "best practice" across national frontiers	* National governments * International agencies

- While various classifications of existing science and technology measures, often called Science and Technology Indicators (STI), are available, the most popular grouping divides STI into:

  (1) Input indicators;
  (2) Output indicators.

- Input indicators attempt to evaluate the resources which are required as inputs for the pursuit of S&T activities. Examples include funds, personnel and institutions. More detailed examples of input indicators at various stages of the S&T system are shown in tabular form.
- Output indicators attempt to measure the results of S&T activities. Some examples of S&T output indicators are publications, patents and innovations. More detailed examples of output indicators are shown in tabular form.

Table 3.2: Review of Existing Science and Technology Indicators

STAGE	INPUT INDICATORS	OUTPUT INDICATORS
BASIC RESEARCH	* Stock of S&T personnel by category - category - field of specialization - type of employer - sectors of performance - primary work activity - qualifications	* Bibliometric measures
APPLIED RESEARCH	* R&D expenditure by - type of expenditure - sector of performance - source of funds - type of R&D activity - type of employer - field of specialization - major socio-economic aims	* Bibliometric measures * Patent measures * Object specific measures of technology
DEVELOPMENT	* Auxiliary personnel associated with S&T	* Bibliometric measures * Patent measures * Object specific measures of technology

Table 3.2 continued

PRODUCTION	* Stock of S&T personnel by category - Category - field of specialization - type of employers - sectors of performance - primary work of activity - qualification * R&D expenditure by - type of expenditure - sector of performance - source of funds - type of R&D activity - type of employer - field of specialization - major socio-economic aims	* Object specific measures * Diffusion measures * Technology transfer payments
NATIONAL LEVEL	* Tertiary level education - student enrolments and graduations by field of study - teachers by field of study - funding by field of study * Primary and secondary level education - student enrolments and graduation by field of study - teachers by field of study - funding by field of study * Publication and S&T subject distribution of academic books * Adult literacy rate	* Technological balance of payments * Trade in high-technology products

Use of Existing Science and Technology Measures

• Application of existing STIs, like other social and economic indicators, always require careful interpretation. They should not be used mechanically and their application requires an awareness and understanding of the complexities affecting both the measurements themselves and the social system which gives rise to these measurements.

• Past experience has indicated that in general, more than one STI should be used to analyze a problem. For instance, while U.K. and U.S.A. show strong performance with respect to bibliometric measures, their patenting performance is inferior to that of Switzerland and Japan. Thus, while the examination of only bibliometric measures or patents may be misleading, their joint examination show that while U.K. and U.S.A. have greater capabilities in basic research, Japan and Switzerland have better innovative capabilities.

Limitations of Existing Technology Measures

• Currently available science and technology measures have been developed over a period of time by the industrialized nations in relation to their development and use of science and technology. The pattern of economic development and usage of science and technology in the developing countries has been substantially different. Thus, it is imperative that technology measurement efforts in the developing countries recognize this fundamental difference and develop measures which can evaluate important technological activities previously not considered to be relevant by the early developers.

• Some of the aspects which are not examined by current technology measurement activities are as follows:

— Evaluation of the level and quality of scientific and technical information;
— Evaluation of national capabilities with respect to management of research and development (R&D);
— Evaluation of national capabilities with respect to commercialization of research results.
— Evaluation of national capabilities with respect to reverse engineering, adaptation and improvement of imported technologies;
— Evaluation of national capabilities with respect to engineering services and quality assurance;
— Evaluation of technology gaps and levels of specific sectors/fields;

— Evaluation of the technology level of national production systems;
– Evaluation of the degree of availability and quality of natural resources;
— Evaluation of the national technology climate.

4. Objectives and Scope of the Technology Atlas Project

• The Technology Atlas may be perceived as a means of strengthening the capacity of ESCAP countries in the planning and implementation of technology-based developed programmes. It is proposed to achieve this objective through the development of a variety of techniques and presentations which will help to provide national level policy-makers and planners with information which has been hitherto unavailable.

Overall Objective of the Technology Atlas Project

• The overall objective of the Technology Atlas is to develop a "decision support tool" for science and technology policy-makers and end-users of technology of a country.

• The Technology Atlas will be a reference guide for technology policy analysis at the national level. It would contain, among other items, methodologies, common indicators, parameters and yardsticks for evaluating technological needs and capabilities at the macro, meso (intermediate) and micro levels. It would also assist in the development of a framework for the integration of technological considerations in the national development planning process.

Specific Objectives of the Technology Atlas Project

• Provision of comprehensive S&T country profiles for ten selected ESCAP countries with a view to present comprehensive S&T status analyses based on currently available data. The in-depth analyses would be carried out in the following areas.

— stock of science and technology personnel;
— research and development expenditure;
— the science and technology scene in industry;
— the academic science and technology scene;
— advances and efforts in selected areas of science and technology;
— the national science and technology climate.

• Development of a methodology for assessing technological capabilities of a country.

• Testing of the capabilities assessment methodology in four selected ESCAP countries.

• Development of a methodology for technological gap and level assessment in a specific area.

• Testing of the gap and level assessment methodology in four selected areas.

• Development of a methodology for assessing technological needs of a country.

• Testing of the needs assessment methodology.

• Identification of information needs for S&T planning and the development of guidelines for information collection.

• Development of suitable formats for the presentation of the Technology Atlas Project findings. These formats would include narratives, diagrams, tables, matrices and other forms of visual, print and computer-based presentations for a variety of users.

Potential Benefits of the Technology Atlas

• The Technology Atlas is based on the realization of the fact that technology measurement activities currently in use do not provide adequate information to the S&T policy maker and planner in developing countries. Thus, steps to overcome this limitation have been deliberately built into the analytical framework of the Technology Atlas.

• The Technology Atlas attempts to develop measures in important areas that have not received adequate attention from conventional S&T measurement activities of the early developers.

• The Technology Atlas may help to meet basic information requirements for technology planning and may provide a medium through which analytical approaches can be introduced in the formulation and refinement of national technology policies.

• The various publications of the Technology Atlas may be of relevance and interest to a variety of users. This may also help in improving the technology climate

• The micro-computer based approach, that is being used in the preparation of the Technology Atlas, will enable easy and cost-effective updating of the Atlas publications and easy adaptation by the developing countries.

• To ensure that the Technology Atlas would have greater relevance to the developing countries of the ESCAP region, the S&T measurement activities would emphasize aspects of direct interest to these nations.

• It is also envisaged that the Technology Atlas would help to foster harmonious and concerted efforts by the private and public sectors in advancing the technological level of a country through an appreciation of the soundness of national and sectoral policies and an understanding of national technological needs and capabilities.

Part II
Basis for the Technology Atlas

5. Technological Transformation for Economic Growth

• It is generally accepted that the systematic application of technology led to gradual sophistication of economic activities which in turn caused a great upliftment of the standard of living in the developed countries over the past two hundred years. Thus, technology may be considered to be the engine of growth for the national economy.

Technological Transformation of Natural Resources

• Technology is a "means" for transforming the "natural world" into a "man-made world". Thus, the production system of a country is the key "actor" in transforming natural resources into produced resources.

• Natural resources in a country may include the following types:

Geophysical	— hydrologic, volcanic, oceanographic etc.
Geographic	— land, water, air, etc.
Living Creatures	— wild life, fisheries, etc.
Plants	— vegetation, forests, etc.
Raw Materials	— minerals, ores, rocks, etc.
Energy	— coal, oil, gas, sunlight, wind, etc.

• Produced resources in a country may include the following:

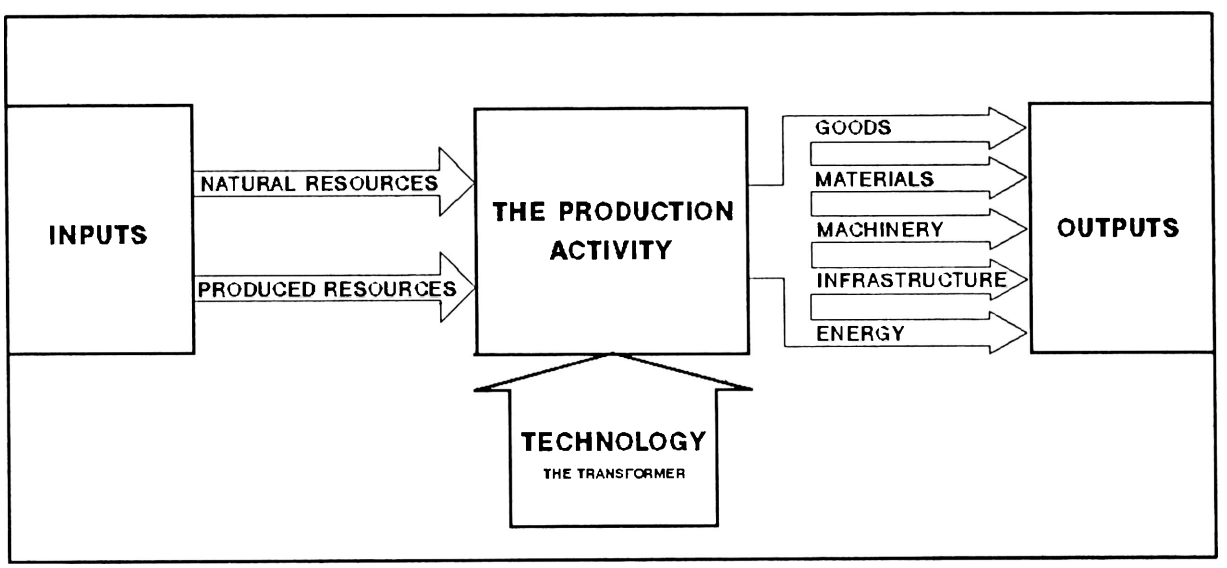
Goods	— food, medicines, apparel, applicances, etc.
Materials	— chemicals, hardware, components, etc.
Machinery	— machine tools, vehicles, plant, equipment, instruments, etc.
Infrastructure	— buildings, roads, dams, ports, etc.
Energy	— electricity, etc.

The General Stages of Technological Transformation

• Any transformation of natural resources into produced resources may be described schematically in terms of the following elements:

Inputs	— natural resources and produced resources;
Outputs	— produced resources
The Production Activity	— the mode of converting inputs into outputs
Technology	— the transformer and the core of the transformation facility

Figure 5.1: Representation of Transformation of Natural Resources into Produced Resources



• The production activity involved in the conversion of natural resources into produced resources may be viewed as comprising of transformation stages which can be broadly classified as follows:

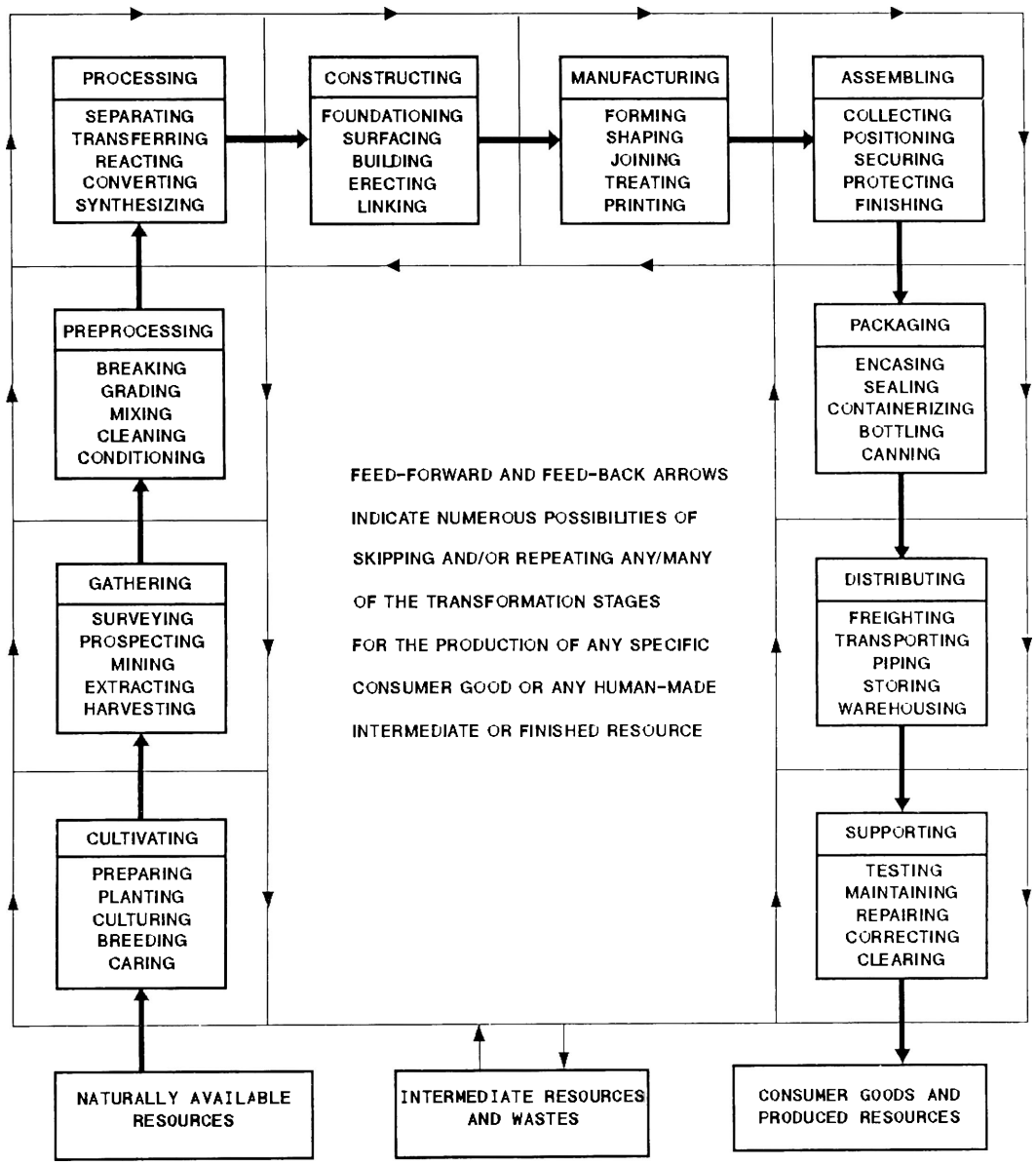
- Cultivating
- Gathering
- Preprocessing
- Processing
- Manufacturing
- Constructing
- Assembling
- Packaging
- Distributing
- Supporting

• Some of the generic activities in each of these transformation stages are as follows:

Cultivating	— preparing, planting, culturing, breeding, caring, etc.
Gathering	— surveying, prospecting, mining, extracting, harvesting, etc.,
Preprocessing	— breaking, grading, mixing, cleaning, conditioning, etc
Processing	— separating, transferring, reacting, converting, synthesizing, etc.,
Manufacturing	— forming, shaping, joining, treating, printing, etc.,
Constructing	— foundationing, surfacing, building, erecting, linking, etc.,
Assembling	— collecting, sealing, containerizing, bottling, canning, etc.
Distributing	— freighting, transporting, piping, storing, warehousing, etc.,
Supporting	— testing, maintaining, repairing, correcting, cleaning, etc.

• The sequence of necessary transformation stages will vary from one production activity to another and there can be both feed-forward (skipping) as well as feed-back (repeating) loops. Thus, there are many possibilities of skipping and/or repeating any/many of the transformation stages for the production of any particular produced resources. The general stages of technological transformation are also shown schematically.

Figure 5.2: General Stages of Technological Transformation



• The operation of any production system can be decomposed and analyzed in terms of the transformation stages involved in the production process. Thus, for instance, rice milling which is a very common activity in the developing countries can be analyzed as tabulated below:

Sequence of Production Activities	Equivalent Transformation Stage
1. Cleaning raw paddy	Preprocessing
2. Milling/De-husking	Preprocessing
3. Removing milled rice from paddy	Preprocessing
4. Polishing milled rice	Preprocessing
5. Grading polished rice by size	Preprocessing
6. Packing graded rice	Packaging

• The example of rice milling also shows that it is predominantly a preprocessing type of transformation. Thus, in practical situations it may be useful at times to classify a production system as predominantly belonging to a particular transformation stage. Illustrative examples are tabulated in the next column.

Production Activity	Predominant Transformation Stage
1. Agriculture and Livestock Production	Cultivating
2. Coal Mining	Gathering
3. Grain Mill Products	Preprocessing
4. Petroleum Refining	Processing
5. Manufacture of Fabricated Metal Products	Manufacturing
6. Road Construction	Constructing
7. Assembly of Radio, TV and Communication Equipment	Assembling
8. Soft Drink Bottling and Canning	Packaging
9. Electric Power Distribution	Distributing
10. Appliances Repairing	Supporting

• Since the transformation of natural resources in space, time and form is at the heart of modern economic growth processes, it is imperative that a thorough assessment be made of a country's transformation stages.

6. Components of Technology for Resources Transformation

• Since technology is the transformer of natural resources into produced resources, a clear understanding of its elements and scope is essential. Ordinarily technology is understood to be merely a physical tool for transformation. Very often it is not clearly recognized that technology is a combintation of both the physical tool and the related know-how either to make or use that tool. Without the know-how, a tool alone is not a useful technology.

The Basic Components of Technology

• When one looks into the complex process for resources transformation, it is possible to discern four basic components of technology namely:

- Object-embodied technology which can be called Technoware.
- Person-embodied technology which can be called Humanware
- Document-embodied technology which can be called Inforware
- Institution-embodied technology which can be called Orgaware

• Technoware consists of tools, equipment, machines, vehicles, physical facilities, etc.

• Humanware refers to experiences, skills, knowledge, wisdom, creativity, etc.

• Inforware includes all kinds of documentation pertaining to process specifications, procedures, theories, observations, etc.

• Orgaware is required to facilitate the effective integration of Technoware, Humanware and Inforware, and consists of management practices, linkages, etc.

• The effective usage of these four components requires that certain minimum conditions be satisfied. These may be expressed concisely as follows

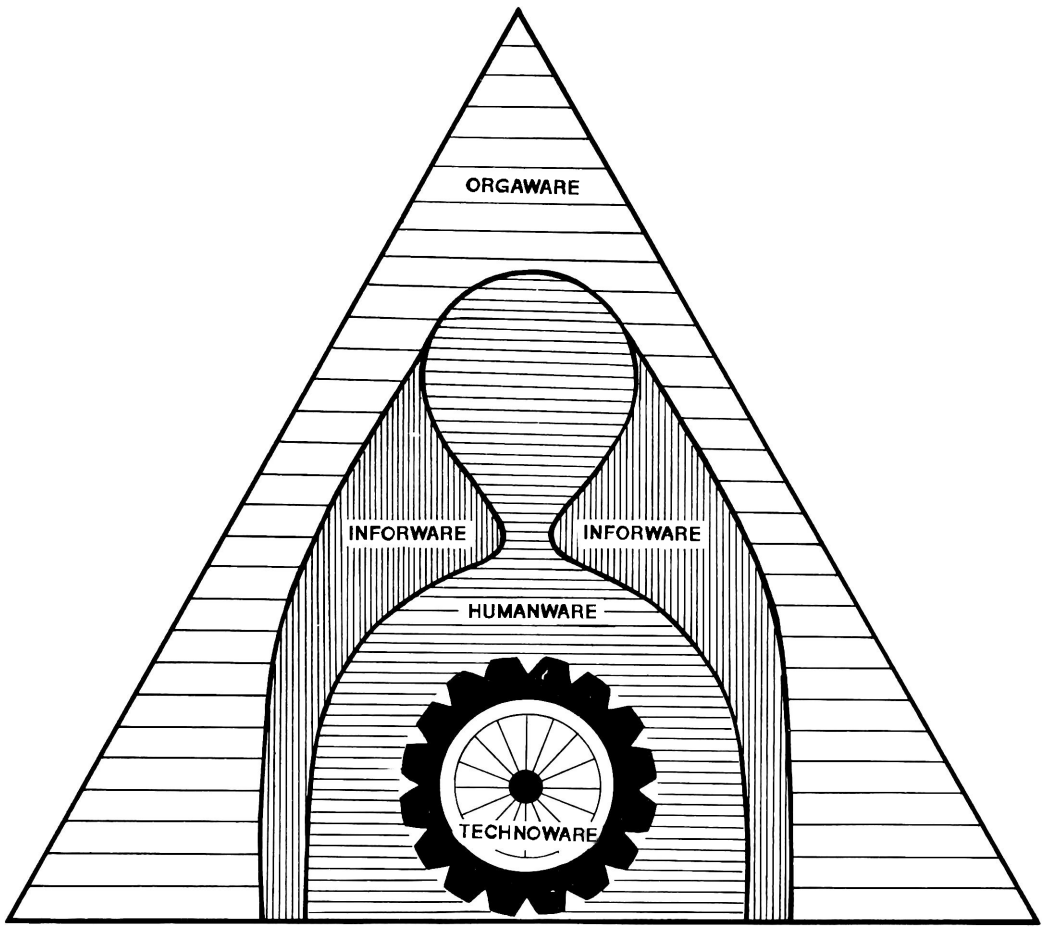
- Technoware needs operators
- Humanware needs motivation
- Inforware needs update
- Orgaware needs evolution

The Dynamic Interaction of the Four Components of Technology

• In any resource transformation, all four components of technology are required simultaneously. No transformation can take place in the complete absence of any of these components. This simultaneity requirement is shown in the schematic figure that is presented and could be summarized as follows:

- Technoware is the core of any transformation facility. It is developed, installed and operated by Humanware.
- Humanware is the key element of any transformation operation and Humanware is in turn guided by Inforware.
- Inforware is generated and also utilized by Humanware for decision-making and operation.
- Orgaware acquires and controls Inforware, Humanware and Technoware to effect the transformation operation.

Figure 6.1 Dynamically Interacting Components of Technology



• The interrelationship among the four components also has implications for technological advancement. Some of the more important are as follows:

With the increase in the level of sophistication of Technoware, the required level of sophistication of Inforware and Humanware are likely to change considerably.

With the increase in the level of sophistication of Inforware, better choices of Technoware and Humanware are possible.

With the increase in the level of sophistication of Humanware, Inforware is self-generated and the utilization of Technoware is improved.

With the increase in the level of sophistication of Orgaware, the effectiveness of Technoware, Humanware and Inforware are all increased.

7. Incremental Levels of Sophistication of Technology

• Within each component of technology there can be varying degrees of sophistication. Thus, for instance while a hand drill and a power drill are both Technoware, it is evident that the latter is more sophisticated than the former. Similarly, specific examples could be easily presented to illustrate the existence of such a situation in the case of the other three components as well. Thus, the development of a generalized classification, of the four components of technology in terms of increasing levels of sophistication would be of value in understanding and analyzing the behaviour and characteristics of transformation facilities.

Increasing Levels of Sophistication of the Four Components

• The level of sophistication of the four components of technology can increase, in a step-wise manner, due to the following reasons:

— Increased operational complexities in the case of Technoware.

— Increased value of documentation in the case of Inforware.
— Increased requirements of individual skills and experiences in the case of Humanware.
— Increased interaction and dynamisms in the case of Orgaware.

• One possible generalized classification of the four components of technology may be as follows:

Technoware	— Manual tools — Powered Equipment — General Purpose Machines — Special Purpose Machines — Automatic Machines — Computerized Machines Machines — Integrated Facilities
Inforware	— Familiarizing Facts — Describing Facts — Specifying Facts — Utilizing Facts — Comprehending Facts — Generalizing Facts — Assessing Facts
Humanware	— Operating Ability — Setting Ability — Repairing Ability — Reproducing Ability — Adapting Ability — Improving Ability — Innovating Ability
Orgaware	— Individual Linkages — Collective Linkages — Departmental Linkages — Enterprise Linkages — Industrial Linkages — National Linkages — Global linkages

The above classification is also shown in a schematic form and some examples are presented in tabular form for each level of sophistication. In the case of Orgaware the term linkage is used to include both vertical and horizontal interactions.

Figure 7.1: Step-wise Increasing Levels of Sophistication of Technology Components

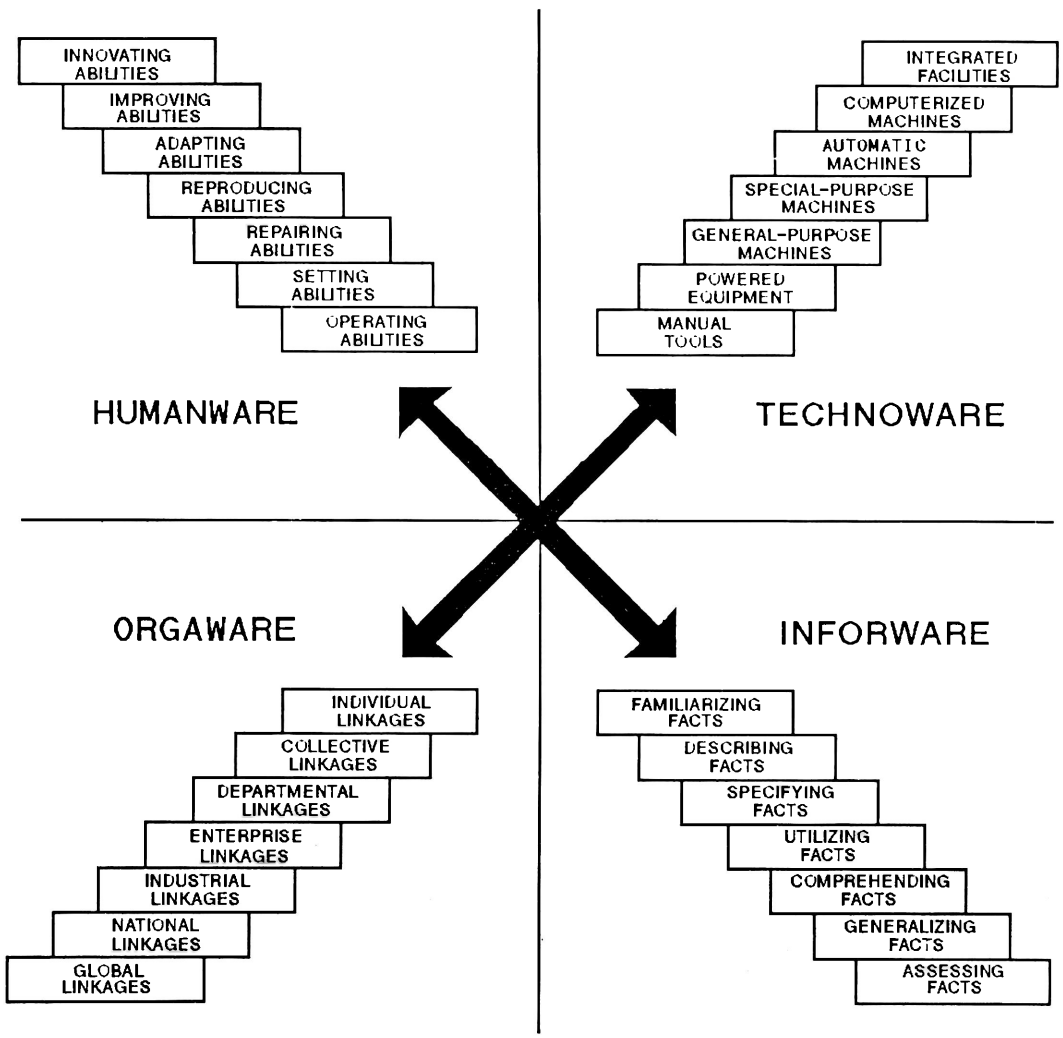


Table 7.1: Examples at the Various Levels of Sophistication of the Components of Technology

	Level of Sophistication	Some Illustrative Examples
TECHNOWARE	Manual Tool	Hand drill
	Powered Equipment	Power drill
	General Purpose Machines	Centre Lathe
	Special Purpose Machines	Air jet weaving loom
	Automatic Machines	Soft drink bottling plant
	Computerized Machines	Bar code sensing cash register
	Integrated Facilities	Computer chip manufacturing
INFORWARE	Familiarizing Facts	Brochure
	Describing Facts	Technical booklet
	Specifying Facts	Performance and usage specifications
	Utilizing Facts	Operating and maintenance manuals
	Comprehending Facts	Design data and calculations
	Generalizing Facts	Comparative techno-economic performance data
	Assessing Facts	State-of-the-art information
HUMANWARE	Operating Ability	Semi-skilled operator
	Setting Ability	Skilled operator
	Repairing Ability	Maintenance technician
	Reproducing Ability	Production engineer
	Adapting Ability	Design engineer
	Improving Ability	Improvement engineer
	Innovating Ability	Development engineer
ORGAWARE	Individual Linkages	Garage shop
	Collective Linkages	Cottage industry
	Departmental Linkages	Small-scale industry
	Enterprise Linkages	Medium-scale industry
	Industrial Linkages	Large-scale industry
	National Linkages	Multi-location industry
	Global Linkages	Transnational corporations

• In view of the desirability of "leap-frogging" for rapid technological advancement of the developing countries, the above classification provides a useful means of examining the extent to which such short circuiting is possible with respect to all four components.

8. Choices of Technology and Substitutability of Components

• Several studies have been done on the economics of technological possibilities open to developing countries. Such studies were prompted by the concern of development planners and researchers over whether there is any possibility of substituting labour for capital vis-a-vis the capital intensive techniques used in the developed world. In fact it has been demonstrated that there is indeed scope for such substitution in certain situations. However, these carefully planned successes have often been misconstrued as implying the possibility of always being able to substitute capital intensive Technoware by lower levels of Humanware. It is possible to avoid this mistake if choices of technology and the substitutability of the components are viewed in the light of some generic criteria that normally affect such analysis.

Factors Affecting the Choice of the Level of Sophistication of the Components of Technology

- Since Technoware is the core of any transformation facility, it would be useful to commence the choice of technology analysis by examining this component.
- Four factors which can be used to determine the level of Technoware required, are as follows:
  - **Scope** of the transformation activity
  - **Precision** required with respect to the transformation activity
  - **Handling** of in-process and finished resources
  - **Control** of the transformation environment
- The parameters for each of these Technoware Choice Factors are shown in tabular form. By applying these factors to any resource transformation stage, it should be possible to select an appropriate level of sophistication.

Table 8.1: Parameters for Technoware Choice Factors

Factors	Parameters
1. Scope	* Output rate * Product mix * Number of components * Number of materials * Temperatures * Pressures
2. Precision	* Ration of variation allowed to specification with respect to - Dimensions - Materials - Process - Components - Operating environment
3. Handling	* Physical attributes - State - Flowability - Unit size - Geometric configuration - Abrasiveness - Corrosiveness - Durability * Movement - Route (fixed/variable) - Path (horizontal/inclined/declined/vertical) - Imparting motion (manual/gravity/pneumatic/ vibration/power actuated devices) - Periodicity (intermittent/continuous) - Speeds
4. Control	* Number of steps * Environemental regulation adherence requirements * Safety measures adherence requirements * Standardization levels required * Process/product monitoring requirements

- The level of Humanware required can be estimated by examining the four major functions required for the effective utilization of the Technoware. These are listed below:
  - **Production** function (eg. operators, technicians, engineers)
  - **Evaluation** function (eg. monitoring and assessment personnel)
  - **Planning** function (eg. production planning and design engineering personnel)
  - **Control** function (eg. quality assurance and maintenance personnel)
- Due to the criticality of Inforware in decision-making, the desire for gaining access to the highest level possible is common. The minimum level of Inforware required can be determined on the basis of the following functions.
  - **Production** (eg. operating manuals)
  - **Services** (eg. maintenance manuals, circuit diagrams)
  - **Research** (eg. equations, formulae, theories, criterial)
  - **Quality** Assurance (eg. specifications, sampling schemes)
- The level of Orgaware required depends on the scope of operations with respect to the following specific functions:
  - **Marketing** (eg. market surveys, distribution channels, promotional measures)
  - **Production** (eg. material suppliers, sub-contracting)
  - **Personnel** (eg. training, development, unions)
  - **Finance** (eg. banks, venture capital institutions)
- The choice of levels of sophistication of the four components cannot, in general, be determined in the above sequence due to the existence of interdependence among the four components. It is, thus, desirable that this examination be carried out simultaneously.
- It is possible that for a specified resource transformation, the sophistication level analysis may generate more than one alternative combination of the four components. When this happens, the eventual decision as to which alternative is to be chosen would depend largely on economic factors.

Indicative Examples Illustrating the Choice of Levels of Sophistication of the Components of Technology

- When the "Scope" factor is high due to the occurence of high process temperatures or pressures the, in general, it will be necessary to use Technoware which is at a high level of sophistication.
- When the "Handling" factor is high due to complex physical attributes and/or movements, then, in general, it will be necessary to use Technoware which is at a high level of sophistication.
- When the "Precision" and "Control" factors are high, and if it is possible to use lower levels of Technoware, then a high level of Humanware will be necessary to achieve the desired resource transformation.
- When the "Scope" factor is high due to large output rates and product/component/material mixes, then a high level of Inforware will be necessary for economic operation of the resource transformation.
- In general as the "Scope" factor increases the level of Orgaware required also increases.

9. Phases of the Technology Component Life Chains

- If the pattern of the development of each of the four components of technology are examined, it is possible to perceive certain distinct phases in their growth process. These phases taken together may be called the Technology Life Chain and it is possible to describe a Life Chain for each component of technology. An advantage of examining the Life Chain of each of the four components is that it could help to identify the strengths and weakness of a nation at each of these phases. This could thus help in the assessment of the technological capability of a country with respect to the four components.

The Life Chain for Technoware

- The Life Chain for Technoware can be broadly classified into the following phases:
  - Researching/Selecting
  - Developing/Adapting
  - Testing
  - Demonstrating
  - Producing
  - Diffusing
  - Substituting

These phases are also shown schematically in the next page.

- The first two phases represent the origin of Technoware resulting from R&D activities. Two alternatives are shown to convey the fact that the Technoware need not necessarily emanate from within a country and that it can be selected from sources outside the country. It is also emphasized that if selected from exogenous sources, it is desirable to adapt the Technoware to suit the local environment.
- The next three phases namely, Testing, Demonstrating and Producing refer to the commercialization of the Technoware with potential for immediate utilization. This is a critical phase because many innovations are shelved in R&D laboratories and only a small percentage of these are commercialized. Successful commercialization depends on many technical, economic, social, legal and political factors.

Figure 9.1: Life Chain for Technoware

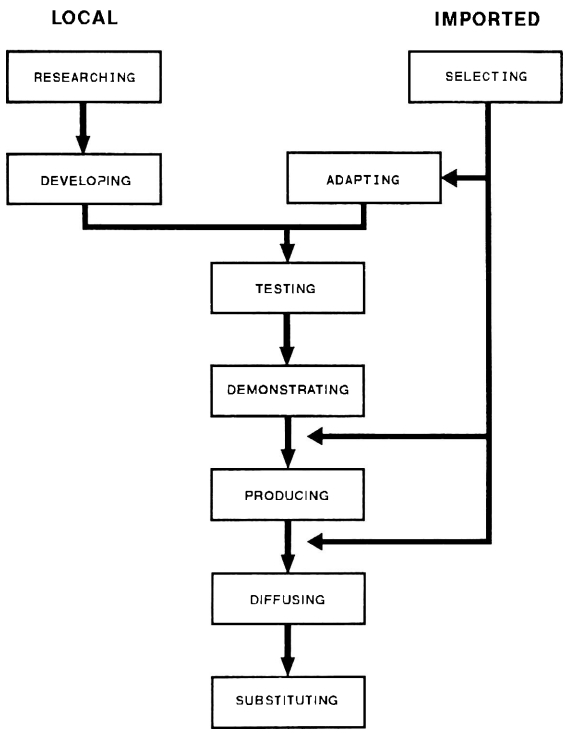


Figure 9.2: Life Chain for Inforware

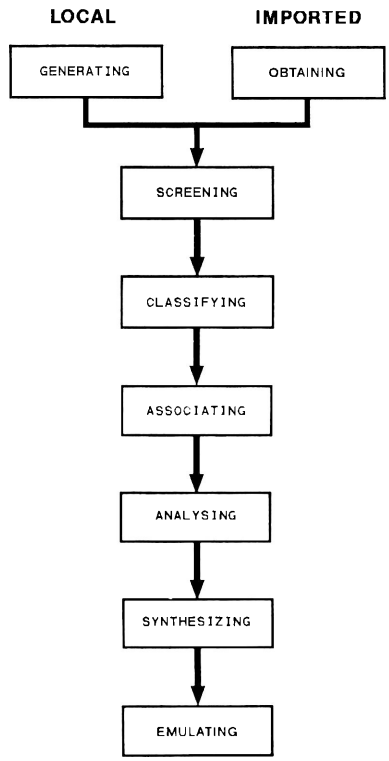


Figure 9.3: Life Chain for Humanware

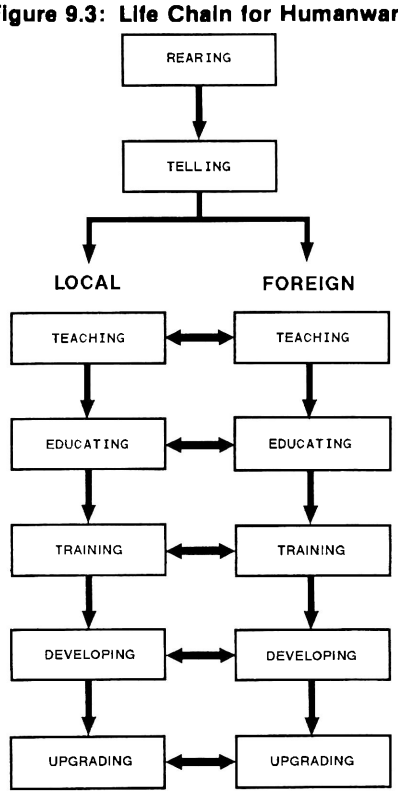
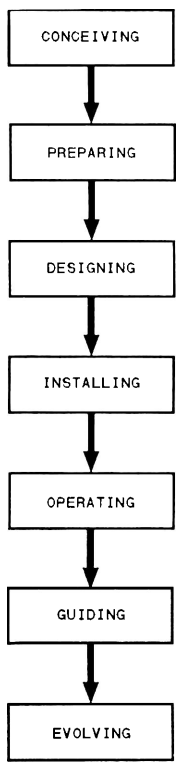


Figure 9.4: Life Chain for Orgaware



• The diffusion phase represents the market penetration of a Technoware through its acceptance by potential users. Both supply and demand factors jointly determine the rate of diffusion.

• The substitution phase represents the decline in the use and the eventual extinction of a Technoware due to its replacement by another. Many technical and non-technical factors influence the rate of substitution and the time taken in the substitution phase depends on the market dynamics.

The Life Chain for Inforware

• The Life Chain for Inforware can be broadly classified into the following phases:

— Collecting
— Screening
— Classifying
— Associating
— Analyzing
— Synthesizing
— Emulating

These phases are also shown schematically.

• The Collecting phase refers to the procurement of relevant information to meet a specific objective. The numerous sources that are currently available for this purpose include the following:

— Brochures and pamphlets
— Books and journals
— Government and business organization publications
— Handbooks and manuals
— Research reports
— Specially commissioned study reports
— Documentation service reports and abstracts

It is evident that information can be either generated locally or obtained from exogenous sources.

• The world today is witnessing a proliferation of information especially due to the rapid advancements in the fields of computers and telecommunication. Thus, it is imperative that the collected information be screened to ensure that only relevant and valid information is allowed to proceed on to the next phase of the Inforware Life Chain. This is carried out during the Screening phase.

• The next phase deals with the Classification of the collected and screened information from the point of view of potential users. The categories of users may include the following:

— Researchers
— Engineers
— Entrepreneurs
— Consultants
— Business planners
— National planners

• The fourth phase, namely Associating, deals with the grouping of various items of information to present a comprehensive picture of any area that is of interest. This phase too has to be necessarily user oriented.

• The Analyzing phase can be carried out only when Humanware at a fairly high level of sophistication is available. This phase focuses its attenton on providing comprehensive analyses, of an area of interest, based on information that has been generated during the associating phase. The comprehensive analyses generated attempt to provide and explain cause-effect relationships.

• While the first five phases may be said to deal mainly with areas of interest at the micro-level, the Synthesizing phase deals with areas of broader interest and requires the integration of several micro-level areas. This phase too requires very high levels of Humanware inputs. Generally the information generated in this sixth phase has implications for policy and strategy formulation.

• The Emulating phase, which is the last, deals with information generated as a result of the inputs provided by the previous six phases. It is an artificial representation of any real world situation for simulating actual operations. It would mainly consist of information pertaining to new knowledge, theories, designs, strategies and other developments with respect to a particular situation and reflects the capability of a firm or nation to generate state-of-the-art information based on complete digestion of existing information.

The Life Chain for Humanware

• The Life Chain for Humanware may be said to consist of the following phases:

— Rearing
— Telling
— Teaching
— Educating
— Training
— Developing
— Upgrading

These phases are also shown schematically.

• There is a general tendency to view labour as an expendable, substitutable factor of production. However, experience has shown that creation of effective human resources is a necessary prerequisite for economic development. This implies that it would be necessary to examine the process of Humanware development in a comprehensive manner instead of merely confining the examination to tertiary and higher education as in the past.

• The first phase, namely Rearing, covers the period from the birth of a child right up to the pre-school period and ranges about five years. It has already been well accepted that nutritional aspects during this period contribute substantially in determining the future physical and mental capabilities. However, research has indicated that the psycho-social environment too is important in

enhancing the development of mental capabilities. The development countries spend substantial resources in providing a sound psycho-social environment through pre-school education. In the developing countries, national efforts are minimal in this area and the existing facilities are generally availed of only by the urban elite.

- The next phase which is called Telling refers to the primary school phase of children. It is during this phase that children acquire the basic skills of reading, writing and arithmetic. This phase is very weak in many developing countries where the target of universal primary education is still a long way off.

- The third phase which is referred to as Teaching applies to the period of secondary education. It is during this phase that the ability to apply the knowledge learnt at school to everyday life is developed. Unfortunately in many developing countries the excessive emphasis on liberal arts, at the expense of science and technology, has led to a lack of appreciation of the importance of science and technology in national development.

- The Educating phase, which is the fourth, refers to formal technical and tertiary level education up to a Bachelor's degree or its equivalent. It is during this phase that formal skills in selected specialized fields are imparted. Here too, in many developing countries, the emphasis is in the liberal arts and thus from the development point of view these countries tend to produce too many people of the type not needed and too few of the type that is required.

- The Training phase is one that is often neglected by organizations in many developing countries. This phase is necessary to ensure that what has been learnt during the Educating phase is reinforced through the demonstration of its practical relevance. In some well managed organizations this takes the form of carefully planned orientation and on-the-job training. Some countries require the completion of a certain amount of prescribed practical training before the qualifications are formally recognized. The field of medicine is a good example. However, such mechanisms are rare in many developing countries and even if they do exist it is possible to perceive a lack of consistency and rigour in their implementation.

- The Developing phase refers to post-graduate education. R&D is a key element in technological growth. The rapid growth of technology implies that the Educating and Training phases alone cannot impart the specialized education necessary for undertaking high-level R&D work. Post-graduate education leading to post-graduate diplomas, masters and doctoral degrees is therefore essential for the development of high level Humanware. Due to resource constraints it may not be possible for many developing countries to set up institutions capable of imparting post-graduate education in many fields.

- The last phase, namely, Upgrading refers to the continuing education for Humanware. This is very often neglected in developing countries with the result that the knowledge of even high-level professionals quickly becomes obsolete along with a gradual decay in their abilities. This then is a matter of grave national concern because all the resources spent in the development of Humanware cannot be allowed to go waste due to skill and knowledge obsolescence.

The Life Chain for Orgaware

- The Life Chain for Orgaware may be considered to consist of the following phases:

  — Conceiving
  — Preparing
  — Designing
  — Installing
  — Operating
  — Guiding
  — Evolving

These phases are also shown schematically.

- One of the difficulties faced by many of the developing countries is that many of them are attempting to bring about rapid economic development with outdated and ineffective organizational arrangements. This has often led to failure of these development programmes. Thus, it is imperative that attention be paid to the Orgaware component to ensure that it does not become a barrier to national technology development programmes.

- The Conceiving phase as the name itself implies, refers to the recognition of the need to develop Orgaware for a specific purpose.

- The Preparing phase refers to the stage where anticipatory decisions are taken with respect to the objectives that have to be met by Orgaware that is to be developed.

- The Designing phase refers to the working out of the modalities through which the objectives are to be achieved. This may entail the formulation of goal-oriented systems, resource allocation, allocation of tasks to subsystems etc.

- The Installing phase refers to the setting up of the Orgaware and involves actual deployment of required resources and making the Orgaware operational in consonance with the objectives identified during the Preparing phase.

- The Operating phase is concerned with the actual operation of the Orgaware to achieve the identified objectives.

- The Guiding phase is concerned with ensuring conformity of operations to the objectives set and would involve the use of monitoring and feedback techniques.

- The Evolving phase is a logical sequence of the Guiding phase. During this phase, the relevance of the existing Orgaware is examined in the light of changes that may have taken place in the other three components and the external environment with a view towards adapting it.

10. Framework for Assimilation of Imported Technologies

• One major determinant of use of technology for development is the ability to assimilate imported technologies. It is not necessary that every country should develop every technology and in some cases it is better to use imported technology. Therefore, capability to assimilate imported technology becomes an important issue in development The steps involved in assimilation of imported technologies is given in tabular form. In the technology policy making circles, assimilation has received much attention because it needs a higher level of risk bearing capability.

Mastery of Imported Technology

• Technological mastery cannot be achieved by passively importing Technoware. It can result from adaptation (digestion) and upgradation of technoware and from indigenous efforts (generation). The mastery gained in assimilating Technoware helps in a number of ways.

- — enables greater indigenous participation in subsequent transfer of related Technoware, thereby increasing the effectiveness with which they are assimilated;
- — reduces the need for reinventing the wheel;
- — helps in leap-frogging certain generation (skipping some generation) to a higher level.

• In the case of importing Technology, Technoware can be bought internationally. Humanware can be imported temporarily, and success in acquiring the technological capability in a field depends primarily on local learning ability. Inforware, beyond the level of simple operating instructions, are usually not given to the ordinary technoware importer. Orgaware from abroad cannot easily be transplanted as such, and needs considerable adaptation to suit the local work conditions and practices. The above may explain why mere import of machinery and plants might not lead to technology transfer or capability building.

• Assimilation has to be basically a quick process otherwise the orginally imported source can provide again the next higher generation to the same buyer before the assimilation efforts succeed. The planning efforts for assimilation has to be comprehensive and quick.

Issues in Technology Assimilation

• The following are some of the major issues faced by developing countries with respect to technology assimilation:

- — In any field, technology is being continuously upgraded and unless the countries possess skill and capabilities needed for upgradation with respect to all four components of technology (Orgaware, Humanware, Inforware and Technoware), mere assimilation will not reduce obsolescence.
- — Assimilation of technology will also need upgradation of manufacturing facilities.
- — Upgradation of imported technologies need very strong technological monitoring and forecasting capability.
- — Many countries have primarily concentrated on importing mature Technoware for only consumer goods production. Transformation facilities for the production of Technoware has not received adequate attention.
- — When buying technologies from outside, achieving optimal combination of all the four components (Technoware, Humanware, Inforware and Orgaware) together might not be possible.
- — Technology decision makers have limited information except that provided by the sellers because of the absence of comprehensive technology monitoring mechanisms, and this makes it difficult to have comprehensive assimilation programmes.
- — Unless there is a proper plan for unpackaging critical components, assimilation efforts will be slow.
- — It is necessary to have strong commitment for assimilation of technology and without an Orgaware component the assimilation exercise will not be successful.

Steps Involved in Assimilation

• Important aspects with respect to assimilation of imported technologies can be understood by examining the steps involved. A schematic representation of the possible mechanisms for assimilation of imported technologies is shown in Page 30.

• Effective assimilation of imported Technoware requires matching investment in the three components of technology, in local R&D for development of suitable Humanware, Inforware and also compatible Orgaware. When Humanware is well developed in any particular technological area, buying Technoware is a lucky option. Developing Humanware and Inforware in identified areas seems to be the most important step in assimilating imported technology.

Prerequisites for Assimilation

• It is important that attention should be given to allt he four components of technology for strengthening the capabilities for assimilation. Country to country, the situation differ, but some of the prerequisites for the successful assimilation of imported technologies in developing countries are as follows:

Technoware: Facilities for testing, quality control and instrumentation related to the manufacturing of the required product.

Humanware: Skills for unpackaging and upgrading technology.

Inforware: A strong technology monitoring mechanism and a data base to support design, testing, instrumentation and production as well as upgradation

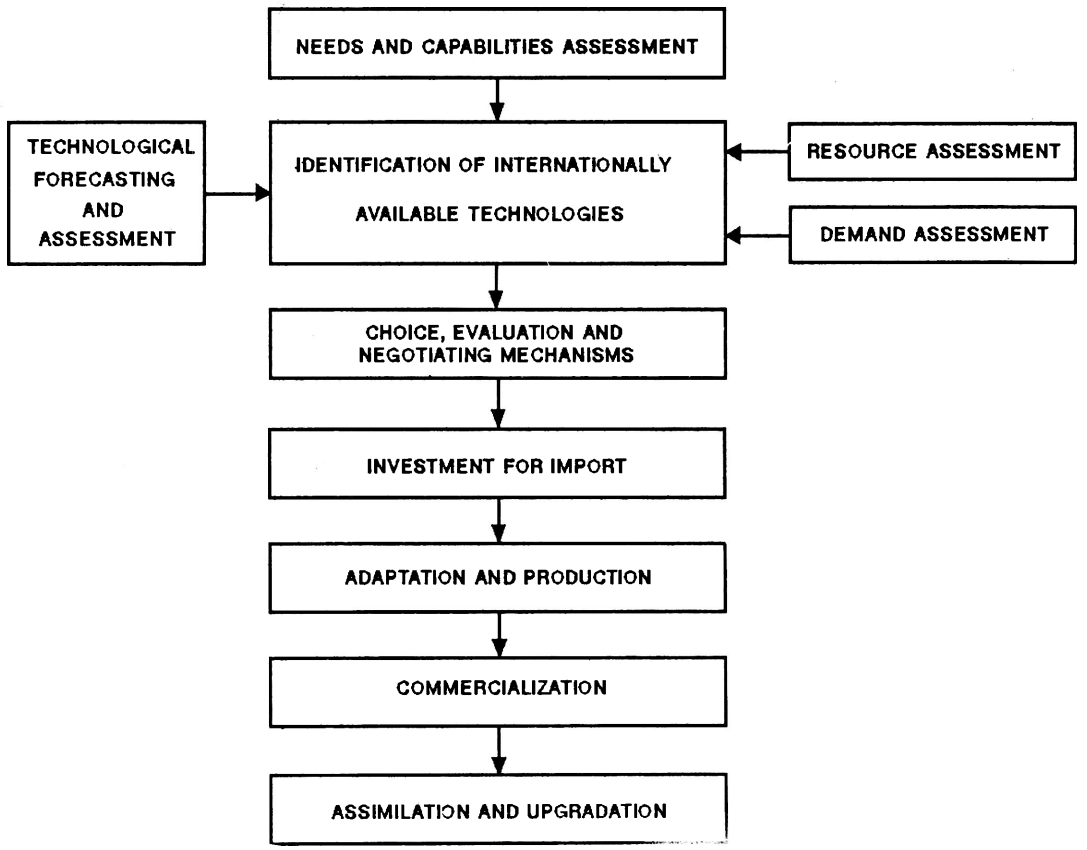
Orgaware: Government policies that can speed up assimilation;
Centres of excellence where assimilation is the major thrust
Mechanisms for identification of priority areas for assimilation
Incentives for successful assimilation efforts.

- Using the schematic representation shown, the capability of each country to assimilate imported technology can be analyzed by evaluating the existence and strength of various linkages.

Table 10.1: Framework for the Assimilation of Imported Technology

Steps Involved	Requirements with Respect to Four Components			
	Technoware	Humanware	Inforware	Orgaware
1. Needs and capability assessment	Facilities for storing analyzing and upgrading information	Assessment skills	Database and technology gaps and imports/exports	Institutional mechanism for assessment
2. Resource assessment		Assessment skills	Resource profile	
3. Technology forecasting and assessment		Forecasting and assessment skills	Technology trends	
4. Demand assessment		Market need assessment skills	Market trends	
5. Identification of internationally available technologies		Skills for searching	Technology database for specific areas	Criteria for identification
6. Choice, evaluation and negotiating mechanism		Negotiating management and legal skills	Proper service	Negotiating agencies
7. Investment for import		Skills for investment analysis	Industry performance profile	Foreign exchange credit providing agencies
8. Adaptation and production	Production facilities	Adaptation and setting up skills	Maintenance manuals and other documents	Entrepreneurial promotion agencies
9. Commercialization	Testing and maintenance equipments	Marketing skills	Feedback from users and field services	Distribution networks
10. Assimilation and upgradation	Design equipments, CAD and CAM equipments	Skills for unpackaging design and production engineering	Process simulation models and technology trends	Incentives for assimilation

Figure 10.1: Framework for Assimilation of Imported Technologies



11. Framework for Development of Indigenous Technology

• Another major determinant of the use of technology for development is the indigenous capability for generating technologies. The steps involved in the developement of indigenous technology is given in terms of Technoware, Humanware, Inforware and Orgaware in tabular form Strengthening of the indigenous technology development mechanism needs development of all phases in the life chains of Technoware, Humanware, Inforware and Orgaware.

Issues in Technology Generation

• One of the primary reasons for the ineffectiveness of R&D activities aimed at generation of technologies is the inadequate attention given to the four basic components of technology. When generating technologies indigenously, all basic components of technology have to evolve over time in a consistent and integrated way. Inadequate attention to any one of the components can produce a mismatch. Capability building with respect to generation of technology has to be viewed from this perspective.

• Technology generation needs strong design-engineering capabilities supported by prototype construction, testing and scaling up facilities.

• An up-to-date technology information base is needed which can help in evaluating the various options as well as supporting the development of state-of-the-art technology.

• Understanding the customer needs and developing strong marketing and supporting capabilities, has to proceed simultaneously along with efforts to develop Technoware.

• Because of the tremendous urge to generate indigenous technologies simultaneously, efforts are taken up in too many areas resulting in lack of focus, allocation of subcritical amounts of resources and spread of R&D in too many areas. This has to be avoided.

• Technology generation will need a thorough knowledge of the resources available (which will go as inputs) as well as their specific characteristics. Agricultural residues (in the Asian region) can be an example. Very little information is found on their availability, utilization and development of new fuels in order to design the required capital equipment, etc.

• In developing countries there is a tendency to avoid risk

taking. In a changing world, taking no risk is the highest risk of all. Unless an entrepreneurial spirit against a status quo mentality is promoted, new technologies will not be generated and utilized.

Prerequisites for Developing Indigenous Technology

- Indigenous technology development should give emphasis to all the necessary components in a balanced way. Development of indigenous technology has to be a coordinated effort covering a large number of organizations. This requires proper linkages, coordination mechanisms, incentives and a systematic policy planning process.

- Some of the prerequisities for developing the capability for generation of indigenous technology are as follows:

Technoware: Design-engineering and prototype construction facilities.

Humanware: Systematic skill development with strong technology orientation and continuous upgradation.
High levels of creative skills.

Inforware: A strong technologically oriented data base along with systematic monitoring and forecasting mechanisms.
Information resources available as well as their characteristics.
Design information and 'know-why' in specific areas rather than 'know-how'.

Orgaware: A mechanism for focussing the technology development process so as to reduce the dilution of thrust into too many areas.
Centres of excellence where technology generation is the thrust by coordinating Technoware, Inforware, Humanware and Orgaware so as to reduce the fragmentation of efforts under various agencies.
Mechanisms for identification of priority technologies for indigenous development.
Incentives for generation of new technologies.

- The trends of deliberate specilization throughout the world is expected to increase technological interdependence. Therefore, selectivity and specialization in generating technologies should be properly recognized. Natural resources and human capability being so widely scattered, attempting self-sufficiency is indeed uneconomical. It may be needed to foster small, flexible and innovative enterprises for technology development in selected areas. Active intermediaries for linking suppliers, and users of technology, particularly consulting firms, need support.

- Using the schematic representation shown, the capability of each country to generate technology can be analyzed by evaluating the existence and strength of various linkages

Figure 11.1: Framework for Generation of Indigenous Technology

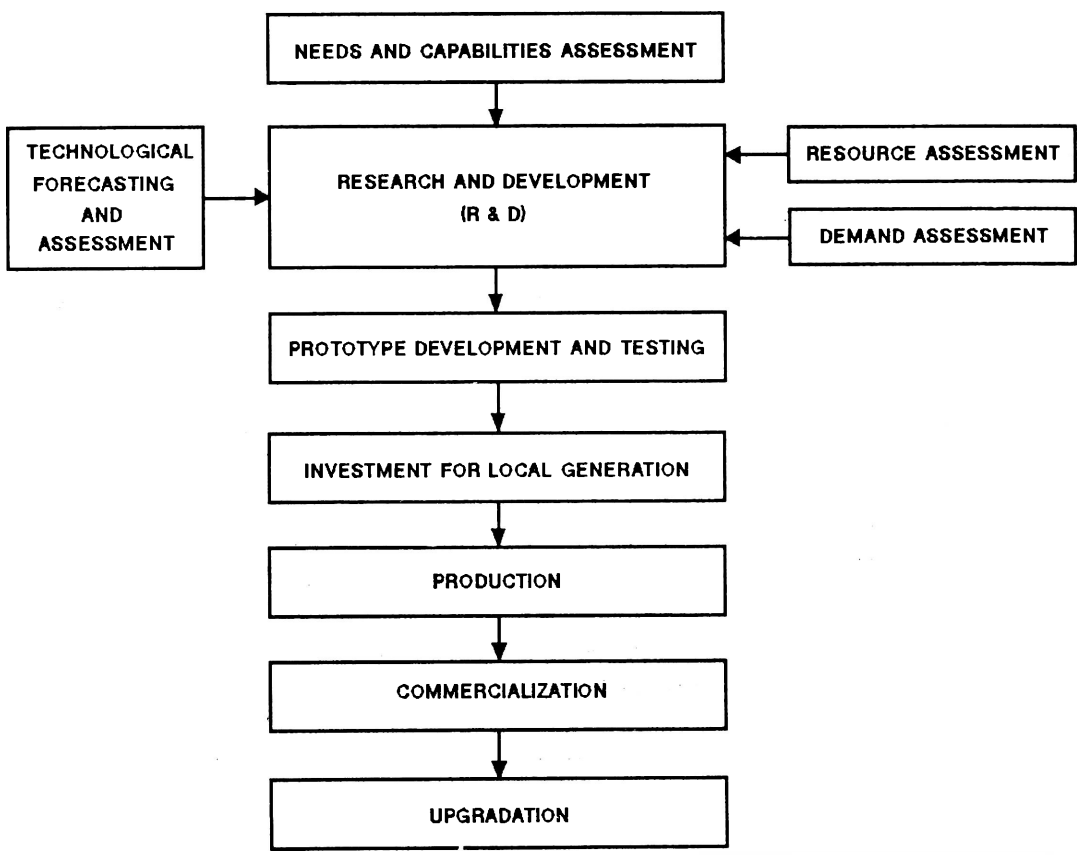


Table 11.1: Framework for the Development of Indigenous Technology

Steps Involved	Requirements with Respect to Four Components			
	Technoware	Humanware	Inforware	Orgaware
1. Needs and capability assessment	Facilities for storing analyzing and upgrading information	Assessment skills	Database and technology gaps	Institutional mechanism for assessment and analysis
2. Resource assessment		Assessment skills	Resource profile	
3. Technological forecasting and assessment		Forecasting and assessment skills	Technology trends	
4. Demand assessment		Market needs assessment skills	Market trends	
5. R&D		Skills for idea generation Skills for motivating creative technologists	Idea generation methods Technology database for specific areas	Project selection and management systems Integration of efforts into technology missions
6. Prototype development and testing		Design and engineering skills	Design manuals, "Know-why" collection	Test centres
7. Investment for local generation		Skills for investment analysis		Venture capital providing agencies
8. Production	Production facilities	Adapting and setting up skills	Maintenance manuals	Entrepreneurial development agencies
9. Commercial-ization	Testing and maintenance equipment	Marketing skills	Feedback from users and field services	Distribution networks, Market promotion agencies
10. Upgradation	Design equipments, CAD and CAM equipment	Skills for design and upgradation	Technology trends	Agencies for promoting indigenous generation

12. Technology Content Added at a Transformation Activity

• Current technology measurement activities generally focus their attention on the measurement of inputs into and the outputs from the science and technology system of a country. However, very little attention has been paid to the evaluation of the technological transformation activities which are really the key actors in transforming natural resources into produced resources. Thus, the evaluation of a transformation facility from a technological view point would go a long way in bridging this measurement gap.

The Concept of Technology Content Added (TCA)

• Economists have used the concept of value added to evaluate the monetary contribution of a production system to the national economy. However, no attempt has been made to disaggregate this total value added into the contributions made by the four components of technology (Technoware, Humanware, Inforware, Orgaware) which may provide a better vehicle for technology related decision-making.

• Value addedd can also be considered to be equal to the total cost of the factors of production (Technoware, Inforware, Humanware, Orgaware) used in effecting the input-output transformation. It has already been stated that the four components of technology are the transformers of natural resources into produced resources. Thus, these can be viewed as being equivalent to the factors of production. Based on this recognition it would seem reasonable to propose the measurement of the amount of "Technology Content" that is addedd at a transformation facility by these four components.

• The measurement of TCA therefore needs a close examination of the four components of technology and a good understanding of their unique features.

Measuring the Contribution of each Component of Technology at a Transformation Facility.

• Any given transformation facility can be sub-divided into its respective transformation stages. Thus, strictly speaking the technology contribution measurements of the four components has to be carried out at all these stages before being aggregated to give a composite measure. However, it has already been mentioned that it is often possible to view a transformation facility as predominantly being a particular transformation. Thus, it may be more useful, as a preliminary step, to view a transformation facility in this manner.

• The measurement of the contribution of Technoware could be the starting point. The contribution of the Technoware would have to be estimated by examining the four factors that have already been outlined, namely, Scope, Precision, Handling and Control. In addition the state-of-the-art of Technoware would also have to be examined. The criteria to be used in evaluating the state-of-the-art is presented in tabular form for the four components of technology. After an examination of the factors and state-of-the-art using expert opinion a score can be assigned to indicate the status of Technoware of the transformation facility. The suggested scoring procedure is shown in tabular form. The highest value of 9 indicated in the table refers to the best in the world and all scores would have to be made against this datum. This score will be denoted by "T".

Table 12.1: Criteria for the State-of-the-Art Assessment of the Technology Components

Technology Component	Criteria	Technology Component	Criteria
Technoware	Competitiveness Criteria : Technological figure of merit with respect to : - production and process attributes - energy utilization - yield	Inforware	Adequacy Criteria : * Adequacy with respect to : - ease of retrieval - linkages - updation - communication modes - networking modes
Humanware	Social Value Criteria : * Orientation with respect to : - creativity - achievement - affiliation - efficacy - risk bearing - decision-making - time	Orgaware	Cultural Influence Criteria: * Institutional effectiveness with respect to organizational - leadership - autonomy - direction - involvement - service orientation - innovation orientation - integrity - societal consciousness

Table 12.2: Table of Scores for Assessing Level of Technology Components

Level of Sophistication	Possible Scores			Level of Sophistication	Possible Scores		
I	1	2	3	V	5	6	7
II	2	3	4	VI	6	7	8
III	3	4	5	VII	7	8	9
IV	4	5	6				

- The measurement of the contribution of Humanware would follow a similar procedure where a score is assigned after examining the contributions of Humanware in Production, Evaluation, Planning and Control activities, and its state-of-the-art. The score for Humanware will be denoted by "H".

- The measurement of the contribution of Inforware would also proceed along similar lines with the information status in Production, Services, Research and Quality Assurance being examined along with the state-of-the-art of the Inforware. The score for Inforware will be denoted by "I".

- The Orgaware measurement would involve the examination of the linkages required in the functional areas of Marketing, Production, Personnel and Finance. The state-of-the-art factor too, will have to be examined before arriving at the score for Orgaware which will be denoted by "O".

- The estimation of T, I, H, O is thus the starting point for evaluating the Technology Content Added at a transformation facility.

Evaluation of the Technology Content Coefficient (TCC)

- It has already been mentioned that the four components of technology, taken together, contribute towards the Technology Content of a transformation facility. It is, thus, proposed that a Technology Content Coefficient (TCC) be defined by a multiplicative function as follows:

$$TCC = \alpha \cdot T^{\beta_1} \cdot I^{\beta_2} \cdot H^{\beta_3} \cdot O^{\beta_4}$$

where the β_i's may be called the intensity of contribution of each component towards the TCC and, α is the "climate factor" which is an index of the country's commitment to technology as evaluated by the effectiveness with which technology activities are facilitated by the national environment. The estimation of the α and β_i's would require expert opinion. As part of the Atlas Project specific case-studies will be undertaken to develop guidelines for the evaluation of α and the β_i's.

- The multiplicative model is intuitively appealing due to the fact that it satisfies the necessary properties listed below:

Property 1

T, I, H, O should all be strictly non-zero to ensure that TCC is non-zero. This is in accordance with the postulate that no transformation is possible without all four components of technology.

Property 2

Partial differentiation of the TCC function shows that if

$$O < \beta_i < 1$$

then it meets the condition of the simultaneous requirement of all four components while satisfying the practically recognized phenomenon that the law of diminishing returns operates when attempts are made to increase TCC by upgrading the level of only one component while keeping the others constant.

Property 3

It can also be shown that a proportionate increase of TCC would be equal to the sum of the proportionate increases of the four components weighted by the β_i's.

Property 4

By an extension of Property 3, it can be shows that if

$$\beta_1 + \beta_2 + \beta_3 + \beta_4 < 1$$

then the TCC function obeys the condition of decreasing returns to scale.

Property 5

The maximum value of TCC would be obtained only if $\alpha = 1$. This is recognised by actual experience which indicates that any transformation can deliver its full technological capability only if the national technology climate is of a supportive nature.

- Based on the above considerations it would be possible to summarize the important attributes of the TCC computation as follows:

  - Expert opinion should be used to obtain estimates for the values of T, I, H, O, α and the β_i's.
  - The maximum value attainable by T, I, H, O is 9.
  - The minimum value attainable by T, I, H, O is 1.
  - The maximum value attainable by α is 1.
  - The minimum value attainable by α is 0.
  - $0 < \beta_i < 1 \qquad i = 1, 2, 3, 4.$
  - $\beta_1 + \beta_2 + \beta_3 + \beta_4 < 1$
  - The theoretical maximum of TCC will be very close to 9.
  - The theoretical minimum of TCC will be 0.

Evaluation of the Technology Content Added (TCA)

- Once the TCC has been calculated the computation of the TCA requires only the economic value added (EVA) by the transformation facility. The expression for TCA then becomes,

$$TCA = TCC/9 \cdot EVA$$

- If the TCC is 9, then the TCA and the EVA become equal. If TCC < 9, then the TCA is less than the EVA.

- If one wants to make a monetary evaluation of the contribution of technology, then the above expression means that in the absence of market imperfections, the TCA could be considered as equivalent to EVA.

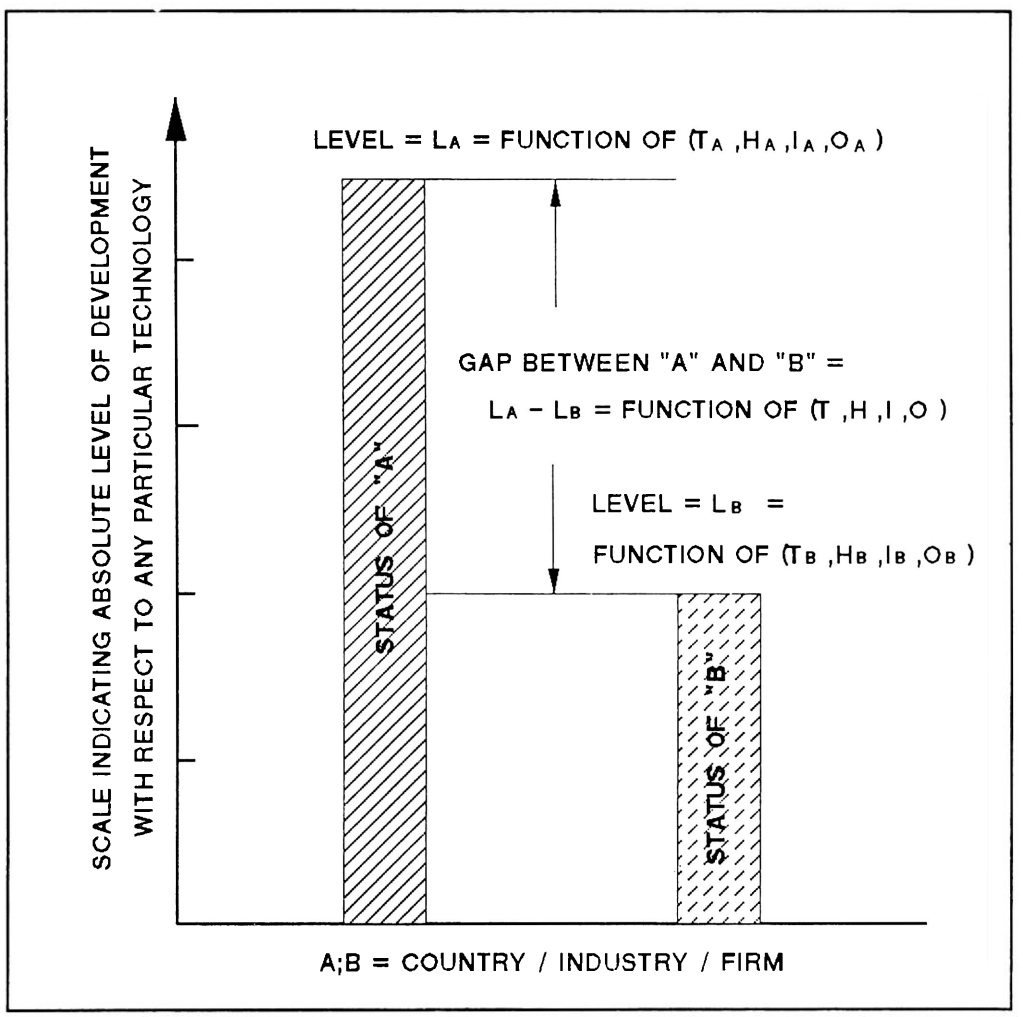
- Thus, it may be said that the TCA measurement is really a method to reinterpret the conventional EVA measurements in the light of the level of technological sophistication of the transformation facilities.

- The measurement of Technology Content Added (TCA) at a transformation facility, in addition to the traditional value added analyses, would be advantageous because TCA measurements can give a good indication of the technological capabilities of the transformation activities and also facilitate the evaluation of the real contribution of the components of technology to such activities.

13. Measurement of Gap and Level of Technological Development

- Though national policy planners and corporate decision-makers are aware of the existence of variations in the status of technology between two or more countries/industries/firms, very little efforts have been made for measuring this difference in quantitative terms. This section presents some methodologies for the evaluation of technological gaps and levels since these measures can give a better insight for technological decision-making. A schematic representation of technological gap and levels, is presented below.

Figure 13.1: Schematic Representation of Technological Gap and Level



Technology Level Measurement

- The status of a specific technology can be measured in an absolute way in the form of technology levels of specific elements. The measurement of technology levels in any field of activity can be carried out by disaggregating the technology into specific elements. Once a complex field (like steel or energy) is disaggregated then the levels of that particular technology can be assessed.

- The technology can be assessed in terms of a 0.0 to 1.0 rating system by compating the status of levels of specific elements of that technology. The scores are derived by normalizing a specific technical parameter with respect to the best value achieved for the figure of merit of that technology. For example, Japan uses 4.06 million kcals of energy per tonne of steel produced whereas India uses 9.5. Since a better technology has a lower level of energy use, Japan has a score of 0.9 and India 0.4. By comparing the status of various elements of steel technology, an aggregate index of level of steel technology can be derived.

Gap Analysis

- In many cases evaluation of absolute values of levels of technological development may be difficult. Gap analysis overcomes this difficulty by the measurement of the relative status of technology levels in an area. Gap analysis involves the identification of a measure as the figure of merit for a technology in a given field. The gap can be measured for the technology or after disaggregating the technology into its elements and then measuring the gap for each element. The indicator should be such that it represents the technology content.

- After identification of the gaps indicator, the status of technologies can be measured either qualitatively or quantitatively. Then the reasons for the existence of the gap could be identified in terms of the four basic components of technology (Technoware, Humanware, Inforware and Orgaware). This analysis provides better mechanism for evaluating action imperatives needed for reducing the gap.

Illustrations of Gap Analysis

- The iron and steel technology is used here to illustrate the gap analysis methodology. Relative differences in energy consumption for making iron and steel can also be used for illustrating the gap analysis. Specific energy consumption, that is, energy needed for making one tonne of steel (obtained by adding energy equivalents used in all transformation stages), for various countries (in million kcals per tonne of steel) can be used to measure the gaps in steel technology. The gap can be with respect to the best achieved figure in any country. For example, Italy uses 4.0, Japan 4.06, FRG 5.20, France 5.7, USA 6.0 and India 9.5 million kcals of energy per tonne of steel produced. Specific energy used for steel making is a good estimator since all measurements are in energy terms and not in monetary terms.

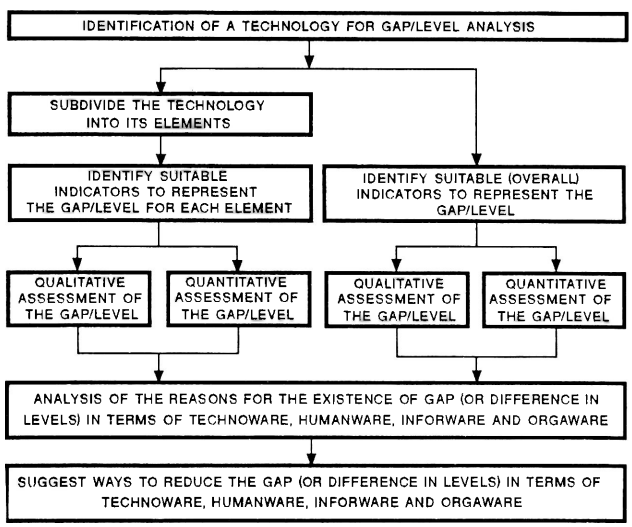
- In the case of agricultural technology, the gap can be measured in a relative sense with respect to the highest yield achieved so far for that crop.

- In the area of forest resources utilization technology, the gap can be measured using a parameter namely fuelwood used, as a percentage of total wood extracted.

- The analysis of the reasons for the existence of gap can help in identifying ways in which it can be reduced.

- Gap can also be measured at the industry level or firm level. A flow chart giving the salient features of gap/level analysis is given in schematic form.

Figure 13.2: Flowchart for Gap/Level Analysis



Implications of Gap

- A zero indicates that the technologies that are being compared are at the same level or state-of-the-art.

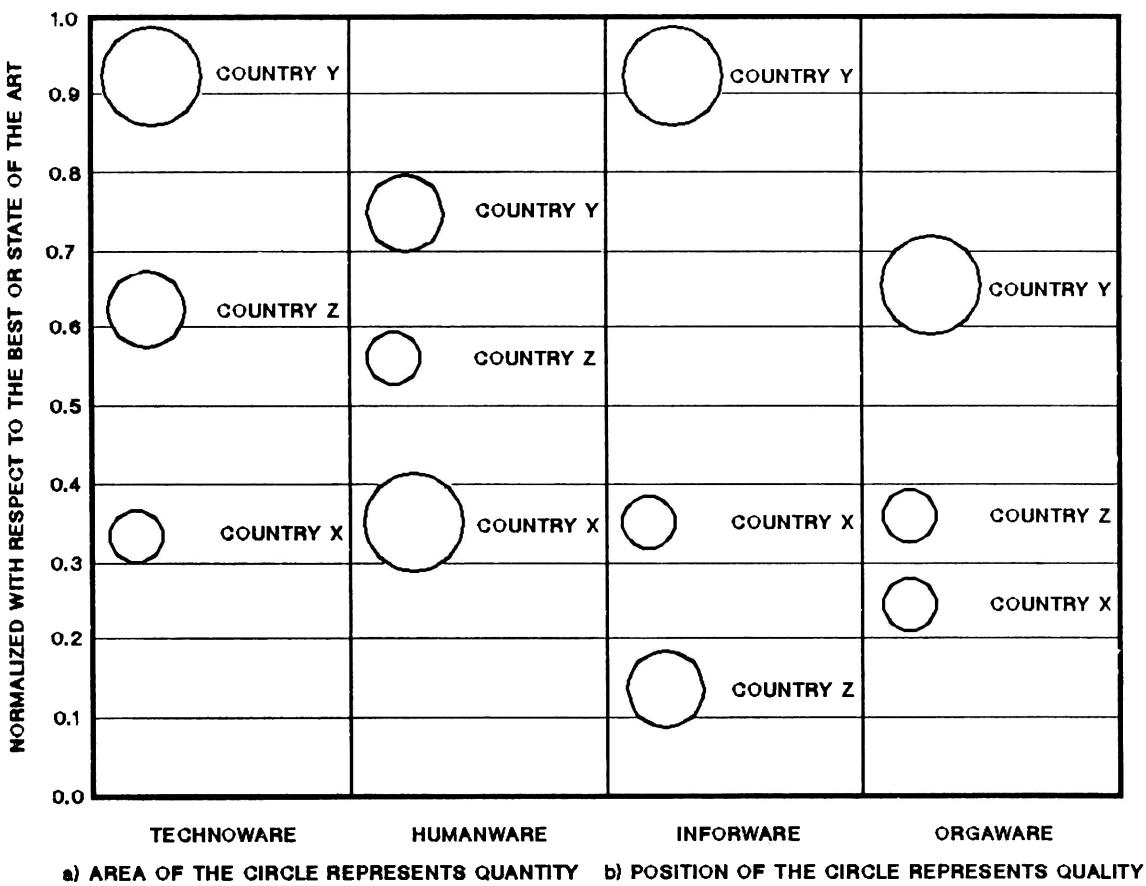
- A large gap with respect to the best technology indicates that there is a need to look into the reasons for its existence. A large gap also implies that there is a good potential for technology upgradation. Further, it indicates that substantial changes may be needed in Technoware, Humanware, Inforware and Orgaware, if the gap is to be reduced.

- A small gap indicates that the technologies that are being compared are almost at the same level.

Advantages of Gap/Level Analysis

- Some of the reasons why measuring gaps/levels would be more useful than the currently used S&T indicators are as follows:
  - — Using S&T indicators, it is not easy to measure gaps or changing levels of technology in a specific field.
  - — Gap/level analysis is better suited for comparison in any field since gap indicators are not distorted unlike publication counts or patent counts or resource indicators.
  - — The aggregate S&T indicators are not useful for assessing the status of the elements of technology in a disaggregated way, whereas gap analysis can pinpoint the deficiencies in each element of a technology. technology.
  - — Publication counts are biased towards the Inforware component and do not depict the status of Technoware per se, whereas gap analysis can indicate deficiencies in all the four components.
- Measuring gaps or levels of technologies in terms of Technoware, Humanware, Inforware, Orgaware has the following advantages.
  - — Policy makers can easily identify the weakness and can act on it to correct the deficiencies in various elements of a technology.
  - — Precise planning exercises can be initiated in terms of improving Technoware, Humanware, Inforware and Orgaware capabilities.
  - — Measurements in terms of technology components are sensitive to productivity changes which may otherwise remain undetected if only input/out indicators are used.
  - — Precise mapping of the entire field into elements of a technology and measuring the levels in each of this is possible.
- Detailed and disaggregated analysis of levels and gaps of technologies can be used for pinpointing the areas that need strengthening.
- The gap/level analysis may be presented in a visually recognizable form, as shown below:

Figure 13.3: A Comparative Representation of Technological Levels/Gaps



Part III
Contents of the Technology Atlas

14. Assessement of National Technology Climate

• In many of the developing countries of the ESCAP region, the absence of systematic and sustained efforts to maintain an updated database has been a barrier to the launching of well planned technology development programmes. Based on the experience gained during the APCTT Technology Policy Studies (1986), it was possible to conclude that some useful S&T related information are alredy available in many of these countries. Thus, one objective of the Technology Atlas is to provide profiles of the S&T scene in selected countries utilizing information available at various sources in these nations. The Technology Atlas will contain comprehensive S&T profiles of at least ten countries, based on detailed data collection, which is scheduled for completion in late 1987. As, a preliminary effort, S&T profiles are presented here for only a few countries based on information collected by APCTT during the Technology Policy Studies.

Level of Development as Measured by Classical Indicators

• The sectoral composition of GDP provides a reasonable measure of the technological advancement of a nation. In developing countries the sum of the shares of agricultural and mining sectors is likely to be higher than the individual shares of the other sectors. In the case of developed countries the manufacturing sector is likely to be the highest. This aspect is shown in tabular form below. However, a high GDP/capita need not necessarily reflect a high level of technology development in that country. Thus, for instance some countries which are very rich in natural resources (e.g. oil) are technologically weak but have a high GDP/capita.

Table 14.1: Levels of National Economic Activities

Type of Economic Activity	Gross Domestic Product (Year:1983) - Million US$					
	Japan		Sri Lanka		Thailand	
	Value	%	Value	%	Value	%
1. Agriculture, hunting, forestry and fisheries	39,186.1	3.31	1,244.8	26.28	8,888.7	22.12
2. Mining and quarrying	5,012.9	0.42	57.9	1.22	716.5	1.78
3. Manufacturing	361,033.6	30.49	697.7	14.73	7,660.9	19.06
4. Electricity, gas and water	38,794.1	3.28	65.4	1.38	709.6	1.77
5. Construction	93,342.0	7.88	388.4	8.20	2,049.1	5.10
6. Transport, storage and communication	82,179.2	6.94	446.5	9.43	3,204.8	7.98
7. Wholesale and retail trade	144,354.0	12.20	972.2	20.52	8,703.0	21.66
8. Banking, insurance and real estate	199,801.9	16.88	256.1	5.41	3,605.7	8.97
9. Community, social and personal services	272,364.3	23.01	412.2	8.70	4,646.5	11.56
10. Adjustments	- 52,097.3	- 4.41	195.8	4.13	-	-
Gross Domestic Product	1,183,970.8	100.00	4,737.0	100.00	40,184.8	100.00
Population in Millions (Year 1983)	119.48	-	15.42	-	49.46	-
GDP/Capita (US$)	9,909.00	-	307.20	-	812.50	-

• Basic demographic statistics can also be used to obtain a broad picture of technological development. In technologically advanced countries while the percentage of urban population and life expectancy are likely to be high, the crude birth and death rates, and infant mortality rates will be low. This is illustrated below in tabular form.

Table 14.2: Basic Demographic Statistics

Description	Demographic Statistics (Year:1983)		
	Japan	Sri Lanka	Thailand
Mid Year Population (millions)	119.48	15.42	49.46
Population Density (No./Sq.Km.)	304	242	100
Urban Population (%)	76	22	18
Crude Birth Rate (Per '000)	12.70	26.20	21.30
Crude Death Rate (Per '000)	6.20	6.10	5.10
Infant Mortality Rate (Per '000)	6.20	32.60	12.40
Expectation of Life at Birth			
Male	74	66	61
Female	80	70	65

• Classical health indicators too may reflect the level of S&T development in a country. High rates of physicians, dentists, nurses and hospital beds per capita are also useful indicators. However, as the level of economic development increases there may be a drop in per capita calorie intake at the expense of an increase in per capita protein intake. These aspects are shown below in tabular form.

Table 14.3: Basic Health Indicators

Description	Health Indicators (Year:1981)		
	Japan	Sri Lanka	Thailand
Physicians	162,900.00	2,989.00	6,931.00
Dentists	56,800.00	269.00	1,057.00
Nurses	546,600.00	7,040.00	37,942.00
Hospitals	9,403.00	388.00	359.00
Hospital beds	1,402,000.00	42,902.00	65,616.00
Mid-year Population (millions)	118.45	14.99	47.99
Physicians per 1000 population	1.38	0.19	0.15
Dentists per 1000 population	0.48	0.02	0.02
Nurses per 1000 population	4.61	0.47	0.80
Hospital beds per 1000 population	11.84	2.86	1.38
Protein per capita per day (gm)	79.00	47.00	47.00
Calories per capita per day (calories)	2,119.00	2,200.00	2,350.00

• The educational system of a country is a measure of its capability to produce the Humanware needed for technology development. However, indicators such as the student-teacher ratio, and students per institution will have to be interpreted carefully taking into consideration factors such as quality of teachers, teaching methods and degree of specialization of the institutions. Student enrolment profiles are tabulated below for some countries.

Table 14.4: Student Enrolment Profiles

Description	Enrolment Values (Year:1980)		
	Japan	Sri Lanka	Thailand
Primary and Secondary Schools			
- Number	24,900	9,117	35,149
- Number of students	11,827,000	3,280,000	7,449,000
- Number of teachers	471,000	143,182	416,729
- Student-teacher ratio	25	23	18
- Students per school	475	360	212
General and Vocational Schools			
- Number	16,700	22	248
- Number of students	9,521,000	9,321	1,572,000
- Number of teachers	494,900	689	16,557
- Student-teacher ratio	19	14	95
- Students per school	570	424	6,339
Tertiary Level Educational Institutions *			
- Number	1,900	7	25
- Number of students	2,503,800	18,111	162,000
- Number of teachers	246,500	1,827	13,263
- Student-teacher ratio	10	10	12
- Students per institution	1,318	2,587	6,480

* In the case of Thailand, the number of students and teachers are estimated values.

• The communication media of a country can play a key role in creating a technology culture by popularizing S&T ideas and activities. Thus, measurement of the status of mass communication systems of a country can provide useful insights into the strengths and weaknesses of its mass media. Some indicators for measuring mass communication aspects are tabulated below. In general, higher values of these measures indicate greater mass communication capabilities.

Table 14.5: Measures of Mass Communication Status

Description	Communication Statistics (Year:1980)		
	Japan	Sri Lanka	Thailand
Newspapers per 1000 population	396	17	42
Telephones per 1000 population	496	6	11
Radio receivers per 1000 population	677	81	127
Television receivers per 1000 population	249	4	17
Books published			
- Titles	45,596	1,875	4,091
- Percentage of S&T publications	22	13	21
Libraries			
- Number	44,878	1,253	N.A.
- Volumes per 1000 population	4,332	256	N.A.

Evaluation of Stock of S&T Personnel

• The stock of S&T personnel in a country assumes special importance because they cnstitute the higher levels of Humanware needed for self-reliant technology development. The number of S&T personnel in Sri Lanka and Thailand are tabulated below for comparative purposes. The table shows that a higher proportion of S&T personnel in Thailand, in the fields of Engineering, Agricultural and Medical Sciences, are engaged in R&D than in the case of Sri Lanka. The proportion of S&T personnel engaged in R&D, in the field of Natural Sciences, is higher in Sri Lanka.

Table 14.6: Stock of S&T Personnel by Field of Specialization

S&T Personnel by Field of Specialization	Number of S&T Personnel (Year:1984)					
	Sri Lanka			Thailand		
	Total	In R&D (% of total)		Total	In R&D (% of total)	
Engineering Sciences						
Engineers	3,017	115	(3.81)	20,689	2,338	(11.30)
Scientists	417	54	(12.95)	3,283	1,133	(34.51)
Technicians	983	44	(4.48)	176,538	13,769	(7.80)
Natural Sciences						
Engineers	608	113	(18.59)	66,070	10,565	(16.00)
Scientists	1,022	677	(66.24)	34,123	6,618	(19.39)
Technicians	650	233	(35.85)	43,058	919	(2.13)
Agricultural Sciences						
Engineers	126	17	(13.49)	11,345	2,269	(20.00)
Scientists	1,389	683	(49.17)	8,678	3,523	(40.60)
Technicians	1,120	305	(27.23)	38,752	25,847	(66.70)
Medical Sciences						
Engineers	1	-	(-)	7,341	-	(-)
Scientists	141	18	(12.77)	10,085	4,091	(40.57)
Technicians	60	4	(6.77)	12,917	-	(-)

S&T Personnel by Field of Specialization	Number of S&T Personnel (Year:1984)					
	Sri Lanka			Thailand		
	Total	In R&D	(% of total)	Total	In R&D	(% of total)
Social Sciences						
Engineers	62	-	(-)	6,007	1,129	(18.70)
Scientists	125	27	(21.60)	9,851	-	(-)
Technician	140	6	(4.29)	30,140	-	(-)
Overall Totals						
Engineers	3,814	245	(6.42)	111,452	16,301	(14.63)
Scientists	2,967	1,459	(49.17)	66,020	15,365	(23.27)
Technicians	2,953	592	(20.05)	301,405	40,435	(13.42)

• In all categories of S&T personnel, the number per 1000 population, is much higher in Thailand than in Sri Lanka. This is summarized in tabular form.

Table 14.7: S&T Personnel Per 1000 Population

Description	Number of S&T Personnel (Year:1984)		Description	Number of S&T Personnel (Year:1984)	
	Sri Lanka	Thailand		Sri Lanka	Thailand
Total engineers	3,814	111,452	Engineers per 1000 population	0.24	2.21
Total engineers in R&D	245	16,301	R&D engineers per 1000 population	0.02	0.32
Total scientists	2,967	66,020	Scientists per 1000 population	0.19	1.31
Total scientists in R&D	1,459	15,365	R&D scientists per 1000 population	0.09	0.30
Total technicians	2,953	301,405	Technicians per 1000 population	0.19	5.98
Total technicians in R&D	592	40,435	R&D technicians per 1000 population	0.04	0.80
Mid-year population (millions)	15.60	50.40	S&T personnel per 1000 population	0.62	9.50

• An examination of the table of distribution of S&T personnel by sector of performance shows that it is the General Service Sector that employs the largest number in Sri Lanka. In the case of Thailand, it is the Production Sector that consistently accounts for the largest number of S&T personnel.

Table 14.8: Distribution of S&T Personnel by Sector of Performance

Description	Number of S&T Personnel (Year:1984)		Description	Number of S&T Personnel (Year:1984)	
	Sri Lanka	Thailand		Sri Lanka	Thailand
Engineers			Technicians		
Total Stock	3,814	111,452	Total Stock	2,953	301,405
Percentage in Production Sector	38.2	49.0	Percentage in Production Sector	29.4	64.3
Percentage in Higher Education Sector	4.1	26.6	Percentage in Higher Education Sector	8.1	6.1
Percentage in General Service Sector	57.7	24.4	Percentage in General Service Sector	62.5	29.6
Scientists					
Total Stock	2,967	66,020			
Percentage in Production Sector	24.6	59.7			
Percentage in Higher Education Sector	19.3	19.8			
Percentage in General Service Sector	56.1	20.5			

• The qualification profile of S&T personnel tabulated shows that a larger percentage of engineers and scientists in Thailand have post-graduate qualifications. However, the percentage of engineers and scientists with doctoral degress is higher in Sri Lanka than in the case of Thailand. This does not imply that the absolute figures are higher.

Table 14.9: Qualification Profile of S&T Personnel

Description	Percentage Distribution of S&T Personnel (Year:1984)			
	Sri Lanka		Thailand	
	Total	In R&D	Total	In R&D
Engineers				
Percentage with only Bachelors Degree or equivalent	89.1	62.9	84.3	47.7
Percentage with Post Graduate Diploma and/or Masters Degree	9.1	20.4	13.7	46.3
Percentage with Doctoral Degree	1.8	16.7	2.0	6.0
Scientists				
Percentage with only Bachelors Degree or equivalent	72.6	61.2	67.8	56.7
Percentage with Post Graduate Diploma and/or Masters Degree	15.2	18.9	26.9	38.7
Percentage with Doctoral Degree	12.2	19.9	5.3	4.9

Evaluation of R&D Activities

• R&D expenditure evaluation provides a means of understanding the type of emphasis given by a country with respect to technology development. R&D current and capital expenditures are tabulated below for Sri Lanka and Thailand. In the case of Sri Lanka it can be seen that both the Production and General Service Sectors emphasize Applied Research while the Higher Education Sector focuses its attention on Applied and Basic Research. On the contrary, in Thailand, the Production Sector spends an overwhelming proportion of its current expenditure on Development while distributing most of its capital expenditure on Applied Research. The Higher Education Sector in Thailand appears to follow a pattern similar to Sri Lanka with respect to R&D expenditure. However, the General Services Sector in Thailand appears to distribute its R&D expenditure somewhat evenly over the three sectors but with a bias towards Basic Research.

Table 14.10: Current Expenditure on R&D by Sector of Performance

Description	R&D Current Expenditure			
	Sri Lanka (1984)		Thailand (1985)	
	Manpower Costs	Other Costs	Manpower Costs	Other Costs
Production Sector				
Total current expenditure (US$)	341,362	123,630	15,343,930	806,779
On Basic Research (% of total)	0.72	0.83	6.70	2.67
On Applied Research (% of total)	88.57	81.20	8.94	1.88
On Development (% of total)	10.71	17.97	84.36	95.45
Higher Education Sector				
Total current expenditure (US$)	72,793	479,528	20,759,471	323,043

Description	R&D Current Expenditure			
	Sri Lanka (1984)		Thailand (1985)	
	Manpower Costs	Other Costs	Manpower Costs	Other Costs
On Basic Research (% of total)	49.97	50.00	54.88	39.75
On Applied Research (% of total)	40.05	40.00	30.43	38.20
On Development (% of total)	9.98	10.00	14.69	22.05
General Services Sector				
Total current expenditure	3,234,703	2,178,805	42,083,048	1,127,042
On Basic Research (% of total)	8.61	6.57	44.30	35.53
On Applied Research (% of total)	72.18	79.51	26.48	22.17
On Development (% of total)	19.21	13.92	29.22	42.30
All Sectors				
Total current expenditure (US$)	3,648,858	2,781,963	78,186,449	2,256,864
On Basic Research (% of total)	8.70	13.80	39.73	24.39
On Applied Research (% of total)	73.07	72.77	24.09	17.21
On Development (% of total)	18.23	13.43	36.18	58.40

Table 14.11: Capital Expenditure on R&D by Sector of Performance

Description	R&D Capital Expenditure			
	Sri Lanka (1984)*		Thailand (1985)**	
	Plant and Equipment Costs	Other Costs	Plant and Equipment Costs	Other Costs
Production Sector				
Total Capital Expenditure	210,807	27,310	1,037,851	874,570
On Basic Research (% of total)	0.45	11.78	34.00	34.00
On Applied Research (% of total)	70.58	73.63	56.00	56.00
On Development (% of total)	28.97	14.59	10.00	10.00
Higher Education Sector				
Total Capital Expenditure	27,435	34,323	7,952,516	6,701,318
On Basic Research (% of total)	50.00	50.00	60.00	60.00
On Applied Research (% of total)	40.00	40.00	28.00	28.00
On Development (% of total)	10.00	10.00	12.00	12.00
General Services Sector				
Total Capital Expenditure	1,514,193	1,208,029	12,512,939	10,186,268
On Basic Research (% of total)	8.84	5.21	51.00	51.00
On Applied Research (% of total)	77.40	75.65	30.00	30.00
On Development (% of total)	13.76	19.14	19.00	19.00
All Sectors				
Total Capital Expenditure	1,752,435	1,269,482	21,078,506	17,762,156
On Basic Research (% of total)	8.48	6.58	54.00	54.00
On Applied Research (% of total)	76.00	74.63	30.00	30.00
On Development (% of total)	15.52	18.79	16.00	16.00

* Breakdown of capital expenditure for the Higher Education Sector are estimates made by the University of Grants Commission, Sri Lanka

** Breakdown of capital expediture for all sectors are estimates made by the Ministry of Science, Technology and Energy, Thailand.

• An examination of current and capital expenditures on R&D by field of specialization shows that Sri Lanka spends an overwhelming percentage of its R&D expenditure on the Agricultural Sciences. Thailand appears to emphasize heavily on the Medical and Agricultural Sciences. In the field of Engineering Sciences the emphasis placed by Thailand appears to be extremely low.

Table 14.12: Current Expenditure on R&D by Field of Specialization

Field of Specialization	Expenditure as a Percentage of Total					
	Sri Lanka (1984)			Thailand (1985)		
	Basic Research	Applied Research	Develop-ment	Basic Research	Applied Research	Develop-ment
Engineering Sciences	0.50	4.85	16.89	0.26	0.44	0.97
Earth and Space Sciences	4.31	1.39	0.79	2.98	0.67	0.67
Physical Sciences	4.88	2.38	3.89	10.42	11.36	3.67
Biological Sciences	12.63	6.15	3.30	21.67	18.09	0.52
Mathematics and Computers	2.18	0.88	0.49	2.87	8.56	1.51
Agricultural Sciences	46.98	64.36	70.22	11.31	16.64	24.79
Medical Sciences	16.21	3.43	2.30	34.11	23.53	62.46
Social Sciences	10.21	16.31	1.84	16.14	20.39	4.97
Aesthetic Sciences	2.10	0.25	0.28	0.24	0.32	0.44
Total Percentage	100.00	100.00	100.00	100.00	100.00	100.00
Total Expenditure ('000 US$)	701	4,691	1,039	31,613	19,220	29,611

Table 14.13: Capital Expenditure on R&D by Field of Specialization

Field of Specialization	Expenditure as a Percentage of Total					
	Sri Lanka (1984)			Thailand (1985)		
	Basic Research	Applied Research	Develop-ment	Basic Research	Applied Research	Develop-ment
Engineering Sciences	0.00	23.60	15.11	0.34	0.54	2.74
Earth and Space Sciences	5.89	2.45	1.04	2.37	1.08	1.38

Field of Specialization	Expenditure as a Percentage of Total					
	Sri Lanka (1984)			Thailand (1985)		
	Basic Research	Applied Research	Develop-ment	Basic Research	Applied Research	Develop-ment
Physical Sciences	6.95	3.62	3.57	11.45	14.52	9.58
Biological Sciences	19.67	8.49	3.18	18.57	10.74	1.34
Mathematics and Computers	2.89	1.21	0.51	3.03	2.69	4.11
Agricultural Sciences	44.16	51.12	74.11	15.83	30.11	42.46
Medical Sciences	16.59	3.75	1.77	29.28	24.73	28.78
Social Sciences	3.85	5.76	0.71	18.86	15.06	8.23
Aesthetic Sciences	0.00	0.00	0.00	0.33	0.53	1.35
Total Percentage	100.00	100.00	100.00	100.00	100.00	100.00
Total Expenditure ('000 US$)	232	2,279	511	20,873	11,795	6,173

• An examination of sources of funds for R&D shows that in the case of Sri Lanka the Government provides almost 90% of the funds while productive enterprise funds are minimal. Foreign funds too do not constitute a large percentage of R&D funds in Sri Lanka. On the contrary, foreign funds account for the largest percentage for Basic and Applied Research in Thailand. The Government of Thailand contributes almost 80% of the funds for Development. Productive enterprises in Thailand contribute very little towards R&D.

Table 14.14: Sources of Funds for R&D

Source of Funds	Expenditure as a Percentage of Total					
	Sri Lanka (1984)			Thailand (1985)		
	Basic Research	Applied Research	Develop-ment	Basic Research	Applied Research	Develop-ment
Government (% of total)	92.27	81.05	87.76	36.00	34.00	78.75
Productive Enterprise Funds (% of total)	0.23	1.54	1.37	7.00	0.80	0.05
Foreign Funds (% of total)						
- Bilateral	3.91	5.78	-	45.00	47.20	18.89
- Multilateral	3.59	11.63	10.87	8.00	14.00	0.43

Source of Funds	Expenditure as a Percentage of Total					
	Sri Lanka (1984)			Thailand (1985)		
	Basic Research	Applied Research	Develop-ment	Basic Research	Applied Research	Develop-ment
Special Funds (% of total)	-	-	-	4.00	4.00	1.88
Total	100.00	100.00	100.00	100.00	100.00	100.00
R&D Expenditure ('000 US$)						
- Current Expenditure	701	4,691	1,039	31,613	19,220	29,611
- Capital Expenditure	232	2,279	511	20,873	11,795	6,173
- Total	933	6,970	1,550	52,486	31,015	35,784

• When the distribution of R&D expenditure by major socio-economic aims is examined, it is seen that the development of agriculture, forestry and fisheries accounts for almost 60% of total R&D expenditure in Sri Lanka. In Thailand the largest amount is spent on development of health services with almost equal emphasis being placed on other areas such as development of agriculture, energy conservation, development of transport/communica-tion, and social development. It is of interest to note that Sri Lanka spends very little by way of R&D on production, conservation and distribution of energy in spite of the fact that it imports all its fuel requirements.

Table 14.15: Distribution of R&D Expenditure by Major Socio-Economic Aims

Major Socio-Economic Aims	Percentage of R&D Expenditure		Major Socio-Economic Aims	Percentage of R&D Expenditure	
	Sri Lanka (1984)	Thailand (1985)		Sri Lanka (1984)	Thailand (1985)
Exploration and assessment of biosphere	-	3.08	Development of health services	1.19	13.32
Utilization of civil space for social welfare	-	0.35	Development of urban/ rural settlements	0.36	0.74
Development of agriculture, forestry and fisheries	59.72	11.83	Social development and socio-economic services	6.37	11.44
Promotion of industrial development	19.93	8.33	Protection of the environment	0.12	3.73
Production, conservation and distribution of energy	0.81	11.78	General advancement of knowledge	4.50	7.41
Development of transport/ communication	0.14	10.46	Defence	0.18	8.44
Development of educational services	6.68	8.69	Others	-	0.40
			Total (of all 14 areas)	100.00	100.00

• Macro-level indicators of R&D expenditures, given in tabular form, shows that both Sri Lanka and Thailand are nowhere near the target of spending 1% of GDP on R&D. The R&D expenditure per capita of Thailand while low, is about 4 times higher than that of Sri Lanka.

Table 14.16: Macrolevel Indicators of R&D Efforts

Description	Sri Lanka (1984)	Thailand (1985)
Total R&D Expenditure (US$)	9,452,738.00	119,283,975.00
Mid-year population (millions)	15.60	51.71
Stock of S&T personnel (number)	9,734.00	478,877.00[a]
GDP (millions of US$)	5,258.00	41,131.00[b]
R&D expenditure per capita of population (US$)	0.61	2.31
R&D expenditure per S&T personnel (US$)	971.00	249.00
R&D expenditure as a percentage of GDP	0.18	0.29

[a] 1984 values; [b] estimates

Evaluation of the Technology Scene in Industry

• The level of technology development in industry can be broadly perceived by examining the contribution made by the different branches of economic activity towards GDP. This data is tabulated below for Sri Lanka and Thailand. In 1980, the agriculture, hunting and fisheries sector contributed most towards the GDP for both Sri Lanka and Thailand. This pattern has persisted in the case of Sri Lanka in 1984, while in Thailand the manufacturing sector has become the most dominant. Also in the case of Sri Lanka, the percentage share of the manufacturing sector has come down from the 1980 value. This pattern of development may thus be said to reflect an increase in the technology content of the economic activities in Thailand during the period 1980-1984.

Table 14.17: Contribution of Branches of Economic Activity to GDP

Branches of Economic Activity	Percentage Contribution to GDP			
	Sri Lanka		Thailand	
	1980	1984	1980	1984
ISIC 1 : Agriculture, hunting and fisheries	27.25	29.38	25.38	19.51
ISIC 2 : Mining and quarrying	2.02	2.31	2.12	2.15
ISIC 3 : Manufacturing	17.87	15.29	19.64	19.85
ISIC 4 : Utilities	0.97	1.20	0.92	1.90
ISIC 5 : Construction	8.98	8.18	5.81	5.32
ISIC 7 : Transport, storage and communication	8.56	11.34	6.61	8.43
ISIC 6,8,9 : Other Services	33.85	33.20	39.52	42.84
TOTAL	100.00	100.00	100.00	100.00

• The overall export to import ratios with respect to different commodities, can give a good indication as to the technological capability of a country in producing and selling these commodities in the international market. Some relevant information is tabulated below for Sri Lanka and Thailand. This reflects the fact that both these countries still rely on low technology content commodities such as agricultural raw materials and food items for their foreign exchange earnings (ratios greater than 1). However, the overall picture appears to be better for Thailand than Sri Lanka. Although it imports all its fuels and combustibles, Sri Lanka appears to have used its strategic geographical location to export refined fuels.

Table 14.18: Export to Import Ratios of Main Categories of Commodities

Description	Average Export/Import Ratios over the period (1975-1982) based on Monetary Values	
	Sri Lanka	Thailand
Food items [SITC: 0 + 1 + 22 + 44]	1.35	8.11
Agricultural raw materials [SITC: 2 less (22 + 27 + 28)]	6.63	1.91
Fuels and combustibles [SITC: 3]	0.27	negligible
Ores and Metals [SITC: 27 + 28 + 67 + 68]	0.26	0.73
Manufactured Goods 0.47 [SITC: 5 + 6 + 7 + 8 less (67 + 68)]		0.27

• More detailed import and export profiles are also tabulated below for all categories of items for Sri Lanka and Thailand. This information too reflects the weakness of these countries in the trading of high technology products (SITC:5 and 7). However, in both these nations the value of imports per capita appears to have come down, during the period 1980-1985, while the value of exports per capita has registered a modest increase.

Table 14.19: Import and Export Profile

Categories of Imports/Exports	Value of Imports/Exports (nearest million US$)							
	Sri Lanka				Thailand			
	1980		1985		1980		1985	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
SITC:0 - Food and live animals	250	444	250	552	281	2,891	347	3,182
SITC:1 - Beverages and tobacco	136	6	106	11	74	68	83	61
SITC:2 - Crude materials (inedible) except fuels	130	28	137	38	524	930	580	721
SITC:3 - Mineral fuels/ lubricants/ others	482	71	417	65	2,861	4	2,085	90
SITC:4 - Animal and vegetable oils/fats	3	4	13	38	71	11	18	21
SITC:5 - Chemicals	125	5	137	7	1,089	46	1,292	90
SITC:6, 8 - Manufactured goods	267	400	368	532	1,906	1,849	2,090	2,201
SITC:7 - Machinery	466	4	366	7	2,100	371	2,593	624
Total	1,859	962	1,794	1,250	8,906	6,170	9,088	6,990
Mid-year population (millions)	14.75		15.60		46.46		51.71	
Imports/Exports per capita (US$)	126	65	115	80	192	133	176	135

• The import and export profiles of selected technology intensive industries are tabulated below for Sri Lanka and Thailand. The data shows that Sri Lanka is overwhelmingly dependent on foreign sources for technology intensive industry products. In the case of Thailand this dependence is moderated by the fact that it has developed some capabilities in the areas of electrical equipment, primary metals, and fabricated metal products.

Table 14.20: Import and Export Profile of Selected Technology Intensive Industries

Technology Intensive Industries	Value of Imports/Exports (nearest million US$)							
	Sri Lanka				Thailand			
	1980		1985		1980		1985	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Chemicals and allied products (ISIC:35)	125	5	137	7	1,751	89	1,573	138
Machinery (ISIC: 3821-3825, 3829)	189	2	140	5	508	14	777	92
Electrical equipment (ISIC: 3831-3839)	86	0.6	84	1	453	331	418	351
Aircraft and missiles (ISIC: 3845)	5	0.2	30	0.3	250	0.1	95	2
Professional and scientific equipment (ISIC: 3851,3852)	14	0.2	20	0.6	149	22	227	47
Primary metals (ISIC: 37)	114	0.9	100	6	812	610	819	319
Fabricated metal products (ISIC: 381)	13	0.1	16		830	110	987	128
Motor vehicles (ISIC: 3843,3844)	167	0.3	110	0.4	385	13	375	15
Other transportation equipment (ISIC: 3841,3842, 3849)	20	1.0	2	0.3	48	1	97	2
Total	733	10.3	639	20.6	5,186	1,190.1	5,368	1,094

• The statistics on patents and trademarks is often used as a measure to evaluate the level of technological innovation in a country. While time series data has to be used to form firm conclusions, information for 1981 and 1985 is tabulated for Sri Lanka and Thailand. It can be seen that in the case of Sri Lanka, low levels of indigenous innovative activities are indicated by the fact that only about 25% (in 1981) and 16% (in 1985) of the patents awarded went to Sri Lankan sources. In the case of Thailand, the patenting performance of local sources appears to have improved sharply in 1985. In the case of trademarks too Sri Lankan performance appears to have dropped during the 1980-1985 period while Thailand has made significant progress.

Table 14.21: Patents Applied For and Granted

Categories	Patent Applications Filed and Granted*							
	Sri Lanka				Thailand			
	1981		1985		1981		1985	
	Filed	Granted	Filed	Granted	Filed	Granted	Filed	Granted
National								
Individuals	2	10	22	13	29	3	124	62
Companies	3	5	4	1	21	1	62	17
Government	1	4	2	4	-	-	-	-
Total	6	19	28	18	50	4	186	79
Non-national								
Individuals	37	15	17	25	8	1	38	2
Companies	55	39	51	52	363	20	765	12
Government	10	4	12	17	-	-	-	-
Total	102	58	80	94	371	21	803	14
Percentage accounted for by								
- national individuals	1.85	13.00	20.37	11.61	6.89	12.00	12.54	66.47
- national companies	2.78	6.49	3.70	3.57	5.00	4.00	6.27	18.28
- national governments	0.93	5.19	1.85	0.89	-	-	-	-
Percentage accounted for by								
- non-national individuals	34.26	19.48	15.75	22.32	1.90	4.00	3.84	2.15
- non-national companies	50.92	50.65	47.22	46.32	86.21	80.00	77.35	12.90
- non-national governments	9.26	5.19	11.11	15.18	-	-	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* During a given year the number of patents awarded can exceed the number applied for if a backlog of applications has been cleared.

Table 14.22: Trademarks Applied For and Granted

Categories	Trademark Applications Filed and Granted							
	Sri Lanka				Thailand			
	1981		1985		1981		1985	
	Filed	Granted	Filed	Granted	Filed	Granted	Filed	Granted
National	855	133	1,131	255	3,382	201	5,235	1,546
Non-national	655	113	766	526	2,557	55	2,819	48
Percentage accounted for by national bodies	56.60	54.10	59.60	32.70	56.90	78.50	65.00	97.00
Percentage accounted for by international bodies	43.40	45.90	40.44	67.30	43.10	21.50	35.00	3.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Evaluation of the Academic S&T Scene

• The academic S&T scene plays a major role in technology development since it is here that high level Humanware is produced. Some relevant data on number of degree awarding institutions and their student, faculty strengths is tabulated. Except in the case of social sciences, Thailand has more favourable student-faculty ratios than Sri Lanka. In Thailand this is particularly evident in the case of the medical sciences. This seems consistent with the fairly major role played by medical sciences in R&D activities in Thailand.

Table 14.23: Number of Degree Awarding Institutions

Type of Degree Awarded	Degree Awarding Institutions by Country (Year:1984)			
	Sri Lanka		Thailand	
	Number of Institutions	Degrees Awarded	Number of Institutions	Degrees Awarded
Bachelor's	8	4,043	29	41,957
Master's	5	367	12	479
Post-Graduate Diploma	2	203	4	1,657
Doctoral	4	37	7	4

Table 14.24: Student - Faculty Statistics by Field of Specialization

Field of Specialization	Number of Students Enrolled and Faculty Members (Year:1984)					
	Sri Lanka			Thailand		
	Students	Faculty	Student-Faculty Ratio	Students (*)	Faculty	Student-Faculty Ratio
Engineering Sciences	1,829	255	7.2	6,600	1,604	4.1
Natural Sciences	3,129	458	6.8	12,698	2,354	5.4
Agricultural Sciences	726	97	7.5	4,095	1,145	3.6
Medical Sciences	2,560	177	14.5	11,458	4,817	2.4
Social Sciences	10,915	496	22.0	256,604	5,226	49.1
Total	19,159	1,483	12.9	291,455	15,146	19.2

(*) The distribution of students by field of specialization consists of estimated values while the overall total is exact.

• The qualification profile of faculty members by field of specialization can reflect the relative emphasis placed with respect to the development of these fields. This data is tabulated for Sri Lanka and Thailand. In the case of Sri Lanka the largest percentage of doctorates are in the social sciences. In the case of Thailand the largest percentage is found in the medical sciences. The data also shows that while only 48% of the Sri Lankan faculty have post-graduate qualifications, the corresponding figure for Thailand is about 72%. This lower figure for Sri Lanka may be attributed to braind drain and/or highly qualified personnel leaving the Higher Education Sector to join other sectors.

• The career age profile of faculty members by field of specialization is tabulated. Only 32% of the faculty members in Sri Lanka have over 10 years experience, while the corresponding figure for Thailand is 46%. Thus, in the case of Sri Lanka the task of producing high-level Humanware has to be necessarily carried out by relatively younger faculty members.

Table 14.25: Qualification Profile of Faculty Members by Field of Specialization

Field of Specialization	Percentage Distribution by Qualifications (Year: 1984)							
	Sri Lanka				Thailand			
	Bachelors	Post-Graduate Diploma	Masters	Doctoral	Bachelors	Post-Graduate Diploma	Masters	Doctoral
Engineering Sciences	22.00	16.70	12.40	11.50	13.80	11.10	10.10	6.20
Earth and Space Sciences	2.30	11.10	3.30	3.80	1.80	1.20	2.40	1.50
Physical Sciences	11.30	-	4.40	20.30	2.90	7.40	6.40	8.20
Biological Sciences	9.00	-	7.60	14.30	2.40	3.70	2.60	6.10
Mathematics and Computers	6.20	5.60	5.80	3.30	3.40	2.50	6.20	2.10
Agricultural Sciences	7.30	-	5.50	6.20	6.30	5.00	7.60	10.00
Medical Sciences	13.00	38.80	12.70	8.40	24.20	3.70	32.10	46.30
Social Sciences	28.90	27.80	48.30	32.20	45.20	65.40	32.60	19.60
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Actual No. per Category of Qualifications	771	18	275	419	4,428	81	8,317	2,320
Percentage Distribution Over the Categories of Qualifications	52.00	1.20	18.50	28.30	29.20	0.50	55.00	15.30

Table 14.26: Career Age Profile of Faculty by Field of Specialization

Field of Specialization	Percentage Distribution of Faculty Members by Experience (Year:1984)					
	Sri Lanka			Thailand		
	< 5 years	5-10 years	> 10 years	< 5 years	5-10 years	> 10 years
Engineering Sciences	47.40	31.60	21.00	31.00	29.00	40.00
Natural Sciences	38.00	41.30	20.70	17.00	34.00	49.00
Agricultural Sciences	33.30	56.40	10.30	19.40	30.00	50.60
Medical Sciences	24.10	39.20	36.70	20.00	36.00	44.00
Social Sciences	15.00	39.80	45.20	18.00	35.00	47.00
Overall Fields	27.70	40.20	32.10	20.00	34.10	45.90

• Total S&T publications of faculty members during the period 1980-1982 is tabulated below for Sri Lanka and Thailand. The largest number of publications in Thailand are in the field of medical sciences while in Sri Lanka it is in the social sciences. In both countries the engineering sciences are at the lower end of the scale indicating a low level of publication.

Table 14.27: S&T Papers Published

Field of Specialization	Number of S&T Publications (Year:1980-1982)			
	Sri Lanka		Thailand	
	Total	Percentage Distribution	Total	Percentage Distribution
Engineering Sciences	83	7.40	296	6.80
Natural Sciences	282	25.00	720	16.50
Agricultural Sciences	79	7.00	677	15.50
Medical Sciences	216	19.10	2,021	46.40
Social Sciences	469	41.50	647	14.80
Total (for all 5)	1,129	100.00	4,361	100.00

• The extent of financial assistance provided to students is also tabulated below. 15.3% of the student population in Sri Lanka receive financial assistance while the corresponding figure for Thailand is 1.3%. The percentage of students receiving financial assistance in each field of specialization is also shown.

Table 14.28: Financial Assistance Provided to University Students by Field of Specialization

Field of Specialization	Receipt of Financial Assistance by University Students					
	Sri Lanka (1984/85)			Thailand (1984)		
	Total No. of Students Receiving Assistance	Student Population	Percentage Receiving Assistance	Total No. of Students Receiving Assistance	Student Population	Percentage Receiving Assistance
Engineering Sciences	277	1,829	15.10	826	6,600	12.50
Natural Sciences	644	3,129	20.60	476	12,698	3.70
Agricultural Sciences	132	726	18.20	402	4,095	9.80
Medical Sciences	264	2,560	10.30	520	11,458	4.50
Social Sciences	1,621	10,915	14.90	1,970	256,604	0.80
Total	2,938	19,159	15.30	3,718	291,455	1.30

Measures for Popularizing and Promoting S&T

• Political commitments to technology for development are often made by various individuals, bodies and institutions at different fora. However, the relative strength of such commitments vary significantly. One possible classification of political commitments in increasing order of strength is shown in tabular form and is illustrated for Sri Lanka and Thailand. The illustration shows that there is hardly any commitment above the third level.

Table 14.29: Levels of Commitment to S&T for Development

Level	Type of Potential Commitment to Technology for Development	Country	
		Sri Lanka	Thailand
1.	Public Statement	Frequently made statements indicate awareness of the importance of S&T in national development	Frequently made statements indicate awareness of the importance of S&T in national development
2.	Published Official Statement	First official statement on the objectives of the National S&T Policy was made by the President of Sri Lanka in 1978	First explicit statement on the use of science and technology for development was stated in Article 61 of the 1978 Constitution
3.	Statements in Planning Documents	Commonly found in planning documents and budget speeches In 1985 a National Science Policy Plan and Implementation Document was finalized and is to be implemented.	Commonly found in the National Economic and Social Development Plans and in the Fifth Plan (1982-1986) a whole chapter was devoted to utilization and development of science and technology.
4.	Enactment of laws to ensure long-term validity, sectoral compliance and departmental cooperation	No explicit technology development laws are available other than the Code of Intellectual Policy	No explicit technology development laws are available other than the Patent and Trademark Laws.
5.	Inclusion of envisaged S&T development pattern in the constitution to ensure that frequent policy changes are not made	Not implemented as yet	Not implemented as yet

- In both Sri Lanka and Thailand, public facilitates to popularize S&T appear to be inadequate. Thailand has a Science Museum which is administered by the Ministry of Science, Technology and Energy while Sri Lanka does not have one. However, both countries have a planetarium.

- Both Sri Lanka and Thailand have monthly science magazines for school children but circulation figures are not available. However, no concerted efforts are being made at present to include science and technology literature in newspapers and magazines on a routine basis.

- It is estimated that S&T books and journals in the libraries of Thailand account for about 17%. The corresponding figure for Sri Lanka is likely to be about 13%.

- It is estimated that about 3.5% of the radio broadcasting time in Thailand is devoted to topics on S&T. In Sri Lanka, it was found that in 1985, based on a sample survey, this figure was 1.7%.

- In Thailand it is estimated that the proportion of TV broadcasting time for S&T topics ranges from 1% in one channel to 4% in another. In the case of Sri Lanka, the Education Television Service allocates about 30%-50% of its time for S&T subjects. In the other national broadcasts the proportion varied from 15% in one channel to 5% in another, of total broadcast time in 1986.

- Both Thailand and Sri Lanka hold science exhibitions annually and these are usually organized by government agencies. Invention contests are also a feature of these exhibitions.

- In Thailand, the National Research Council presents five annual awards for outstanding research contributions in the fields of medicine, chemistry, pharmacology, agriculture-biological sciences, and engineering-industry. In Sri Lanka three prestigious awards namely, the President's Award, the NARESA (Natural Resources Energy and Science Authority) Award and the IBM Award are made annually. While the first two are for scientific achievement, the IBM Award is for outstanding technological research.

• Both Sri Lanka and Thailand have about 45 professional associations which cover most S&T disciplines. These associations are yet to be integrated with the national S&T development planning activities.

Special Note

• This is preliminary presentation to illustrate the types of analysis that would be included in the country profile report (covering at least ten countries of the region) of the Technology Atlas due to be published next year.

15. Assessment of National Resource Profile

• All economic activities of mankind are based ultimately on naturally available resources (or "Natureware"). Whether it is consumption or production, or whether it is trade, the commodities which are involved can be traced always to constituents available in nature. In other words, all economic activities of a country are essentially based on either imported or its own natural resources.

• Further, if one breaks down any transformation operation into the most baic inputs involved, it is always possible to trace them ultimately to a combination of "natural resources" and "human resources" (i.e. Natureware and Humanware). Thus, the two important constituents of a national resource profile are the natural resources and the human resources. However, it should be noted that human resources is both a means and end for development.

Natural Resources

• The natural resource base makes no appearance in the conventional national accounting system. Very little attempt is made at the present time to estimate their in situ values. On site these resources are usually treated as free goods.

• In calculating net national product, depreciation of natural resources - i.e. depletion in the index of their stock - is not deducted. It cannot be overlooked that natural resources are also capital assets and perhaps the prime type of capital assets. Therefore, a consistent set of national accounts ought to display the stock and the change in the natural resources.

• The Technology Atlas project would attempt to develop a consistent set of tables providing the natural resource profile of a country. Since data collection has not yet been started, some samples are included here for illustration only.

• The profile of land and water resources is tabulated for selected ESCAP countries. These estimates have important planning implications especially from the point of view of agricultural and human settlements development planning.

Table 15.1: Profile of Land and Water Resources (1985)

Country	Land Resources											Exploitable Water Resources	
	Overall Total (million hectares)						Per Capita (hectares)					Volume Cubic Kilometres Per Year	Per Capita Thousand Cubic Metres Per Year
	Total Area	Land Area	Farm Land	Meadows and Pastures	Forest	Others	Land Area	Farm Area	Meadows and Pastures	Forest	Others		
Bangladesh	14.40	14.40	8.56	N.A.	2.19	N.A.	165.2	98.2	N.A.	25.1	N.A.	1,357	13.37
China	959.69	959.69	100.90	285.70	128.20	444.89	951.9	100.1	284.3	127.2	441.2	2,680	2.52
India	328.70	304.11	172.63	11.96	67.16	52.36	443.8	251.9	17.5	98.0	76.4	1,850	2.43
Indonesia	190.43	181.13	19.50	12.00	121.80	27.85	1,228.0	132.2	81.4	825.8	188.6	2,530	15.34
Japan	37.23	37.23	4.88	0.58	25.20	6.57	318.0	41.7	5.0	215.2	56.1	547	4.55
Korea (ROK)	9.77	9.71	2.19	0.05	6.57	0.90	259.4	58.5	1.33	175.5	24.1	63	1.54
Malaysia	32.90	32.90	4.30	0.03	22.39	6.13	2,879.1	376.3	2.6	1,959.4	540.8	456	29.40
Nepal	14.08	14.08	2.33	1.79	4.45	5.11	937.2	155.1	119.2	296.2	366.7	170	10.31
Pakistan	79.60	79.60	19.78	N.A.	3.05	N.A.	944.8	234.8	N.A.	36.2	N.A.	298	2.93
Philippines	30.00	29.83	11.69	1.00	12.30	4.82	620.2	243.0	20.8	255.7	100.7	323	5.90
Sri Lanka	6.56	6.47	2.16	0.44	2.38	1.50	435.8	145.5	30.0	160.3	100.0	43	2.63
Thailand	51.40	51.80	18.30	0.31	16.55	16.02	1,141.7	408.3	6.9	369.2	357.3	110	2.13

• A possible format for summarizing the national resources base of a country is presented using the examples of China and India. Since comprehensive data collection has not commenced as yet, these tables include only the data available at APCTT.

Table 15.2 (a): Natural Resource Profile - China

Land and Water Resources		Energy					Metallic Ores and Concentrates (1985)	
		Non-renewable			Renewable			
		Resource	Estimated Reserves (bil.tons)	Proven Resources (bil.tons)	Resource	Estimated Potential (bil.kWh/Yr)	Resource	Estimated Reserves (mil.tons)
Land (1982)								
	Area (million hectares)	Coal	9,000.00	1,500.00	Hydro	1,900	Bauxite Ore	1,290
Total	959.69	Oil	1.80	1.62	Solar	100,000 solar collectors	Iron Ore	47,198
Land	959.69	Gas	165.00	-		in use and	Manganese Ore	460
Farms	100.90					100,000 solar		
Pastures	285.70	Oil Sands	400.00	-		cookers are	Phosphate Ore	12,600
Forest	128.20					in use		
Others	444.89	Nuclear	Uranium reserves amount to sustain operation of 15,000 MW pressurised water reactors		Wind	Wind speeds of 6m/sec for 2,500 or more hours per year		
Water (1985)	(cubic kilometres) per year							
Volume	2,680							

Table 15.2 (b): Natural Resource Profile - India

Land and Water Resources		Energy					Metallic Ores and Concentrates (1985)	
		Non-renewable			Renewable			
		Resource	Estimated Reserves (bil.tons)	Proven Resources (bil.tons)	Resource	Estimated Potential (bil.kWh/Yr)	Resource	Estimated Reserves (mil.tons)
Land (1982)								
	Area (million hectares)	Gas (1973)	70.00 (bil.cu.m)	-	Hydro	396.00	Bauxite Ore	2,653.00
							Copper Ore	578.00
Total Area	328.70	Oil (1973)	0.13	0.47			Chromium Ore	135.30
							Diamonds (mil.Carats)	0.12
Land	304.11	Coal (1982)	127.80	105.80				
Farms	172.63						Fluorspar	11.90
Pastures	11.96						Gypsum	1,248.60
Forest	67.16	Nuclear					Gold Concentrates	16.10
Others	52.36	(1982)					Iron Ore	17,750.00
							Ilmenite	300.00
Water (1985)								
	(cubic kilometres) per year	Uranium Oxide	67,000 tons				Lead Zinc Ore	360.00
							Manganese Ore	127.90
Volume	1,357	Thorium Oxide	363,000 tons				Nickel Ore	165.00
							Tungsten Ore	0.01

• From the point of view of energy resources, some information on total energy production and consumption, forest resources, natural gas reserves and petroleum reserves is tabulated below for selected countries.

Table 15.3: Profile of Forest Resources - Availability and Usage (1983)

Country	Forest Area (million hectares)	Current Fuel Extraction Rate Per Year (cubic metres)	As Percentage of World Total		Index of		
			Forest Area	Wood Extraction	Population	Resource Effectiveness: Extraction / Population	Extraction: Extraction / Population	Resource Utilization: Extraction / Forest Area
Bangladesh	2.14	31.11	1.05	1.90	1.88	0.03	1.01	36.25
China	128.20	154.63	3.13	9.47	19.70	0.16	0.48	3.02
India	67.50	212.62	1.65	13.02	14.34	0.12	0.91	7.89
Indonesia	121.80	114.20	2.98	7.00	3.04	0.98	2.30	2.35
Japan	25.20	0.58	0.62	0.04	2.30	0.27	0.01	0.06
Korea (ROK)	6.56	6.98	0.16	0.43	0.77	0.21	0.56	2.67
Malaysia	21.19	0.22	0.54	0.02	0.30	1.83	0.04	0.03
Nepal	4.45	14.12	0.11	0.87	0.31	0.35	2.81	7.95
Pakistan	2.87	18.49	0.07	1.13	1.77	0.04	0.64	16.13
Philippines	12.15	28.49	0.30	1.75	1.02	0.30	1.71	5.87
Sri Lanka	2.38	7.65	0.06	0.47	0.30	0.19	1.54	8.04
Thailand	15.80	36.20	0.39	2.22	0.96	0.40	2.31	5.74

Table 15.4: Energy Production and Consumption (1980)

Unit : million tons of oil equivalent

Country	Production per annum Using Local Resources	Consumption per annum	Surplus/ Deficit
Bangladesh	1.31	2.95	- 1.64
China	438.49	416.20	+ 22.29
India	76.64	97.30	- 20.66
Indonesia	93.63	26.73	+ 66.89
Korea (ROK)	9.88	41.05	- 31.17
Malaysia	15.19	8.40	+ 6.78

Unit : million tons of oil equivalent

Country	Production per annum Using Local Resources	Consumption per annum	Surplus/ Deficit
Nepal	0.05	0.14	- 0.09
Pakistan	8.62	12.62	- 4.00
Philippines	2.14	12.61	- 10.47
Sri Lanka	0.37	2.04	- 1.66
Thailand	0.72	11.93	- 11.21

Table 15.5: Natural Gas Reserves (1984)

Country	Reserves in trillion cubic metres	World Share (%)		Reserves to Production Ratio (Yr.)	Country	Reserves in trillion cubic metres	World Share (%)		Reserves to Production Ratio (Yr.)
		Reserves	Population				Reserves	Population	
Bangladesh	0.2	0.2	1.88	93.7	Indonesia	1.1	1.2	3.04	62.2
China	0.9	0.9	19.70	68.5	Malaysia	1.4	1.5	0.29	100.0
India	0.4	0.4	14.34	80.0	Pakistan	0.4	0.5	1.77	33.2

Table 15.6: Petroleum (Proven) Reserves (1984)

Country	Reserves billion tonnes	World Share (%)		Reserves to Production Ratio (Yr.)	Country	Reserves billion tonnes	World Share (%)		Reserves to Production Ratio (Yr.)
		Reserves	Population				Reserves	Population	
China	2.6	2.7	19.70	22.8	Malaysia	0.4	0.4	0.29	16.3
India	0.5	0.5	14.34	17.0	Middle East	54.2	56.4	2.00	93.8
Indonesia	1.2	1.2	3.04	16.8					

Human Resources

- The quantity and quality of Humanware produced in many developing countries often does not match the requirements of national development. This problem is further complicated by brain-drain and also in many cases by ineffective deployment of available human resources.

- One important prerequisite for technology-based national development is to ensure the availability of properly educated and trained technological manpower corresponding to the needs of the society, and also to provide adequate opportunity for the engagement of such skilled personnel in their respective fields of expertise.

- The technological human resources of a country can be broadly classified into five categories:
  - — Inventors and Innovators
  - — Managers and Engineers
  - — Specialized and General Technicians
  - — Craftsmen and Skilled Workers
  - — Semi-skilled and Other Workers

- The highest level of skills will be found in the category of investors and innovators while the semi-skilled and other workers will have the lowest.

- The data on demographic structure of selected countries is used in many types of planning activities in fields such as education, family planning and food and nutrition planning. The structure for selected ESCAP countries has been tabulated.

Table 15.7: Demographic Structure of Selected Countries

Country	Year	Percentage of population by age group														
		0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-66	> 69
Bangladesh	1981	16.4	15.0	14.6	10.6	8.4	7.0	5.5	5.3	4.0	3.6	2.9	2.1	1.9	1.2	1.5
China	1982	9.5	11.0	13.1	12.5	7.4	9.2	7.3	5.4	4.8	4.7	4.1	3.4	2.7	2.1	2.8

Country	Year	Percentage of population by age group														
		0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-66	> 69
India	1981	13.8	13.1	12.3	10.9	9.3	7.7	6.5	5.7	4.9	4.2	3.4	2.7	2.1	1.5	1.9
Indonesia	1981	14.5	13.2	11.8	10.5	9.3	8.2	6.6	5.2	4.9	4.4	3.6	2.7	1.9	1.4	1.8
Japan	1983	6.5	7.7	8.3	7.2	6.7	6.7	8.6	8.1	7.5	6.9	6.4	5.5	4.1	3.4	6.4
Korea (ROK)	1984	10.7	9.7	11.2	10.7	11.1	9.5	7.0	5.9	5.6	5.1	3.9	3.0	2.5	1.7	2.4
Malaysia	1979	14.2	12.7	12.1	12.0	10.4	8.3	6.2	4.8	4.6	3.5	3.1	2.5	2.1	1.5	2.0
Nepal	1981	15.4	14.6	11.4	8.8	8.9	7.7	6.5	5.9	5.0	4.1	3.6	2.3	2.4	1.3	2.1
Pakistan	1981	15.4	16.0	13.1	9.4	7.8	6.7	5.6	5.1	4.7	3.7	3.6	1.9	2.7	1.2	3.1
Philippines	1983	15.1	13.7	12.2	10.9	9.6	8.2	6.7	5.2	4.3	3.6	2.9	2.3	1.8	1.5	2.0
Sri Lanka	1983	12.5	11.4	11.4	10.8	10.2	8.6	7.6	5.6	4.7	4.1	3.7	2.8	2.3	1.7	2.6
Thailand	1984	12.6	12.4	12.1	11.9	10.1	8.4	7.2	6.0	4.5	3.6	3.2	2.6	2.0	1.4	2.0

• Literacy rates and public expenditures on education and health play a major role in determining the quality of the Humanware of a country. This information is presented in tabular form for selected countries.

Table 15.8: National Level Indicators of Population, Literacy, Education and Health

Country	Population		Adult Literacy Rate in % (1980)	Public expenditure on				
				Education (1981)		Health (1984)		
	Year	Total (Millions)		As Percentage Of Gross National Product	Per Capita (US $)	As percentage of		
						Total Public Expenditure	Gross Domestic Product	Per Capita (US $)
Bangladesh	1981	90.45	29.20	1.70	2.0	13.3	0.9	1.4
India	1981	676.21	42.40	3.00	8.00	2.4	0.6	1.6
Indonesia	1981	161.3	67.30	2.20	12.0	2.2	0.5	2.3
Korea (ROK)	1981	40.57	91.70	3.50	60.0	2.2	0.5	10.6
Malaysia	1979	11.02	69.80	7.00	129.0	4.7	1.2	25.1
Nepal	1981	15.02	20.60	1.90	3.0	4.9	1.2	1.7
Pakistan	1981	84.25	26.20	1.90	7.0	5.2	0.3	0.9
Philippines	1983	52.05	83.30	1.90	15.0	6.8	0.9	5.0
Sri Lanka	1983	15.41	86.10	3.00	9.0	3.3	1.2	4.3
Thailand	1984	50.39	88.00	3.70	28.0	6.1	1.2	8.5

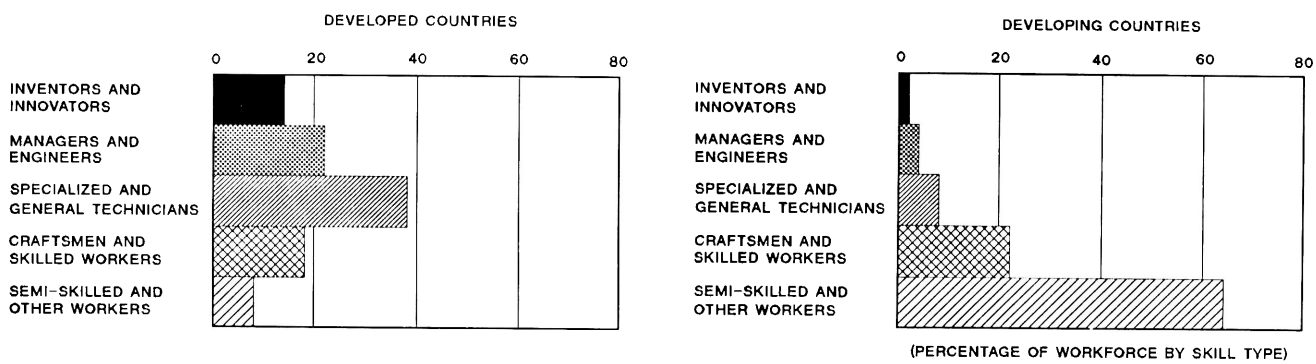
• The measurement of labour productivity provides insights into not only the technological level of economic activities but also the effectiveness of Humanware. The contribution to GDP per unit of labour force in different sectors of the economy may be used as a measure of the labour productivity. Comparative figures are presented in tabular form for selected countries.

Table 15.9: Manpower and Productivity Analysis by Economic Sectors (1982)

Economic Activity	JAPAN		KOREA (ROK)		PAKISTAN		PHILIPPINES		THAILAND	
	Man-power ('000)	GDP per '000 (mil.US$)	Man-power ('000)	GDP per '000 (mil.US$)	Man-power ('000)	GDP per '000 (mil.US$)	Man-power ('000)	GDP per '000 (mil.US$)	Man-power ('000)	GDP per '000 (mil.US$)
Agriculture, forestry and fishery	5,480	6.96	4,623	2.22	13,526	0.47	8,919	0.93	16,985	0.48
Mining and Quarrying	100	52.21	116	9.31	36	7.69	75	0.88	65	9.91
Construction	5,410	17.89	831	6.60	1,267	0.89	604	5.35	520	3.60
Manufacturing	13,800	24.92	3,047	6.35	3,730	1.11	1,714	5.29	2,007	3.57
Wholesale and Retail Trade, Finance and Real Estate	15,010	21.29	382	4.86	3,064	1.64	1,916	5.14	2,298	4.98
Transport, Communication, Electricity, Gas, Water, etc.	3,820	29.02	639	11.95	1,405	1.61	811	3.42	577	5.85
Community,Social and Personal Services	10,650	19.93	1,611	3.87	2,594	0.74	2,922	0.49	2,378	1.04

• Based on the classification of the technological human resources of a country presented above, a skill profile can be developed. In the absence of data according to this classification (to be collected later) a schematic representation of apparent profiles for developed and developing countries are shown. This profile indicates that the developed countries have only a small percentage of the lowest level of skills and a fairly even distribution of Humanware over the other categories. On the contrary in the case of the developing countries only a very small percentage of the Humanware is at the higher level of skills while the majority are at the lower levels.

Figure 15.1: Skill Structure of Technological Manpower



16. Assessment of National Technological Capabilities

• All economic activities of a country are essentially based on the transformation of either its own or imported natural resources into produced resources. It has already been mentioned how the natural resource base may be assessed. Thus, if a methodology is available to assess the capabilities of the "transformer" of natural resources i.e. technology, then this could facilitate both technology development planning and technology policy formulation. In this section some methodologies have been suggested for the assessment of national technological capabilities with specific reference to the production sectors.

Steps in the Assessment of National Technological Capabilities

- Assessment of national technological capabilities can be basically divided into three steps as follows:

Step 1: Assessment of the Technology Content Added (TCA) at any given transformation facility

Step 2: Assessment of the strengths and weaknesses of the life chains of all four technology components pertaining to any given transformation facility.

Step 3: Using a method of systematic aggregation of the activities carried out in step 1 and Step 2 and also validating those through a qualitative analysis of the overall situation

Assessment of TCA at a Transformation Facility

- The methodology for the assessment of TCA at a transformation facility has already been explained in Section 12. It was suggested that:

TCA = [Technology Content Coefficient (TCC)/9] × [Economic Value Added (EVA)]

For any given transformation facility the EVA can be obtained fairly easily from the management accounting system. Thus, it is the TCC computation that would require careful attention. As explained earlier, expert opinion could be used for obtaining the values of T,I,H,O, $\alpha, \beta_1, \beta_2, \beta_3$, and β_4. As an illustration of the methodology the TCC computation for several transformation facilities in Sri Lanka is presented in tabular form. If the EVA for these facilities are known, the TCA can be easily computed by using the expression given above.

Table 16.1: Illustration of the Computation of the Technology Content Coefficient

Description		Values of the Coefficients T	I	H	O	α	TCC
CULTIVATING							
(1) Rice Cultivation		2.50	4.00	2.50	2.75	0.75	1.86
	β_i	0.40	0.05	0.40	0.10		
(2) Prawn Culture		2.50	4.00	3.00	2.75	0.75	1.96
	β_i	0.50	0.05	0.30	0.10		
GATHERING							
(1) Rice Harvesting		2.00	2.00	2.00	2.00	0.75	1.45
	β_i	0.20	0.05	0.60	0.10		
(2) Graphite Extraction		4.00	4.00	3.50	3.50	0.60	2.34
	β_i	0.40	0.05	0.40	0.10		
PREPROCESSING							
(1) Stone Aggregate Preparation		2.00	2.00	2.00	3.00	0.75	1.48
	β_i	0.60	0.05	0.25	0.05		
(2) Agricultural Grading		2.00	2.00	2.00	3.00	0.60	1.21
	β_i	0.20	0.05	0.60	0.10		
PROCESSING							
(1) Cement Plant		5.00	6.00	3.75	4.75	0.75	3.38
	β_i	0.50	0.15	0.15	0.15		
(2) Sugar Mill		5.00	6.00	3.75	4.75	0.75	3.32
	β_i	0.40	0.15	0.20	0.20		
CONSTRUCTING							
(1) Road Construction		2.50	3.00	2.00	2.50	0.75	1.70
	β_i	0.45	0.10	0.30	0.10		
(2) Power Line Erection		3.00	3.00	3.75	2.50	0.75	2.24
	β_i	0.45	0.10	0.30	0.10		
MANUFACTURING							
(1) Textile Manufacture		3.75	5.00	3.00	4.25	0.75	2.75
	β_i	0.50	0.15	0.10	0.20		
(2) Cast Iron Foundry		4.00	5.00	3.00	4.25	0.50	1.81
	β_i	0.50	0.05	0.20	0.20		

Description	Values of the Coefficients					TCC
	T	I	H	O	α	
ASSEMBLING						
(1) Motorcycle Assembly	4.00	5.00	4.00	4.50	0.60	2.35
β_i	0.30	0.05	0.30	0.30		
(2) TV Assembly	3.25	5.00	3.50	4.00	0.75	2.59
β_i	0.30	0.10	0.30	0.25		
PACKAGING						
(1) Soft Drink Bottling	3.75	3.00	2.00	4.00	0.75	2.41
β_i	0.50	0.05	0.15	0.25		
(2) Food Canning	3.75	5.00	3.00	4.00	0.75	2.68
β_i	0.30	0.15	0.20	0.30		

Description	Values of the Coefficients					TCC
	T	I	H	O	α	
DISTRIBUTING						
(1) Piped Water Supply	4.50	4.00	3.00	5.00	0.50	1.87
β_i	0.35	0.25	0.10	0.25		
(2) Electricity Distribution	5.50	6.00	4.50	5.00	0.50	2.42
β_i	0.40	0.15	0.20	0.20		
SUPPORTING						
(1) Home Appliance	2.50	4.75	4.00	3.00	0.75	2.37
β_i	0.35	0.15	0.35	0.10		
(2) Automobile Repair Shop	3.50	4.75	4.00	3.00	0.75	2.70
β_i	0.15	0.15	0.50	0.15		

• A preliminary review of the TCC computation for the transformation facilities used in the illustrative examples show that cultivating, gathering and preprocessing facilities generally rank low with respect to TCC while procesing facilities rank high. By carrying out a more comprehensive review of many types of facilities in the various transformation it may be possible to classify the transformation stages in increasing order of TCC.

• The TCC and TCA computations thus help in determining the overall contribution made by the four components of technology, to any transformation facility. Based on such analyses of the transformation facilities of a nation it may be possible for the technology planners to classify the national facilities into high, medium and low technology categories.

Life Chain Analysis of Technology Components at a Tranformation Facility.

• While the TCC and TCA analyses help to determine the technology intensity of a transformation facility it does not provide an insight into the strengths and weaknesses with respect to the four components of technology. This can be carried out as follows:

i) assessment of the levels of sophistication of the four components;

(ii) assessment of the strength of each life chain.

• The assessment of the levels of sophistication of the four components can be carried out by applying the rating procedure, presented in tabular form, for all four components. This procedure can be applied to any transformation facility.

Table 16.2: Rating Procedure for Assessing the Level of Sophistication of the Technology Components

Level of Sophistication	Score		
TECHNOWARE			
Manual Tools	1	2	3
Powered Equipment	2	3	4
General Purpose Machines	3	4	5
Special Purpose Machines	4	5	6
Automatic Machines	5	6	7
Computerized Machines	6	7	8
Integrated Facilities	7	8	9

Level of Sophistication	Score		
INFORWARE			
Familiarizing Facts	1	2	3
Describing Facts	2	3	4
Specifying Facts	3	4	5
Utilizing Facts	4	5	6
Comprehending Facts	5	6	7
Generalizing Facts	6	7	8
Assessing Facts	7	8	9

Level of Sophistication	Score		
HUMANWARE			
Operating Ability	1	2	3
Setting Ability	2	3	4
Repairing Ability	3	4	5
Reproducing Ability	4	5	6
Adapting Ability	5	6	7
Improving Ability	6	7	8
Innovating Ability	7	8	9

Level of Sophistication	Score		
ORGAWARE			
Individual Linkages	1	2	3
Collective Linkages	2	3	4
Departmental Linkages	3	4	5
Enterprise Linkages	4	5	6
Industrial Linkages	5	6	7
National Linkages	6	7	8
Global Linkages	7	8	9

- The strengths of the life chain for each of the four components is arrived at by carrying out a simple computation in two stages. In the first stage, the national level efforts at each phase of the life chain, for all four components, is estimated using the following scoring procedure:

Effort Level	*Score*
Nil	0
Very very low	1
Very low	2
Low	3
Medium	4
High	5
Very High	6
Very very high	7

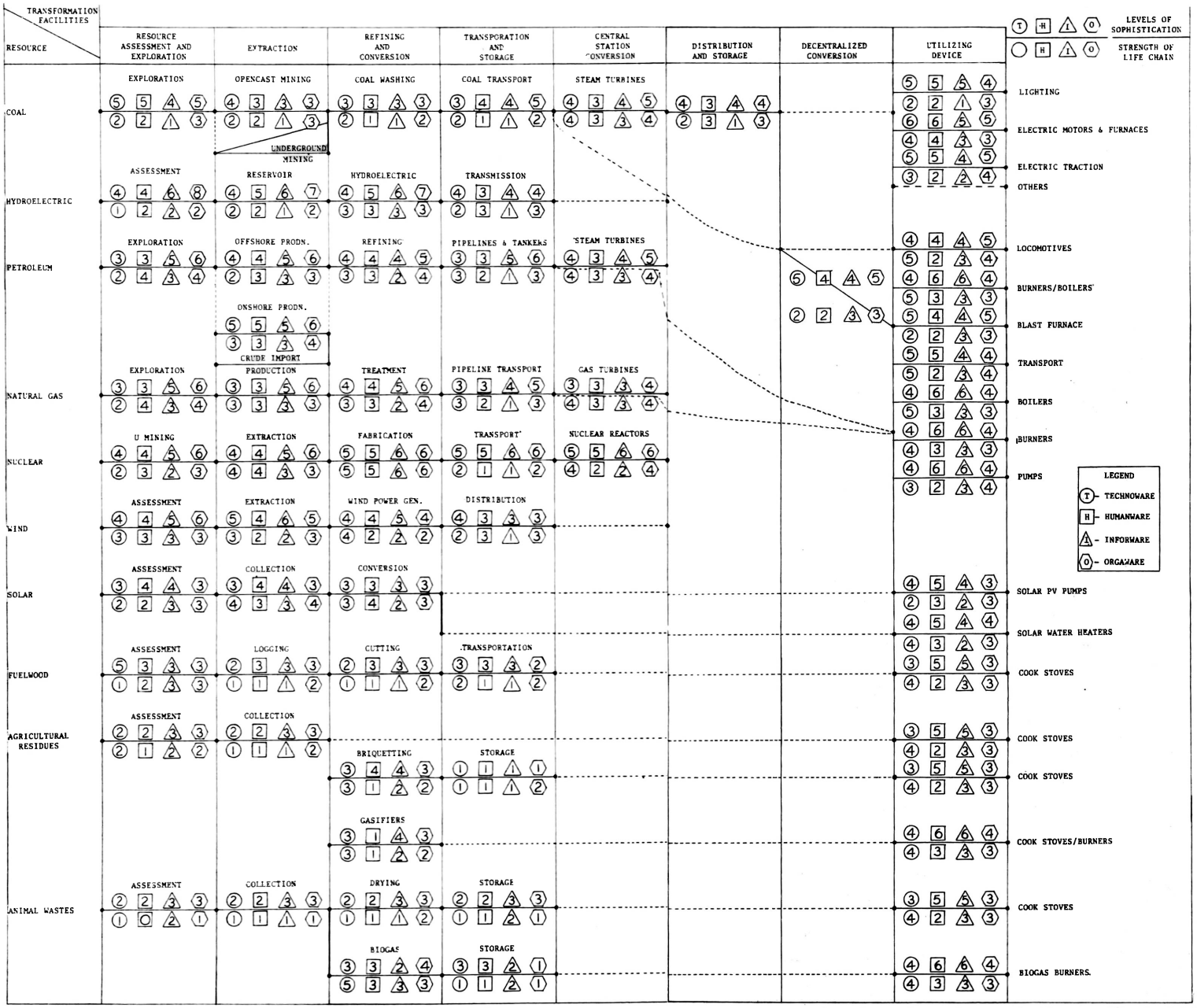
In the second stage a composite index is arrived at by weighting the scores at each phase using the values given in the table below. This strength index computation can be carried out for all the four components. If in a particular life chain, a phase is not relevant, in a given instance, the score for that particular phase is taken as 0.

Table 16.3: Values for Weighting the Scores of the Phases of the Life Chain

TECHNOWARE		HUMANWARE		INFORWARE		ORGAWARE	
Researching	0.10	Rearing	0.05	Collecting	0.05	Conceiving	0.10
Developing	0.10	Telling	0.05	Screening	0.10	Preparing	0.10
Testing	0.05	Teaching	0.15	Classifying	0.10	Designing	0.15
Demonstrating	0.20	Training	0.10	Associating	0.15	Installing	0.15
Producing	0.20	Educating	0.15	Analyzing	0.15	Operating	0.20
Diffusing	0.20	Developing	0.30	Synthesizing	0.20	Guiding	0.10
Substituting	0.15	Upgrading	0.20	Emulating	0.25	Evolving	0.20

- The case of energy technology in India is taken as an example to illustrate the methodology for assessement of the level of sophistication and the strengths of the life chain for all four components. In this illustrative example, energy technology is subdivided into its elements using a relevance tree approach. For each element, the levels of sophistication and the life chain strength index has been computed and is presented in matrix form. In each cell the sophistication levels are presented first and the life chain strength indexes are given below it. In this example, the scores used for both the sophistication and the life chain analyses are indicative. It is proposed to use expert opinion to derive these scores for the full report on the Technology Atlas.

Figure 16.1: Assessment of National Capability in Energy Technology - India



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• From the illustrative example, the following observations can be made regarding the Indian energy technology scene.

— A number of elements in energy technology are weak.
— In case of fuelwood and agricultural residues, the strength of the life chain is weak and the levels of sophistication achieved are low.
— In areas where there is strong commitment such as oil exploration or nuclear energy the levels of sophistication and the strengths of the life chain are relatively high.
— The Inforware component is not well developed for a number of elements.

The summary of the life chain analysis for energy technology is represented below in tabular form.

Table 16.4: Energy Technology in India - Assessment of Overall Capability

Energy Source	Levels of Sophistication				Strength of Life Chain			
	T	H	I	O	T	H	I	O
Coal	4	4	4	4	3	2	2	3
Hydro Power	5	5	5	6	2	3	2	3
Oil	4	5	5	5	3	3	3	4
Natural Gas	4	3	4	5	3	3	2	4
Nuclear Energy	5	5	6	6	3	3	4	4
Wind Energy	4	4	5	4	3	3	2	3
Solar Energy	4	5	5	4	4	4	3	4
Fuelwood	3	3	3	3	2	1	2	2
Agricultural Residues	2	3	4	3	2	1	2	2
Animal Wastes	3	3	3	3	2	2	2	2

Derivation of National Technological Capability Profile

• Due to the complexity of the technological system or a country, and as explained earlier, a national technological capability profile would essentially include the examination of several aspects. One way of studying this system would be to look at:

(i) a national level TCA profile:
ii) a national level analysis of the strengths and wea knesses of the life chain.
(iii) a national level gap and level analysis

• A national level TCA profile can be developed by taking the aggregate of individual TCA for all the national transformation facilities categorized by transformation stages. Based on data available at APCTT for EVA and using indicative values of TCC, the TCA analysis for Sri Lanka is tabulated below. If this analysis is validated by further data collection to be undertaken later, then the fact that the TCA is only 21% of EVA would reflect the weakness of the technological system of the country. Such national level analysis if carried out for several countries may provide useful insights into the causes and nature of technological under development.

Table 16.5: Illustration of National Level Technology Content Added Analysis

Type of Transformation Stage	Technology Content Coefficient TCC	Economic Value Added EVA*	Technology Content Added TCA
Cultivating	1.75	20,771	4,039
Gathering	1.65	6,425	1,178
Preprocessing	1.25	3,153	438
Processing	2.25	3,760	940
Manufacturing	2.25	4,997	1,249
Assembling	2.00	1,665	370
Packaging	1.75	1,699	330
Constructing	2.10	7,163	1,671
Distributing	2.00	7,151	1,589
Supporting	2.25	3,733	933
Total for all 10		60,517	12,737
TCA as a Percentage of EVA at National Level			21.05

* In millions of local currency for the year 1984 at 1982 constant prices

• A qualitative national level analysis of the strengths and weaknesses of the life chain for the four components can also be carried out after analyzing the characteristics of several technologies/sectors. As an illustrative example, the strengths and weaknesses of the life chain, at a national level, is tabulated for India.

Table 16.6 (a): Analysis of Life Chain of Technoware for Technology Development in India

Life Chain	Strengths	Weaknesses
Researching	Large numbers of labs and industrial units with R&D facilities	Inadequate resources Duplication of investment
Developing	Availability of a large number of labs with facilities	Activities spread too thinly Subcritical inputs into too many areas
Testing	Availability of testing centres in industrial zones	Poorly equipped for diversified needs Lack of calibration facilities
Demonstrating	Agencies available specifically for demonstrating technology generated by government labs	Lack of formal mechanisms for dealing with technology generated by private sector
Producing	Large internal demand	Poor use of economies of scale Lack of concern for quality
Diffusing	Mechanisms for diffusion are strong in a few selected countries	Lack of market surveys Shortcoming with respect to competitiveness
Substituting	--	Very little effort for modernization of production facilities

Table 16.6 (b): Analysis of Life Chain of Humanware for Technology Development in India

Life Chain	Strengths	Weaknesses
Rearing	--	Illiteracy of parents Malnutrition Non-use of educational toys
Telling	Availability of televised instructional programmes	Staff/student ratio unfavourable Inadequate facilities
Teaching	Use of local language	Inadequate teaching material in local language Poorly paid teachers
Training	Strong skill development efforts in traditional areas	Poor development of technical personnel Skill development weak in the small-scale sector Design and assimilation skills are weak Limited off-the-job training
Educating	Availability of a pool of educated manpower	Poor facilities in institutions Average quality of educated manpower pool is low
Developing	Availability of broadbased post-graduate education	Lack of emphasis on "doing-science"
Upgrading	Institutional arrangements for upgrading knowledge and skills are available	Continuing education for technologists neglected Limited exposure to high-tech Motivation for upgradation poor

Table 16.6 (c): Analysis of Life Chain of Inforware for Technology Development in India

Life Chain	Strengths	Weaknesses
Collecting	Availability of four major databases	No centralized technology monitoring arrangements Duplication of information collection agencies
Screening	Formal screening arrangements are available in some large enterprises	Lack of systematic methodologies for screening
Classifying	Availability of specialized databases	Lack of compatibility among various classifying schemes
Associating	Availability of associating skills	Lack of schemes for associating
Analyzing	Availability of modelling capabilities and facilities	Emphasis on models rather than the problems Poor documentation of findings
Synthesizing	Existence of some reasonably good networks	Limited facilities and capabilities
Emulating	–	Limited appreciation

Table 16.6 (d): Analysis of Life Chain of Orgaware for Technology Development in India

Life Chain	Strengths	Weaknesses
Conceiving	High-level of conceptual ability	Idea generation methods not used widely
Preparing	Objective setting is mandatory in many organizations	Diluted effort, non-specific objectives and lack of focus
Designing	Skills available in selected areas	Organizations are started without analysis of structural details and linkages needed
Installing	–	Lack of sense-of-urgency
Operating	–	Lack of productivity consciousness Lack of team spirit Low emphasis on quality
Guiding	Availability of formal mechanisms for review	Implementation of corrective measures is weak
Evolving	–	Too much emphasis on short-term gains with little concern for long-term perspective

- If a technological capability level analysis is required at an industry level rather than at the national level, then the overall qualitative analysis could be performed in a more specific manner. This is illustrated in tabular form for the growth of the Korean (Republic of Korea) electronics industry.

- In attempting to carry out technological capability measurements, along the lines suggested, there is always scope for some error due to the use of ratings. However, the measurements can be useful in identifying major strengths and weaknesses of a nation with respect to technology development.,

- In the present world of technological interdependence, once the strengths and weaknesses are identified, normative prescriptions for corrective measures can be evolved using technological gap and the level analysis. (This is explained in details in Section 17).

Table 16.7: Growth in TCA and the Levels of Sophistication of technology in the Korean Electronics Industry

STAGE	OUTPUTS	TCA	TECHNOWARE	INFORWARE	HUMANWARE	ORGAWARE	REMARKS
Stage 1 Random Exploration (1958-1962)	Manufacture (with low indigenous component) of - Vacuum tube radios - Electric fans - Telephone sets	Low	Manual Tools Powered Equipment General Purpose Machines	Familiarizing Facts Describing Facts Specifying Facts Utilizing Facts	Operating Ability Setting Ability Repairing Ability	Individual Linkages Collective Linkages Departmental Linkages	* Fairly low indigenous portion in the products * Very low formal management skills * No emphasis on quality * Work-force with fairly low level of skills * Objective of organizations was to secure a beach-head and survive in the face of competition from imported products
Stage 2 Technology Introduction (1963-1968)	Additions Manufacture with low indigenous component of - Refrigerators - Watt-hour meters - Telephone switching equipment (mechanical type) - Transistor radios - Cables - Elevators - Black and white TVs	Medium	Manual Tools Powered Equipment General Purpose Machines Special Purpose Machines	Familiarizing Facts Describing Facts Specifying Facts Utilizing Facts Comprehending Facts Generalizing Facts	Operating Ability Setting Ability Repairing Ability Reproducing Ability Adapting Ability Improving Ability	Individual Linkages Collective Linkages Departmental Linkages Enterprise Linkages	* Enactment of the Foreign Capital Introduction Law * Foreign technical collaboration * Emphasis on import substitution through indigenous production * Creation of a large-scale good quality output oriented corporate culture * Export marketing on a modest scale
Stage 3 Equity Joint Venture and Export Marketing (1969-1975)	Additions Manufacture of - Colour TVs - Cassette radios Conventional Products A large increase in indigenous content was brought about especially in basic components	Medium to High	Manual Tools Powered Equipment General Purpose Machines Special Purpose Machines	Familiarizing Facts Describing Facts Specifying Facts Utilizing Facts Comprehending Facts Generalizing Facts Assessing Facts	Operating Ability Setting Ability Repairing Ability Reproducing Ability Adapting Ability Improving Ability Creating Ability	Individual Linkages Collective Linkages Departmental Linkages Enterprise Linkages Industrial Linkages	* Acquisition of managerial skills by means of equity joint ventures * Upgrading of quality assurance and testing techniques * Enhancement of export marketing activities * Development of design capabilities * Waiving of customs duties on imported materials for the production of export products

STAGE	OUTPUTS	TCA	TECHNOWARE	INFORWARE	HUMANWARE	ORGAWARE	REMARKS
Stage 4 Reproducing and Adapting (1976-1980)	Additions - Audio components & equipment - Car radios - Electronic typewriter - Electronic cash register - Key telephone systems - Electronic PABX - PCM carrier - Optical fibre cable - Automatic vending machines	High	Manual Tools Powered Equipment General Purpose Machines Special Purpose Machines Automatic Machines	Familiarizing Facts Describing Facts Specifying Facts Utilizing Facts Comprehending Facts Generalizing Facts Assessing Facts	Operating Ability Setting Ability Repairing Ability Reproducing Ability Adapting Ability Improving Ability Creating Ability	Individual Linkages Collective Linkages Departmental Linkages Enterprise Linkages Industrial Linkages	* Strengthening of design capabilities * Development of own private technology development institutes * Strengthening of high calibre manpower pool through increased rate of repatriation of overseas Korean scientists and engineers, development of mission oriented courses at KAIST, industry-oriented educational programmes,etc. * Concentrated export development
Stage 5 Development of Own Technologies/ Products (1980-)	Additions - Computers - Peripheral equipment - VLSI - VCR - New materials for electronic use - Applied electronic devices	Very High	Manual Tools Powered Equipment General Purpose Machines Special Purpose Machines Automatic Machines Computer Controlled Machines	Familiarizing Facts Describing Facts Specifying Facts Utilizing Facts Comprehending Facts Generalizing Facts Assessing Facts	Operating Ability Setting Ability Repairing Ability Reproducing Ability Adapting Ability Improving Ability Creating Ability	Individual Linkages Collective Linkages Departmental Linkages Enterprise Linkages Industrial Linkages National Linkages	* Establishment of KIET and KETRI * Self-reliance in designing and manufacturing * Build-up of own overseas sales network * Establishment of own overseas manufacturing base

17. Assessment of Technological Gaps and Levels

• In this section a number of examples of assessment of technological gaps and levels are presented. These examples are only indicative of what is likely to be included in the Technology Atlas. The examples are used to illustrate the methodologies that have been developed so far. Since data has not been collected at this stage of work, material available at APCTT was used for preparing the examples given in this section.

Illustrative Examples of Gap Analysis

(a) *Iron and Steel Technology*

• In earlier section dealing with assessment of technological gap, it was mentioned that there is a big gap in energy used for steel making in India and Japan. One way to understand how gaps could be reduced is to analyze how Japan upgraded the Iron and Steel technology between 1973 and 1986. This illustrates the changes made in the four technology components by Japanese iron and steel industries. Steps taken by Japan for upgrading iron and steel technology in the form of changes in Technoware, Humanware, Inforware and Orgaware are presented in tabular form.

Table 17.1 (a): Upgradation of Technoware in Japanese I&S Industry for Energy Efficiency

Sintering Plant	New ignition facility Leakage of air reduction Product coolers Sinter heat recovery Heat pattern control
Coke Oven	Coking control system Coke dry quenching units Optimum combustion control Fuel gas heat control
Oxygen Gas	Ladle heating Ceramic heat exchangers Pretreatment heat recovery
Blast Furance (BF)	Sensors for monitoring (1000 sensors per BF) Heat recovery systems (Top pressure recovery turbines) and Hot Blast Oven (exhaust recovery) Fuel gas reheating Slag heat recovery BF total computer control Burden distribution control High corrosion resistant Alumina-SIC-micropore carbon blocks as refractories Sensors to measure erosion of furnace walls
Continuous Casting	Computer aided micro analzer for improving slab quallty Slab castlng Continuous casting cooling control Continuous casting and direct rolling Continuous casting ratio - 10.0% in 1971; 92.5% in 1985.
Reheating and Rerolling	Low nitrogen oxides and surface combustion burners for uniform temperature distribution with short flames Hot charge rolling Air recuperator Gas recuperator Ceramic Fibure Insulation
	Furnace computer control On line measuring instruments for rolling lines for thickness, width, sectional shape, flatness, temperature coating weight, degree of alloying, internal defects and surface defects.
Control	Direct digital control of electricity, fuel, steam and oxygen
Electric Furnace	Exhaust reuse Scrap preheating systems
Computerized Process Control	Complete data logging through process computer system (1034 computers out of 1402 computers are process computers)

Energy Saving Equipment	Number of Units	
Equipment	1976	1986
Coke dry quenching units	0	26
Product cooler waste heat recovery unit for sintering	0	29
Main waste gas heat recovery unit for sintering	0	9
Top recovery turbines for blast furnace	1	35
Hot stove waste heat recovery for blast furnace	1	39
Scrap preheater units using waste gas for electric furnaces	0	50

Table 17.1 (b): Upgradation of Humanware in Japanese I&S Industry for Energy Efficiency

Energy Management	Importance indicated by deployment of specialized humanware for energy management Kawasaki Steel has the following staff : 1 General Manager 7 Managers 38 Staff Engineering 363 Operators	Motivation	Worker motivation schemes for improving production and productivity
		Participation	Worker participation in idea generation
		Large Deployment for New Technology Development	8.5% of the employees work in new technology area
Training	Intensive training for - sealing of door - maintaining thermal regimes - cleaning of regenerators - gas ratio control - proper control of cycles - maintaining turbo compressors - BF operation		Deployment of Persons for Development Research in Iron and Steel Industry
Incentives	For energy saving Group and individual rewards for new technologies, new products and energy conservation ideas		

Description	1979	1984
Research labs owned by steel industries	8	10
Number of Research Staff	1636	1688
Number of supporting personnel	2379	2210

Table 17.1 (c): Upgradation of Inforware in Japanese I&S Industry for Energy Efficiency

Monitoring Schemes Utilized	Energy input/output indices Overall energy balance Overall energy balance Total and disaggregated energy cost Computer-based integration of monitoring consumption and supply of energy sources	R&D	Technology information updation and development of new process
		Management Information Systems	Extensive use of computer-based information systems 368 business computers for corporate planning, administrative control and production planning
Integrating Monitoring & Operating System	Integrated operation of electric power demand fuel and steam and oxygen plant and use	Software Development and Industry Oriented System	Steel Industry Information System has a centralized database and this is shared by firms
Maintenance Information System	Computer control system for equipment maintenance so that condition based equipment maintenance is possible with the help of machine condition diagnosis techniques	Database and Technical Information Service	Japanese Information Centre for Science and Technology collects latest scientific and technological information. Specific fields covered are powder metallurgy, composite materials, corrosion and energy saving. Every month about 14,000 items are added. This is an on line information system and covers Japanese and English sources.
Process Simulation Models	Sintering plant simulator Blast furnace simulation Gas recovery analysis Molten metal analysis		

Table 17.1 (d): Upgradation of Orgaware in Japanese I&S Industry for Energy Efficiency

Commitment to Energy Saving	Intensive technology development as an organizational objective Improving competitiveness through cost reduction and energy conservation Reduced use of oil and electricity as an objective	Planning	Optimum planning of coke oven operation Optimum of blast furnace Balancing energy supply and demand Inspection and maintenance schedules for energy saving

Table 17.1 (d) contd..

Quality Circles	For cost reduction, waste reducing and energy saving
Reporting System	Energy Manager with a high rank and a routine energy reporting system
Linkages	Linkages with R&D Institutes for process simulation Strong linkages with National Research Institute
Fiscal Incentives for Energy Conservation Investment	Tax deduction for saving over and above 25% Low interest loans upto 40% investment for (7.6% to 7.9% interest) conservation 30% additional depreciation for conservation
Regulations	Law concerning the rationalization of energy conservation was passed in June 1979 requiring efficient use of fuel and to conserve fuel through rationalizing business operations
Organizational Support	National Energy Conservation Centre was started in 1978 for collection and dissemination of information on energy saving in industry with 8 offices in locations other than Tokyo
Investment for R&D	R&D Expenditure as % of sales - 1.50 (1984) Expenditure in 1984 for R&D :

Nippon Steel - 333 Million US$
Kawasaki Steel - 153 Million US$

Total R&D Expenditure by Japanese Steel Industry (Billion US$)

Year	Basic Research	Applied Research	Development Research	Total for Research
1981	0.075	0.288	0.768	1.13
1982	0.083	0.267	0.867	1.21
1983	0.087	0.312	0.840	1.24
1984	0.088	0.341	0.850	1.28

Investment for Modernization

Investment for Making Special Steels (Million US$)

1978	268
1982	939
1984	457
1985	471
1986	533

Total Investments for Steel Industries for Continuous Modernization (Billion US$)

1976	8.42
1984	4.77
1985	4.48

• Based on this data an attempt has been made to measure the state of iron and steel technology in India and Japan using a scoring index on a comparative scale. The scores are only indicative of where the industry stands in terms of best in the world on a 0 to 1 scale.

Table 17.2: Measuring Technology Levels in I&S Industry

Components	India	Japan	Basis of Score/ Remarks
TECHNOWARE			
1. Blast furnace coke rate	0.50	0.90	Consumption rate
2. Steel making : Bessemer	0.51	0.00	(Percentage of steel
Basic oxygen	0.54	1.42	made) x (State-of-
EAF	0.64	0.87	art factor)
3. Continuous casting ratio	0.20	0.93	
4. Computers in use	0.20	0.90	1043 in 8 plants in Japan
5. Hot rolling special products	0.30	0.80	
6. Special steels	0.10	0.90	India does not make boiler steel
7. Surface treated steel	0.00	0.90	
8. Top recovery turbines for BF	0.05	0.90	% coverage
9. Hot stove waster recovery	0.05	0.90	% coverage
10. Energy used per tonne (Kcal.)	0.50	0.99	4.01 Japan, 9.50 India
HUMANWARE			
1. Training	0.20	0.90	Japan 50 days/person/ year India 10 days/person/ year
2. Skills	0.50	0.90	

Components	India	Japan	Basis of Score/ Remarks
INFORWARE			
1. Computerized MIS	0.30	0.90	Strength and coverage
2. Process simulation	0.20	0.90	Strength and coverage
3. Steel industry info system	0.00	0.90	Strength and coverage
4. Monitoring procedures	0.20	0.90	Strength and coverage
ORGAWARE			
1. Investment	0.10	0.90	Regular modernization in Japan
2. Commitment	0.40	0.90	Management commitment to upgradation
3. Energy Manager	0.40	0.90	Organizational level of Energy Manager
4. Energy Team	0.20	0.90	Size of energy team
5. Decentralized Administration	0.50	0.90	Extent of decentralization
Aggregate Index for Technology	6.48	20.31	-

• The basic lesson that can be derived from the exercise is that the higher level of iron and steel technology in Japan is not due to the upgradation of Technoware alone, but also due to substantial changes in Humanware, Inforware and Orgaware that were introduced. The absolute changes also indicate the direction of movement of Japanese iron and steel technology into areas such as continuous casting, hot rolled special steels and surface treated steels.

(b) *Computer Technology*

• A technology may comprise of a number of elements and each element may consist of various sub-elements. For example, computer technology may be sub-divided into the elements and sub-elements using a relevance tree approach. The gaps with respect to each of these sub-elements can then be assessed. An assessment of gaps in computer technology taking India as an example is given in tabular form, in terms of Technoware, Humanware, Inforware and Orgaware. These comparisons are with respect to the best in the world (state-of-the-art).

• Such a detailed analysis of a specific technology can provide insights for technological decision-making.

Table 17.3 (a): Assessment of Gaps in Computer Technology - the Indian Case

Elements	Sub-Elements	Gaps in Technoware	Gaps in Humanware	Gaps in Inforware	Gaps in Orgaware
Hardware	CPU	Facilities for manufacturing other than 8 bit, and 256K not available	Skills for system architecture not well developed	N.A.	No specialized programme for development of this technology for higher memory size
	Memory/Storage				
	- Compact disc ROM	Disc manufacturing facility not available	Low level of skills for developing compact disc technology	Compact disc technology design know-how not available	No institutions concentrating on developing this technoiogy
	- Magnetic discs	Manufactured with collaboration and imported components	N.A.	N.A.	Too many manufacturers with little specialization
	- Memory elements	No manufacturing facility Microphotolithography equipment not available	N.A.	Poor technological forecasting efforts	N.A.
	Peripherals				
	- Laser jet printers	Miniature lasers not manufactured	Lack of specialists in laser technology	Information on laser printer design not available	No specialized agency for development
	- Dot matrix printers	Currently manufactured with imported know-how	N.A.	N.A.	N.A.
	- Line printers	Manufactured with imported know-how	N.A.	N.A.	N.A.
	- Monitors	Opto electronic IC's not manufactured	Opto electronic technology skills not available	Very little R&D to generate new information	Coordinated efforts to develop the technology missing
	- Terminals	Interactive graphic systems not available	N.A.	N.A.	N.A.
Software	System Architecture				
	- Networking system and local area networks	No manufacturing facility	Skills for developing networking technology and system architecture not adequate	Networking algorithms are not available Design information for networking not available	Private networking links not permitted Absence of specialized institutions for capability building
	Applications				
	- Database system	Large systems are not available for testing	Inadequate manpower	N.A.	Too many manufacturers without specialization
	- Expert system	No manufacturing facility	Skills inadequate	N.A.	No coordination mechanisms for technology development
	- Artificial Intelligence (AI)	No manufacturing facility	N.A.	N.A.	No organized efforts for AI software development

N.A. : Information on gaps not available

Table 17.3 (b): Assessment of Gaps in Computer Types- the Indian Case

Type	Gaps in Technoware	Gaps in Humanware	Gaps in Inforware	Gaps in Orgaware
* Personal computers/ Micro computers	Assembled using imported chips/kits	Skill development for application inadequate	Systematic analysis of technology trends not undertaken	No standardization of design is attempted Poor coordination of technology development efforts
* Mini computers	Assembled using imported kits	N.A.	N.A.	Too many manufacturers, upgradation process difficult Promotion of screw-driver technology, and lack of organized assimilation efforts
* Main frame computers	No manufacturing capability	Skills in submicron geometry technology inadequate	No systematic technological forecasting covering computers and high speed peripherals	No coordinated efforts for technology assimilation
* Super computers	Switching circuit manufacturing facilities not available	Skills for system integration and design inadequate	Design know-how for switching systems not available	Absence of a long-term and coordinated programme for technology development
* Fifth generation computers	No manufacturing facility for parallel architecture	Inadequate skills	Information to design knowledge based machines not available Technological forecasting inadequate Know-how not available	Subcritical levels of resource allocation for development Lack of commitment to develop technology Efforts scattered over many institutions without coordination

N.A. : Information on gaps not available

c) Rice Technology

• In the case of agricultural technology the gap can be measured in a relative sense with respect to the highest yield achieved by any country. In the case of rice technology, Korea (ROK) has recorded the highest yield, whereas Nepal has the lowest yield. The difference between best achieved in this region and that of a specific country can be called the potential gap. The dynamics of yield of rice technology over the years is given in tabular form. Korea has reduced the gap, whereas Nepal has remained at the same level.

Table 17.4: Gap in Rice Yield in Selected Countries

Country	Rice yield (kilogrammes/hectare)				Country	Rice yield (kilogrammes/hectare)			
	1948-52	1966	1972	1985		1948-52	1966	1972	1985
Korea (ROK)	2750	3850	4590	6350	Philippines	1180	1310	1490	2440
Japan	4250	4950	5920	6225	Pakistan	1380	1680	2260	2250
China	2170	N.A.	3090	5346	India	1110	1310	1620	2179
Indonesia	1610	1800	2440	4052	Thailand	1310	1610	1770	2037
Sri Lanka	1420	1770	2190	3066	Nepal	1900	2010	1460	2000
Malaysia	1930	2710	N.A.	2807					

• The reasons for the existence of the gaps in rice technology can be disaggregated into Technoware, Humanware, Inforware and Orgaware. From an analysis of the data available on rice technology in this region, it appears that irrigation, fertilizer, seeds and extension are the critical factors that can reduce the gap. Some of the factors responsible for the gap in rice technology, are given in tabular form.

Table 17.5: Factors Responsible for Gap in Rice Technology

Technoware	Humanware	Inforware	Orgaware
Extent of irrigation	Water management skills	Water resources data	Irrigation management systems
Fertilizer usage level	Fertilizer utilization skill	Information on soil and fertilizer characteristics	Fertilizer credit and marketing networks
Extent of use of high yielding variety of seeds	Knowledge and skills for selection and utilization of improved seeds	Information on seed characteristics	Seed distribution and extension networks
Farm equipment usage levels	Equipment operating skills	Information on farm equipment	Credit and equipment maintenance systems
Pest control level/ methods/equipment	Skills for appropriate uses of pesticides	Information on pesticides and plant protection	Pesticide distribution and extension networks

• From the factors identified it can be said that Technoware alone may not reduce the total gap. These factors are based on studies which indicate that:

- — Promotion of extension (Orgaware) along with irrigation seems to be a very important aspect which is missing in some of the countries with low yield.
- — Infoware as it exists in countries with low yield does not cover aspects such as pesticide use, soil management practices, water use practices, etc.
- — Agricultural credit to be effective requires improvement in the Orgaware.
- — Where literacy levels are high among the farmers (better Humanware) the receptivity for technological changes is generally good.

Assessment of Gaps/Levels: Electronics Technology

• In this example, a detailed assessment of gaps and levels in electronics technology has been presented. These gaps can be measured in terms of three parameters:

- — percentage share of electronics in manufacturing;
- — percentage share of electronics to value added in manufacturing;
- — ratio of exports to total production.

Table 17.6: Status of Electronics Industry in the Manufacturing Sector (1982)

Parameter	Japan	Korea (ROK)	India	Parameter	Japan	Korea (ROK)	India
Gross output of electronics industry (Million US$)	66,532	3,622	447	Percentage share of electronics in manufacturing sector	6.71	5.25	0.60
Total output of manufacturing sector (Million US$)	991,510	88,960	73,776				
Value added by electronics industry (Million US$)	26,123	1,342	116	Percentage share of electronics to value added in manufacturing	7.43	5.80	0.87

• These indicate the magnitude of gap existing in the electronic technology area. Electronics accounts for 5 to 7 percent of gross output in manufacturing in Japan and Korea (ROK), whereas in India it is less than 1 percent. The value of the three parameters in the case of Japan, Korea (ROK) and India is given in tabular form as an indicator of the status of electronics technology in that country. The exports to production may be used as an indicator of quality of output.

Table 17.7: Export of Production Ratio for Electronics (1984)

Type of Electronics Industry	JAPAN			KOREA (ROK)			INDIA		
	Production (Million US$)	Export (Million US$)	Export to Production Ratio	Production (Million US$)	Export (Million US$)	Export to Production Ratio	Production (Million US$)	Export (Million US$)	Export to Production Ratio
Communications	6,910	2,390	0.35	N.A.	N.A.	N.A.	257.6	2.57	0.011
Consumer Electronics	19,690	8,100	0.41	2,168	1,436	0.66	471.5	2.33	0.005
Industrial Electronics	27,580	12,080	0.44	1,324	554	0.42	253.1	4.74	0.019
Electronic Components	23,810	9,490	0.40	3,276	1,892	0.58	243.4	5.52	0.023
Overall	N.A.	N.A.	N.A.	6,768	3,882	0.57	1,613.0	127.22	0.078

N.A. : Information not available

• The actual level of electronics technology in Japan, Korea (ROK) and India which represent the nature of gap is described, with respect to Technoware, Humanware, Inforware and Orgaware levels in these countries, in tabular form.

Table 17.8: Level Analysis for Electronics Industry in Terms of Technology Components

Technology Component	Parameters		Japan (1984)	Korea(ROK) (1984)	India (1984)
TECHNOWARE	**Component production :**				
	* Resistors	(millions)	75,635	N.A.	1,087
	* Capacitors	(millions)	71,079	7,365	417
	* Transformers	(millions)	3,405	15.4	7.4
	* Connectors	(millions)	6,019	N.A.	3.5
	* Switches	(millions)	2,784	N.A.	10.0
	Semiconductor device production:				
	* Silicon diodes	(millions)	18,221	2,041	7.5
	* Transistors	(millions)	14,390	3,690	130
	* Rectifier diodes	(millions)	4,051	N.A.	2.5
	Integrated circuit production:				
	* Semiconductor integrated circuits	(millions)	4,795	2,254	2.3
	* Hybrid integrated integrated circuits	(millions)	177		0.07
	Memory devices:				
	Capability to produce memory		1M-DRAM 4M-ROM as as well 4M-DRAM	1M-DRAM 1M-ROM	2M-DRAM planned for 1986
	Number of Computers in use		150,703	2,359	N.A.
HUMANWARE	Number of technical personnel in computer technology		127,978	7,448	About 5,000

Technology Component	Parameters	Japan (1984)	Korea(ROK) (1984)	India (1984)
INFORWARE	* Commercial electronic databases	924	56 (1985)	N.A.
	* Foreign collaborations for technology (1984)	817	77	N.A.
ORGAWARE	* R&D expenditure (million US$)			
	- Government (1984-85)	N.A.	211	6.8
	- Industry (1984)	2,246	317	6.4
	* Research expenditure as % of sales for major firms	12.2	3.9	1.5
	* Venture capital fund	*Research Development Corporation of Japan *Special Reserve for Development of General Purpose Programme	*Korea Technology Finance Corporation *Korea Technology Development Corporation	None as of now

18. Assessment of National Technological Needs

• The integration of technological considertions in the national socio-economic development planning process requires the evaluation of:

i) national technological capabilities
ii) national technological needs

Both these analyses involve the examination of many complex and interrelated issues. Methodologies to analyze technological capabilities have already been outlined and a needs assessment methodology is presented in this section.

Steps in the Assessment of Technological Needs

• The basic steps involved in the assessment of technological needs could be listed as follows:

Step 1: Derivation of technological areas of relevance from an analysis of national socio-economic and production sector objectives.
Step 2: Formulation of geographic and political criteria for guiding further analysis of technological areas of relevance.
Step 3: Forecasting world technological trends for guiding further analysis of technological areas of relevance.
Step 4: Classifying and prioritizing technological areas of relevance into:
  i) those of strategic importance;
  ii) those of high potential;
  iii) general importance
  for purposes of allocation of resources.
Step 5: Classification of technological areas of relevance by transformation stages.
Step 6: Determination of specific, generic and clusters of technologies needed from the technological transformation analysis.
Step 7: Time phasing of technologies needed by Technology Domain (Importing, Traditional and Exporting)
Step 8: Review and Adjustments.

Each of these steps is explained and illustrated below.

Analysis of National Socio-economic Objectives and Derivation of Technological Areas of Relevance.

• Most national socio-economic objectives can be divided into tactical and operational objectives. Common examples belonging to these two categories are:

(a) *Tactical Objectives*
— Satisfying survival, living, community and work needs of the population

— Fostering rapid economic growth by controlling population growth and increasing productivity at all levels.
— Improving quality of life by reducing human drudgery and environmental degradation.

(b) *Operational Objectives*

— Maintaining independence and national integrity.
— Achieving self-reliance by reducing dependence on external assistance and increasing indigenous inventions and innovations.

• These objectives have to be realized through the carrying out of various economic activities in the different productive sectors of the national economy. Thus, for assessing the technological areas of relevance, the national level objectives have to be translated into production sector objectives. The following table illustrates how production sector objectives can be derived from the tactical objectives.

Table 18.1: Derivation of Production Sector Objectives from Tactical Objectives

Production Sector	Production Sector Objectives by Sector-Based on the Tactical Objectives		
	Needs Satisfaction	Economic Growth	Quality of Life
Agriculture - Crops - Fisheries - Livestock - Forestry	- Increase production - Reduce losses	- Reduce imports - Increase exports - Increase agricultural productivity	- Improve nutritive quality of food - Minimise environmental degradation
Communications - Posts and Telegraphs - Telephone - Radio and Television	- Improve access	- Increase efficiency - Increase productivity	- Lower cost of usage - Improve reliability of services
Education - Primary - Secondary - Vocational - Tertiary - Informal	- Provide universal education	- Develop human resources - Develop a balanced skill structure	- Eliminate illiteracy
Energy - Renewable sources - Non-renewable sources	- Increase production - Reduce losses	- Improve distribution - Improve efficiency	- Lower cost of usage - Improve reliability of supply - Minimise environmental degradation
Housing and Construction - Residential buildings - Industrial buildings - Commercial and service buildings - Irrigation and related structures - Bridges - Towers	- Provide mass housing - Provide adequate space for industrial and commercial activities	- Facilitate increased construction activity - Facilitate utilization of local materials - Encourage low cost construction	- Ensure sound construction - Provide adequate shelter from uncomfortable conditions - Provide an aesthetically pleasing environment

• Once the production sector objectives are derived, it should then be possible to derive the technological areas of relevance based on these. This is illustrated in tabular form using the agricultural sector as an example.

Table 18.2: Technological Areas of Relevance for the Agricultural (Crops) Sector

Sectoral Objectives		Technology Requirements
1. Increase production	(i)	Developing improved cultivars
	(ii)	Improving land useage
	(iii)	Improving plant nutrition
	(iv)	Importing water usage
2. Reduce losses	(i)	Protecting crops from pests and diseases
	(ii)	Efficient harvesting
	(iii)	Reducing post-harvest losses
3. Reduce imports	(i)	Producing locally, previously imported crops
	(ii)	Developing import substitutes
4. Increase exports	(i)	Increasing production of traditional export crops
	(ii)	Developing non-traditional export crops
5. Increase productivity	(i)	Improving soil preparation
	(il)	Developing cost-competitive cultivars
	(iii)	Developing cost-effective crop husbandry techniques
	(iv)	Bettering land use
6. Improve nutritive quality	(i)	Developing low-cost cereals and legumes
	(ii)	Developing varieties of cereals and legumes with improved nutrient content
	(iii)	Increasing production of nutritious varieties of vegetables
7. Minimise environmental degradation	(i)	Proper soil conservation
	(ii)	Proper water management
	(iii)	Preservation of primitive and indigenous cultivars and wild plants
	(iv)	Rational use of agrochemicals and energy

Formulation of Geographic and Political Criteria

- To incorporate geographical and political realities into the needs assessment, it is imperative that the technology planners prepare, in consultation with the national-level policy-makers, a set of criteria for guiding and prioritizing the needs assessment.

- For instance, the policy-makers of a country such as Sri Lanka may feel that due to the country's strategic geographic location and its national policy of fostering an open market economy, development of its air and sea port facilities should receive high priority. This could then become a key geographic and political criterion that would have to be necessarily incorporated into the needs assessment.

- Similarly, a country with no oil reserves such as the Republic of Korea may decide that energy conservation and alternate energy resource development are very important for it to be able to preserve its capacity for autonomous decision-making and market competitiveness at the international level.

- Thus, if this step is pursued carefully the technology planners should have, at its conclusion, sufficient information to ensure congruence between their thinking and that of the national-level policy-makers.

Forecasting World Technological Trends

- This step involves forecasting world technological trends and is necessary to ensure that the planners can select, with a fair degree of confidence, the best technological alternatives to meet their needs.

- This exercise could be very sophisticated requiring high level Humanware from inter-disciplinary fields.

- As an illustrative example, if a developing nation needs technologies for upgrading its telecommunication networks, then a technological forecasting exercise may show that it may be prudent for the country to go in directly for fiber optics technology since it may have invested very little in conventional communication networks which are fast becoming obsolete.

Classifying and Prioritizing of Technological Areas of Relevance

- The fourth step of the needs assessment methodology requries classification and prioritization of the technological areas of relevance into those of strategic importance, high potential and general importance. Usually those of strategic importance have political connotations while those of high potential have economic relevance in the case of the agricultural (crop) sector, that has been already presented, a possible prioritization for a South Asian developing country is shown in tabular form.

- Prioritization of technologies in this manner can be carried out only by taking into consideration the specific characteristics of the country and its resources. No generalization is possible. However, some examples for a few selected ESCAP developing countries are:

Technological areas of strategic importance

— Development of mini hydro-power capacity - for countries such as Nepal, Bhutan, Sri Lanka which would

Table 18.3: Technology Requirements Prioritization in the Agriculture (Crops) Sector

Technologies of Strategic Importance Required For:	
(i)	Producing locally, previously imported crops
(ii)	Developing import substitutes
(iii)	Increasing production of traditional export crops
Technologies of High Potential Required For:	
(i)	Developing improved cultivars
(ii)	Developing cost-competitive cultivars
(iii)	Developing cost-effective crop husbandry techniques
(iv)	Developing low-cost cereals and legumes
(v)	Developing varieties of cereals and legumes with improved nutrient content
(vi)	Increasing production of nutritious varieties of vegetables
(vii)	Increasing production of traditional export crops
(viii)	Developing non-traditional export crops
Technologies of General Importance Required For:	
(i)	Improving land use, soil preparation and conservation
(ii)	Improving water management and usage
(iii)	Improving plant nutrition
(iv)	Protecting crops from pests and diseases
(v)	Rational use of agrochemicals and energy
(vi)	Efficient harvesting
(vii)	Reducing post-harvest losses

like to reduce their reliance on imported fossil fuels.

— Development of heat-efficient wood burners - for a country such as the Maldives which has no fuelwood reserves for producing charcoal on any significant scale.

— Development of flood control techniques (i.e. effective water management) - a country such as Bangladesh may consider this of strategic importance. It has been suggested that Bangladesh may construct roads and flood and drainage embankments can act as roadways and vice versa.

Technological areas of high potential

— Increase output of marine products - island countries such as Maldives, Philippines, and Sri Lanka have very high potential for marine prodution.

— Increase output of inland fisheries - land-locked countries such as Nepal and Bhutan have high potential for fish farming.

— Increase output of forestry resources - Bhutan is perhaps one of the few least developed countries which has sufficient forest resources to embark on a program of export-oriented industries.

— Increase output of fertilizer (improved plant nutrition) - Bangladesh, which has a generous reserve of natural gas, can use this effectively for the production of urea.

— Upgrade micro-electronic applications (e.g. better industrial process control), information processing, etc.) - Sri Lanka, which has a very high level of literacy and an established system of free education up to the university level, can re-orient its curricula to take advantage of the advances in micro-electronics since this is a field that relies heavily on good human resources and not much on expensive physical facilities.

• The above examples serve to illustrate the fact that developing countries stand to benefit in the long run by examining technological areas of relevance which have high potential and/or strategic implications.

Classification of Technological Areas of Relevance by Transformation Stages

• In this step, the prioritized technological areas of relevance are classified by transformation stage. This will help in translating the technological areas of relevance into practical forms of technology. This classification is tabulated for the agriculture (crops) sector. The national level capabilities at each of these transformation stages can also be put to good use in meeting, at least partly, these technological requirements.

Table 18.4: Technological Areas of Relevance Classified by Stages of Transformation

Cultivating	- development of improved cultivars - protection of crops from pests and diseases (development of pest and disease resistant cultivars -local production of previously imported crops - developing import substitutes - increasing production of traditional export crops - developing non-traditional export crops - improving soil preparation - developing cost-competitive cultivars - better land use (intensifying cultivation, intercropping, etc.) - developing low cost cereals and legumes - developing varieties of cereals and legumes with improved nutrient content - increased production of nutritious varieties of vegetables - proper soil conservation - preservation of primitive and indigenous cultivars and wild plants	1. Breeding of cultivars with the following characteristics: (i) reasonable yield; (ii) resistance to pests and diseases; (iii) adaptability to moisture stress; (iv) higher nutritive quality; (v) lower fertilizer requirement; (vi) early vigour; (vii) short uneconomic pre-harvest periods. Note : This applies to crops for local consumption, import substitution and exports

Gathering	- improved land usage (surveying, identifying new land, etc.) - improving water usage (surveying, locating, etc.) - efficient harvesting (use of productive methods) - proper water management - improving plant nutrition (collecting natural fertilizer)	1. Surveys of land, water, climate, natural fertilizer deposits and agro-ecology. 2. Extraction of natural fertilizers 3. Good land preparation
Preprocessing	- improving plant nutrition (natural fertilizer usage) - reducing post-harvest losses (cleaning, grading agricultural produce)	1. Basic processing of natural fertilizers
Processing	- improving plant nutrition (chemical fertilizers) - protection of crops from pests and diseases (pesticides, weedicides, etc.) - reducing post-harvest losses (chemicals for crop preservation)	1. Manufacture of chemicals such as : (i) fertilizers (ii)pesticides, weedicides, fungicides, etc. (iii)preservatives
Constructing	- improving water usage (flood control, dams, channels, etc.) - reducing post-harvest losses (construction of appropriate storage space such as silos, bulk stores, etc.	1. Construction of dams, irrigation channels, flood-control embankments, etc. 2. Construction of silos, bulk stores, cold stores, etc.
Manufacturing	- efficient harvesting (manufacture of agricultural machinery and implements) - reducing post-harvest losses (manufacture of solar crop dryers, refrigeration equipment, dehydrating equipment, etc.	1. Manufacture of agricultural machinery and implements 2. Manufacture of crop dryers, refrigeration equipment, etc.)
Assembling	- efficient harvesting (assembly of agricultural machinery and implements) - reducing post-harvest losses (assembly of solar crop dryers, refrigeration equipment, dehydrating equipment, etc.	1. Assembly of agricultural machinery and implements 2. Assembly of crop dryers, refrigeration equipment, etc. 3. Assembly of handling equipment.
Packaging	- reducing post-harvest losses (use of appropriate packaging material)	1. Manufacture of suitable packaging material to minimize losses and preserve quality.
Distributing	- reducing post-harvest losses (use of appropriate equipment to transport produce)	1. Specialized equipment for handling produce (conveyors, pneumatic devices, transport equipments, etc.) to minimize handling losses 2. Developing good storage practices
Supporting	- all areas described above for "cultivating stage" - developing cost-effective crop husbandry techniques - proper water management (controlled release of irrigation water) - rational use of agro-chemicals and energy	1. Developing good crop husbandry practices for: (i) sowing; (ii) optimal pruning; (iii) intercropping; (iv) cover cropping; (v) weed management; (vi) optimal fertilizer application.

Determination of Specific, Generic and Clusters of Technologies

- The classification by transformation stage helps to identify practical forms of technology. However, the same practical form of technology or a technology closely related to it may be found at several of the transformation stages. Thus, a determination of specific, generic and clusters of technology will be useful.

- The term generic technology refers to a technology whose application is common to many areas. Examples include ball-bearing manufacturing technology, electric motor manufacturing technology, microprocessor technology and genetic engineering. Clusters of technologies refer to a group of technologies which may have to be adopted together or may be worthwhile adopting together for optimal results. Thus, if genetic engineering technology is to be imported it may also be worthwhile to obtain germ plasm bank and gene bank technologies so that optimal benefits can be obtained. The term specific technology refers to one which is used for a specific purpose. For example, the technology required for cleaning and crushing naturally occuring rock phosphate (for use as fertilizer) is a specific technology.

- The list of specific, generic and clusters of technology for the agriculture (crop) sector is tabulated below as an illustrative example.

Table 18.5: Specific, Generic and Cluster of Technology Needed for Agriculture (Crops) Sector

Technology Description	Technology Description
Genetic engineering technology	Agrochemical manufacturing technology
Tissue culture technology	Bulk, silo and related storage construction technology
Conventional plant breeding	Agricultural packaging material technology
Germ plasm bank technology	Crop preservation (physical and chemical treatment) technology
Gene bank technology	Agricultural produce transportation technology
Remote sensing technology	Agricultural produce handling technology
Agricultural mechanization technology	Biological and environmental pest control technology
Dam, irrigation channel and related construction technology	Water management technology
Natural fertilizer extraction and manufacturing technology	Crop husbandry technology

Time Phasing of Technologies Needed by Technology Domain

- In this step a plan of action is drawn up for acquiring/developing the technologies needed. The mode of acquiring-/developing technologies may be divided into three domains namely the Importing Technology Domain, the Traditional Technology Domain and the Exporting Technology Domain.

- The Importing Technology Domain represents areas for which a country has chosen to depend on imported technologies. Usually these are:

  — Technologies requiring long periods and large amounts of funds to be developed locally;
  — Technologies which are not currently available in the country but which can have significant impact on quality improvement and cost reduction;
  — Technologies protected by industrial proprietary rights;
  — Technologies embodied in capital goods which cannot be produced locally;
  — Technologies which can have a beneficial impact on other technologies being developed for exports.

- The Traditional Technology Domain represents areas for which a country has chosen to improve endogenous technologies such as:

  — Technologies with traditional heritage;
  — Technologies which attempt to promote harmony in human surroundings;
  — Technologies which are directed to rural people, etc. These projects are based on endogenous technologies which could be modernized by introducing advanced knowledge and techniques, either locally developed or imported, to gradually improve the life of a country's rural population.

- The Exporting Technology Domain represents areas for which a country has chosen to develop state-of-the-art technologies for local consumption and export because;

  — The country has relative advantage in terms of necessary resources;
  — The country has geographical or locational advantage, etc. These projects are expected to provide a source of foreign revenue for making technology import possible in the long-run. The production and export of some high-potential technologies (either hardware, software, or both) represent new and non-traditional activities for a developing country.

- A possible time-phasing by domain, is tabulated below for the agricultural sector for a country such as Sri Lanka with a resonably good record of agricultural crop development. The asterisks denote the areas where a time target is to be set.

Table 18.6: Classification of Technological Needs by Technology Domain

Generic, Specific, or Clusters of Technology	Importing Technology Domain					Traditional Technology Domain					Exporting Technology Domain				
	Time Schedules by Life Chain					Time Schedules by Life Chain					Time Schedules by Life Chain				
	Select-ing	Adapt-ing	Demon-strating	Produc-ing	Diffus-ing	Re-search	Develop-ing	Demon-strating	Produc-ing	Diffus-ing	Re-search	Develop-ing	Demon-strating	Produc-ing	Diffus-ing
Genetic Engineering	*	*	*	*	*										

Generic, Specific, or Clusters of Technology	Importing Technology Domain					Traditional Technology Domain					Exporting Technology Domain				
	Time Schedules by Life Chain					Time Schedules by Life Chain					Time Schedules by Life Chain				
	Select-ing	Adapt-ing	Demon-strating	Produc-ing	Diffus-ing	Re-search	Develop-ing	Demon-strating	Produc-ing	Diffus-ing	Re-search	Develop-ing	Demon-strating	Produc-ing	Diffus-ing
Tissue Culture	*	*	*	*	*										
Conventional Plant Breeding	*	*	*	*	*						*	*	*	*	*
Germ Plasm Banks	*	*	*	*	*										
Remote Sensing	*	*	*	*	*										
Agricultural Mechanization	*	*	*	*	*	*	*	*	*	*					
Dam, Irrigation Channel Related Construction						*	*	*	*	*	*	*	*	*	*
Natural Fertilizer Extraction and Manufacturing						*	*	*	*	*					
Agrochemical Manufacturing	*	*	*	*	*										
Bulk, Silo and Related Storage Construction						*	*	*	*	*	*	*	*	*	*
Agricultural Packaging Material	*	*	*	*	*										
Crop Preservation	*	*	*	*	*										
Agricultural Produce Transportation	*	*	*	*	*										
Agricultural Produce Handling	*	*	*	*	*										
Biological and Environmental Pest Control	*	*	*	*	*						*	*	*	*	*
Water Management	*	*	*	*	*						*	*	*	*	*
Crop Husbandry	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

- Very often a country may have developed a certain amount of expertise in a technology for certain specific applications but not for others. For example, if a country has developed crop husbandry capabilities in the area of tea cultivation but not in horticulture, then it may be necessary to get this latter expertise from another country while exporting available capabilities in this area to some other country. Thus, in the above table, for certain technologies all three technology domains may be relevant. In certain areas such as remote sensing, genetic engineering, and the like, due to lack of local human resources the country may need to rely on foreign technology in the short- and medium-term. However, the ultimate objective should be to master these imported technologies and the table shows that provision has to be made for setting target dates for acquiring certain levels of capabilities or producing desired impacts in all three domains.

- It has to be stressed that at every stage, all four components of technology have to be examined and the targets must be set for reaching prescribed levels in Technoware, Humanware, Inforware and Orgaware.

Review and Adjustments

- Once the classification by technology domain is completed along with the time schedules, the technology planners will have to check whether these targets are attainable given the magnitude and type of technological and financial resources needed. The results of the prioritization exercise can be used at this stage for resource allocation. Sometimes the time schedules may be too optimistic and it may be necessary to revise these. On the other hand, given the tremendous benefits achievable by adopting certain technologies such as genetic engineering, the planners may feel that the target dates should be advanced which may mean diverting resources from other areas into this. Thus, this last stage of review and adjustment is very critical.

- This review and adjustment process may be carried out annually. Each year the technology planners and those responsible for implementing the plan would review the progress to make necessary adjustments to the plan.

Part IV
Policy Implications

19. Development Planning Using Technology Domain Approach

• The role of government in technology planning is a major one in developing countries while it may be a minor one in the developed countries where the private sector is well established and appreciates the role of technology in economic growth.

• Observed trends of deliberate specialization throughout the world is expected to increase technological interdependence among all countries. Natural resources and human resources being so widely distributed, attempting self-sufficiency with respect to all technologies may indeed be uneconomical. Therefore, the "make-some-and-buy-some-technology" is perhaps the most pragmatic strategy for sustainable and self-reliant national development.

• In the present day developing countries, which cannot afford to wait for a gradual technological change in response to the needs of their almost economically stagnant societies, technology is expected to cause rapid socio-economic development. It is also essential that specific considerations be given to the "make-some-and-buy-some-technology" strategy which gives a country an opportunity to take advantage of its later-starter status, the advantage of selecting an appropriate area of specialization, and the potential to exploit the advantages of technology exchange in the international market place.

Importance of the Assessment of National Technological Needs

• It is desirable that an integrated approach to development planning which aims at harnessing the full potential of technology for development, be considered by classifying national development projects into three "Technology Domains":

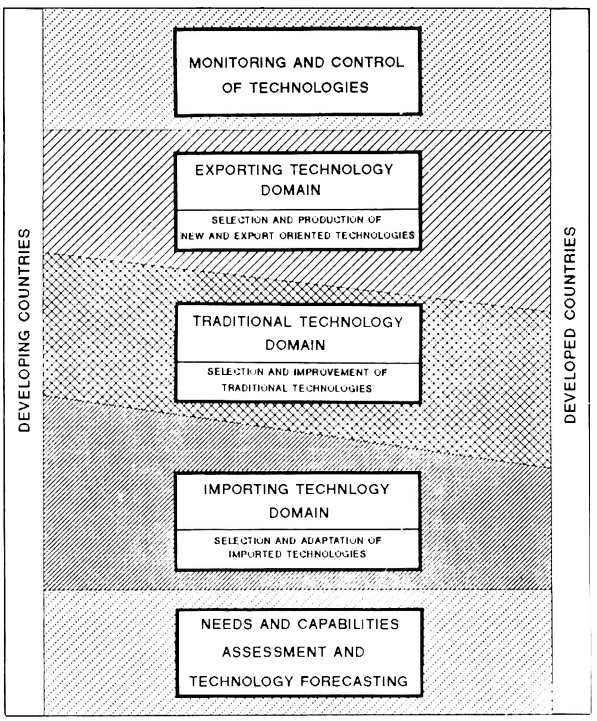
i) projects belonging to the "importing technology domain";
ii) projects belonging to the "traditional technology domain";
iii) projects belonging to the "exporting technology domain".

• A possible approach for carrying out this technology domain based analysis has been outlined in Part III under "Assessment of National Technological Needs".

• The classification scheme by technology domain may provide a simple mechanism for integrating technological considerations in the national socio-economic development planning process such that the choice of the technology question is dealt with explicitly.

• The following schematic diagram presents a likely distribution of projects by technology domain. It also shows that the two other essential elements in development planning are - (i) needs and capabilities assessment; (ii) monitoring and control of technologies.

Figure 19.1: Relative Involvement by Technology Domain



Importance of the Assessment of National Resources

• One of the drawbacks of the current development planning exercises in many of the developing countries is that, plans are normally modest extrapolations of what has been done in the past. This approach makes the tacit assumption that the status of the national resources profile of a country has changed very little. This may not be the case in many situations where considerable changes may have taken place. Thus, it is imperative that an assessment of national resources be carried out prior to the national development planning exercise. A possible approach has been suggested in Part III under "Assessment of National Resource Profile".

• As an illustrative example the case of water resources is used to demonstrate how national resources implications may be considered by national planners.

• National water resource profiles of Asian countries (as shown in Section 15) gives an indication of their ultimate water potential. The trend indicates that some of these countries may have to generate newer technologies which consume less water compared to the traditional technologies. Countries such as Pakistan, Sri Lanka, China, India, Thailand and the Republic of Korea have to be cautious in terms of development of production facilities which consume high volumes of water. The technological implications may be summarized as follows:

Technoware	—	Development of newer equipment and processes which consume lesser quantities of water.
Humanware	—	Development of skills for recycling and reusing water.
Inforware	—	Collection of information on specific water use of alternative process technologies.
		Monitoring of technologies which consume less water per unit of output.
Orgaware		Orientation of development plans to set up industries which consume less water.
		Promotion of R&D for recycling and reuse of water.
		Water conservation and reuse plans.

Utility of Technological Capabilities Assessment in Planning

- Technological self-reliance is the autonomous capacity to make and implement decisions for reducing technological dependence. A basic prerequisite for initiating planned efforts towards self-reliance is the evaluation of national technologies capabilities.

- The efforts of many developing countries in evaluating national technological capabilities are yet to be systematised. Methods have to be developed to evaluate capabilities of a country with respect to specific technologies, transformation facilities, and production sectors. Some methodologies for this purpose are outlined in Part III under "Assessment of National Technologies Capabilities" and "Assessment of Technological Gaps and Levels".

20. Development of Technological Human Resources

- It is clear that the ultimate resource for technological advancement is "brainpower". It is also known that the total population of the developing countries of the world is twice as large as that of the developed countries. If only the population could be developed to Humanware, the potential brainpower would be enormous!

- With the development of human resources for the generation of better technologies in any particular area of relative advantage, the role of a developing country can very well change from that of a follower to a leader in that technology (for example: Japan in microelectronics and automobiles, Republic of Korea in steel and shipbuilding).

- Along with the "brains" that can assimilate imported Inforware and generate indigenous Inforware, a country also needs "hands" that can produce a marketable Technoware of acceptable quality. Hence development of human resources means a balanced development of both brains and hands.

Relevance of Skill Profile Analysis

- It can be observed that the developing countries have lately produced many eminent scientists and philosophers who have made distinctive contributions to world science and knowledge (mostly after migrating to developed countries), while the craftsmanship from these countries have gradually disappeared. This may be due to the orientation towards scientific and technological education in developing countries, that is, towards "knowing" rather than "doing".

- One key factor for human resources development is the skill structure and its effective utilization for the development of a country. The stock of human resources must have a balanced structure, consisting of inventors and innovators, managers and engineers, scientists and technicians, craftsmen and skilled workers, and semiskilled and unskilled workers. The skill spectrum in many developing countries has become unfavourable for technological development due to many reasons:

  - The relative proportion of the "inventors and innovator" group has shrunk considerably due to inadequate growth of infrastructural facilities for such development and due to considerable migration to developed countries.

    Many scientists, engineers, teachers and management level personnel have migrated from developing countries to developed countries. (Many are also working temporarily as expatriates in natural-resource rich countries. Moreover, national production of this type of personnel in developing countries has not grown sufficiently).

    Many developing countries are exporting craftsmen and skilled workers to rich countries to earn foreign currencies, which mainly help debt servicing and the import of consumable.

    Due to continued population growth without a proportional increase in education and training facilities, the fraction of unskilled workers has increased considerable in developing countries. However, in the developed countries, with zero population growth and proportionately increased efforts in skill development, the fraction of unskilled workers has diminished.

    The loss of teachers (educators and trainers) from the developing countries to the developed countries has caused multiplier effects leading to further distortion of the skill structure in developing countries.

- A conceptual framework for the development and analysis of the national skill profile has been presented in Part III under "Assessment of National Resource Profile".

Usefulness of the Humanware Life Chain Analysis

- An analytical framework for examining the phases of the Humanware life chain has been presented in Part III under "Assessment of National Technological Capabilities". The analysis of each phase must be supplemented with an inquiry into key issues, some of which are listed below.

- In most developing countries the Rearing phase has not received much attention and no institutionalized efforts to strengthen this phase appear to be in existence. It is during this phase, which ranges for about five years, that the mental faculties are developed which could make a significant contribution to creativity in the long term. Thus, it is essential that this aspect be given adequate attention in the planning process.

- The Telling phase is still weak in many developing countries. While improving coverage in order to attain the Univresal Primary Education target is important, it should not be done at the expense of quality.

- The Teaching phase in many developing countries appears to be unable to deal adequately with the increasing demand due to the adverse demographic structure. While infrastructure problems have led to the dilution of the quality of education in this phase, the type of coverage of subject matter is also of concern. Inadequate attention to science and technology subjects is a major problem, and in addition the methods of teaching and examinations hinder creative thinking and emphasize memorizing.

- It is the Educating phase that provides a nation with its supply of technological manpower. Exceptionally qualified scientists and engineers play a central role in technological development but, it takes a long time and good facilities to train quality technological personnel in a specified field. Increasing enrolment without improving the facilities for good education is detrimental to development.

- The Training phase assumes special importance because academic institutions produce only the raw material for the development of technological manpower. The products of academic institutions need to be trained and retrained for skill development with respect to specific needs of the society. In-service training and training in pilot or demonstration projects are essential. The advantages and disadvantages of foreign training versus training by hired foreigners should also be considered. Education and training of technological manpower of various skill levels inside the country are important options that require building of adequate infrastructure and careful planning and implementation over a long period of time. Special consideration must also be given for the preparation of training materials and trainers, both in quantitative and qualitative terms.

- Building up a sound R&D base requires the availability of an institutional mechanism which is capable of providing scientist and technologists with post-graduate qualifications as well as specialized on-the-job training. From this point of view the Developing phase becomes very critical for the adaptation of imported technologies and the development of exportable technologies.

- Since technology is changing continuously at an exponential rate, knowledge and skills can become obsolete very quickly. The society of today is knowledge intensive and thus, the Upgrading phase should be a matter of survival. The upgradation is mostly a non-formal activity involving off-the-job training, national and international seminars, etc.

Considerations for Reducing the Effects of Brain-Drain

- Many developing countries have a large number of their high-calibre nationals working in developed countries. One short-term option for these developing countries could be to receive temporary help from their expatriate nationals. However, to have those expatriate nationals return on a permanent basis, specific measures are necessary for improving the work environment in the country. Upgrading the work environment is likely to help in retaining available qualified personnel as well as attracting nationals working abroad. Improvements in work environment require the following considerations:
  - Promotion of research activities in the country using the twofold criteria of ensuring excellence as well as relevance;
  - Creation of a mechanism for direct interaction among academia, research institutions, and the production sector of the country; and
  - Offering proper societal status and recognition to technological manpower, both for "brains" as well as "hands".

21. Strengthening Technological Institutions and Linkages

- Orgaware may be viewed as a medium that binds the other three components to bring about fruitful results. This component can neither be imported nor transplanted from one place to another. It has to be necessarily evolved from within.

- Unfortunately, the Orgaware component has not received due recognition commensurate with its importance. This has led to many developing countries attempting to bring about revolutionary technological change with outdated decision-making systems.

Importance of Orgaware Life Chain Analysis

• In order to strengthen the Orgaware for technology development it may be useful to look at the various stages of the life-chain. Some important factors are mentioned below.

• While capabilities in the Conceiving phase are reasonably strong in most developing countries, weaknesses are prominent in the Preparing, Designing, Installing, Operating, Guiding and Evolving phases.

• Orgaware basically refers to current management practices which facilitate interaction among people both as organizations and as individuals. This interaction has to be carried out through the establishment of linkages. Even the level of sophistication of Orgaware may be measured in terms of the complexity of linkages. In many developing countries one of the reasons for the weakness of Orgaware is the total absence of some vital links or the existence of only weak linkages.

• In order to ensure the effectiveness of Orgaware from the linkage point of view, creation of active intermediaries may be useful. These intermediaries may be established to ensure proper linkages between users and suppliers of technology under the following categories:

— R&D and production bases (e.g. venture capital agencies)
— local and foreign sources (e.g. technology transfer agencies)
— urban and rural settings (e.g. extension services agencies)
— large-scale and small-scale enterprises (e.g. subcontract facilitating agencies)
— emerging and traditional concepts (e.g. promotional agencies)
— public and private ownership (e.g. coordinating agencies)

• Another weakness in Orgaware manifests itself in the preparing phase where objective setting is the ket activity. In many developing countries the setting of non-specific and/or unrealistic objectives leads to lack of focus.

• The Operating phase is where the management of Humanware assumes special importance. Poor motivation of the workforce often leads to the inability of organizations to achieve even marginal growth.

• The Guiding and Evolving phases of the Orgaware life-chain are often neglected in many developing countries. Monitoring of performance and the business environment, critical organizational self-assessment, etc. are not carried out with the result that the Orgaware remains static.

Monitoring and Forecasting the Technological Environment

• In Part II, the sections on the discussions of "Framework for the Assimilation of Imported Technologists" and "Framework for the Development of Indigenous Technologies" shows the weakness of national Orgaware in terms of Technological Forecasting and Technology Assessment.

• Technological forecasting (TF) is a process of predicting with a degree of confidence and consistency, a technological achievement in a given time frame with a specified level of support. This prediction of forecast is essential for proper technology planning, so as to enable the planners to identify possible future courses of action and to select the best technological alternatives available.

• Technology assessment (TA) is supposed to lead to the maximization of positive effects of technology, the development of technologies consistent with the surroundings, the minimization of negative effects of technology and the development of environmentally sound technologies.

• TF and TA are relatively new disciplines and priority should be accorded to training of Humanware in these fields.

The following could be considered the major responsibilities of TF-TA organizations:

— Evaluation of the appropriateness of technologies for input and adaptation;
— Selection of technologies in each domain - the importing domain, the traditional domain and the exporting domain.
— Control of inappropriate technologies to protect the environment; and
— Monitoring and forecasting technological trends.

Vitalization of the Decision-Making System

• Effective national level technology management, free from some of the existing problems, can only be expected with the; (i) introduction of purposeful reforms in the decision-making system; and (ii) availability of a useful and practical technology information database for better decision making.

• Following the evolutionary practice of the developed countries, most of the developing countries also have a national decision-making mechanism, in which the legislators guide the overall direction of socio-economic development through the establishment of policies, while the bureaucrats give real shape to the development process through specific plan formulation and implementation. In contrast to the developed countries, however, in the developing countries the legislators may not have the required diversified professional representation for the formulation of balanced development policies. Also in many developing countries, the bureaucrats may not include science and technology professionals. The vast majority of the professional population, who are not represented among the

members of the bureaucracy thus may not have any direct involvement with the national development planning process.

• Although each country will have to evolve its own unique decision-making system, some of the basic features of the required system may include the following: (i) participation by all affected parties before (and not after) decisions are made; (ii) active involvement (not just expressed interest) of the top leadership in matters of strategic importance (e.g. integration of technological considerations in the socio-economic development planning process of the country); (iii) thorough analysis of all possible alternatives and consequences by using a highly qualified task-force and considering multiple perspectives (involving Technoware, Inforware, Humanware and Orgaware perspectives); and (iv) supported by regularly updated technological information databases.

• Two very important databases necessary for technology-based development planning are: (a) a database which would enable decision-makers to continuously evaluate the national technological capabilities; and (b) a database for regular assessment of national technological needs. The capability assessement is primarily an exploratory forecast on what can be done in the future based on the past and present situation; whereas the needs assessment is normative forecasting on what ought to be done in the future based on the internal and external situation.

22. Creation of a Technology Oriented Mass-culture

• Technology development gains momentum when a suitable environment for its popularization exists. Among other things, the creation and promotion of such an environment is a prerequisite for technology development, particularly in countries where social and economic patterns and customs are bound by tradition. From the long-range point of view, without such an environment, there can be no indigenous technology development and there would be too many constraints for imported technology to be digested or improved. There are numerous tasks to be undertaken in the industrialization of developing countries. However, it is critical that the general public be acquainted with the scientific way of thinking and the proper understanding of the role of technology so that technology can indeed stimulate national socio-economic development.

The Concept of Technology Culture

• Technology culture refers to an attitude of mind. The spirit of enquiry and the acceptance of the right to question and to be questioned is fundamental to the acceptance of the technological temper. It calls upon one to ask about the "how" and the "what" in addition to the "why" and is essentially based upon the scientific method of problem solving. This climate can be created through technological education which includes popularization of technology to increase social consciousness of the importance of technology, technological societies, and the technological community. In order to realize the full potential of technology far more technologically oriented education is necessary for all sections of the population, irrespective of their careers and occupations. The adoption of sound curricula and modes of instruction can help introduce the technological mentality among the general population. Modern technological aids, such as radio, television, and satellites can be very effective in such mass technological education.

• In more specific terms, the creation of a technology culture requires that the following conditions be satisfied.

- A vision for the future of the country in terms of the role of technology in society.
- Passionate commitments to technology for development at all levels.
- National patronage for technology development through generous fund allocation.
- Ensuring high societal recognition for S&T activities.
- Ensuring self-governance of research and development
- Ensuring specialization in selected areas of technology coupled with the promotion of science on a broad front.
- Implementing and encouraging a performance oriented compensation and reward system.
- Internationalization of S&T activities.

Means for the Development of a Technology Culture

• The first step in the development of a technology culture is to realistically assess the status of the country's technology climate. A possible approach for carrying out this technology climate evaluation has been outlined in Part III under "Assessment of National Technology Climate". It is important to ensure that comparative evaluations are made with other countries so that realistic normative prescriptions may be evolved for the development of a technology culture.

• Based on the technology climate evaluation, many programmes may have to be formulated and implemented to facilitate the development of a favourable technology culture. Some popular measures are described below.

• **S&T Movement:** A movement for the popularization of science and technology should form an integral part of a long-range technology development plan. The movement should aim to motivate a universal desire for scientific and technological innovation among all the people in all aspects of their lives. The major goals of this movement may be:

— To encourage the people to develop a habit of applying elementary technical knowledge to every day life and,
— To encourage everyone to acquire technical skills.

- **Mass media:** Society should realize that technology is the master key for development. This realization can be nurtured by awareness campaigns in newspapers, radio and television. In countries with a low literacy level and lack of access to television, the relatively inexpensive radio may provide the best means for reaching the masses.

- **Television:** In addition to its entertainment and propaganda potential, television can be a powerful tool of information, education and attitude change. Television allows exceptional teachers to reach a very large number of students, far beyond the conventional classroom for mass education. Areas which may be covered are basic literacy; strengthening national identity; popularizing science and technology.

- **Technological expositions:** Although relatively more expensive to organize, technological expositions are very useful means of popularizing technology. These should be organized not only in large urban centres, where year-round exhibitions may be organized, but also in the rural areas once or twice every year. Roving exhibitions can be quite effective in this regard. The best results can be obtained by actual demonstrations, with scaled-down working models if necessary.

- **Demystifying technology:** The absence of a technology culture in most developing countries makes it imperative that all segments of the population be involved in the movement. Societies and clubs formed at every level can play an important role. The main aim of this should be to demystify technology which is usually perceived as alien to traditional cultures.

- **Popular scientific and technical literature:** There is a lack of popular scientific and technical literature in almost all developing countries. Organized efforts should be made to encourage the publication of popular literature, which will have a democratizing effect on the masses. S&T societies and clubs can also play a leading role in this.

- **Creation of Development Attitudes:** Inculcating a development oriented attitude should be an integral part of technology culture promotion. In general, the stages of development attitudes lead to the acquisition of the following sequence of abilities:

— solution of existing problems
— improving solutions
— anticipating problems.

Part V
National and International Initiatives

23. Strengthening National Data bases for Decision-making

• Collection, storage analysis and dissemination of information related to rechnology play a key supporting rôle in planning and implementing technology based development programmes. The development of modern computer systems has made possible the storage of large volumes of information and their almost instantaneous retrieval. The rapid growth of international communication networks through satellites will enable even the developing countries to have access to these computerized information banks. Thus, the developing countries can take advantage of these advances to develop appropriate databases for decision-making.

Structuring the National Database

• Some of the problems of existing databases are as follows:

— Absence of information with respect to natural resources;

— Incompatability of existing databases by different agencies as these are narrow in scope and based on different classification systems. For instance, the ISIC and SITC classifications are not compatible.

— Inadequate involvement of the users in the formulation of database structure.

• Thus it may be desirable to restructure the existing databases to harmonize the classification system which is used in national statistical analysis (national accounting, national production, national trade, etc.) and also to provide a consistent mechanism to ensure compatibility for collection and aggregation of data with respect to the various levels of the planning hierarchy.

A Proposal for Restructuring the National Technology Database

• It is proposed that firstly efforts be directed towards the collection of data to assess the national technological climate as illustrated in Section 14. This applies to countries which have not yet commenced the collection of such data.

• It is also proposed that data related to production activities be classified using the stages of technological transformation as the basis. A sample illustration of this classification is presented in tabular form. This does not involve additional data collection and would involve the reclassification of data presently collected for the national accounting system.

• The detailed version of the Technology Atlas will present the following:

— a comprehensive data collection scheme for the assessment of the technology climate;

— a scheme for the reclassification of production sector data by transformation stage.

Table 23.1: Sample of Proposed Reclassification of Production System

Transformation Stage	Description of Production System	Existing ISIC No.
CULTIVATING	* Agriculture and Livestock Production	1110
	* Forestry: Planting and Protection	1210
GATHERING	* Ocean and Coastal Fishing	1301
	* Crude Petroleum and Natural Gas Production	2200
PRE-PROCESSING	* Grain Mill Products	3116
	* Manufacture of Paints, Varnishes and Lacquers	3521
PROCESSING	* Sugar Factories and Refineries	3118
	* Petroleum Refineries	3530
MANUFACTURING	* Spinning, Weaving and Finishing Textiles	3211
	* Manufacture of Structural Metal Products	3813
ASSEMBLING	* Manufacture of Wearing Apparel, except Footwear	3220
	* Manufacture of Containers and Boxes of Paper and Paperboard	3412
PACKAGING	* Canning and Preserving of Fruits and Vegetables	3113
	* Soft Drinks and Carbonated Water Industries: Bottling and Canning	3134
CONSTRUCTING	* Construction: in-site activities	5000
DISTRIBUTING	* Electric Light and Power: Distribution	4101
	* Railway Transport	7111
SUPPORTING	* Ship Repairing	3841
	* Supporting Services to Air Transport	7131

Technology Input-Output Matrix

• On the basis of this database a technology input-output matrix could be developed at the national level. The matrix could give an integrated picture of the inputs and outputs with respect to the stages of technological transformation The Technology Content Added (TCA) could be used to measure the inputs and outputs. An attempt would also be made to decompose these by technology domain.

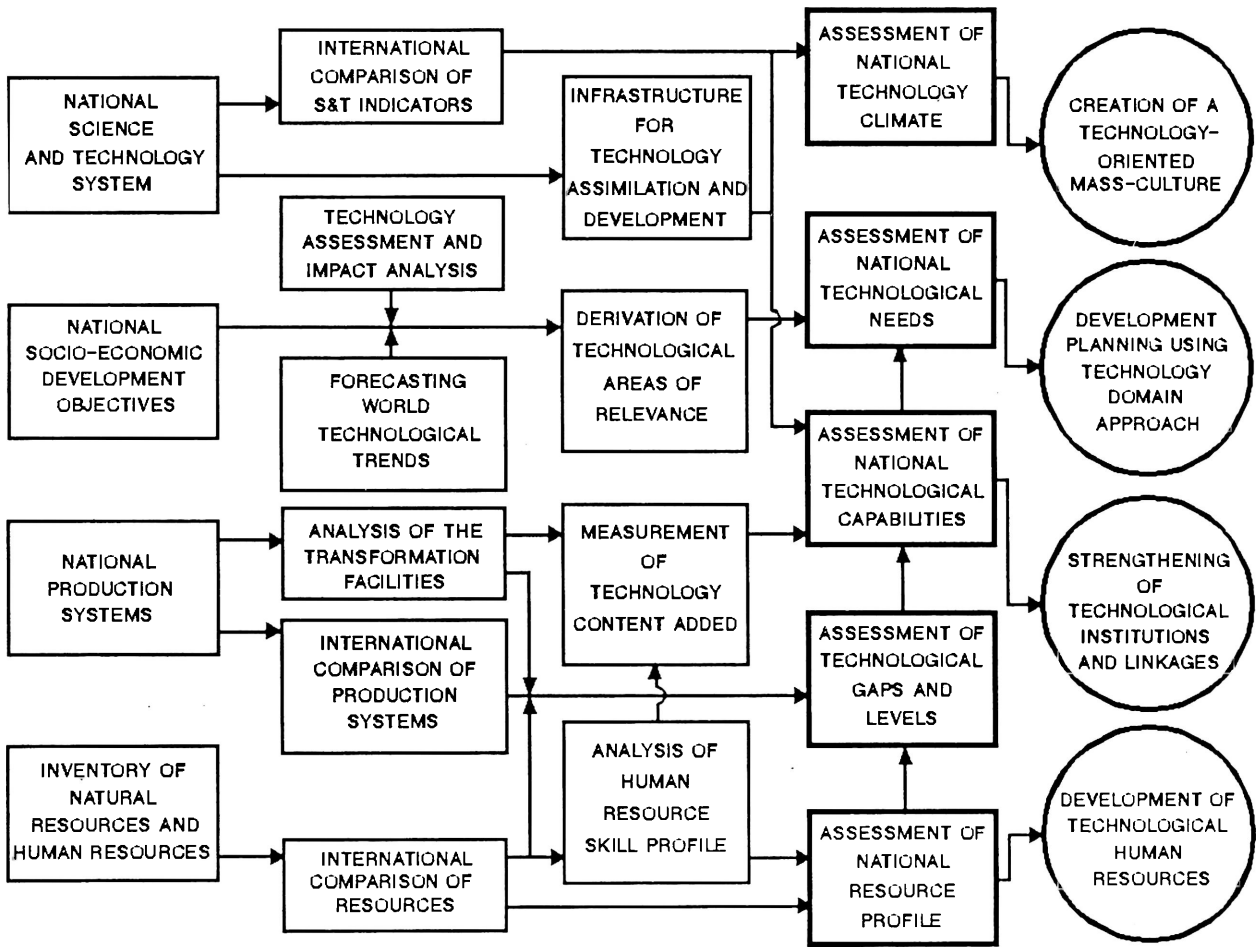
Technology Policy Instrument Matrix

• With respect to the five selected areas of indepth analysis, an attempt will be made to develop some guidelines for the policy-makers in the form of a policy instrument matrix. In this matrix the changing role of the government would be one dimension while the other would reflect the shift in technological advancement (represented by technology domain). Each cell in the matrix would contain possible choices of policy instruments based on case-studies.

Information Flow Chart for Technology Based Development Planning

• The analytical framework of the Technology Atlas is schematically represented in the following diagram.

Figure 23.1: Information Flowchart for Technology-Based Development Planning



24. Regional and International Cooperation

• With the increased trend towards specialization and the universal acceptance of a strategy of technology exchange as the basis for development planning, regional and international cooperation would be beneficial for all countries - both developed and developing.

Regional Cooperation among Developing Countries

• Regional Cooperation might be desirable, yet unlikely to be successful in the area of Technoware, due to market competition. Furthermore, natural resource advantages may not bear any relationship to strategic requirements and national security. Hence, before any plan for regional cooperation could be drawn up, it may be prudent for the partici-

pants to be clear about their areas of non-cooperation due to politico-economic considerations!

- It cannot be over emphasized that mutuality of interest is the foremost requirement for a workable regional cooperation. Thus, it appears that collectively, developing countries could do better in strengthening their Inforware and Humanware.

Areas for Regional Cooperation

1. *Development of Methodologies and Monitoring:*

- Measurement of technology content added is required for realistic evaluation of the national technological capabilities. Monitoring and forecasting world technological trends are also essential for identification of areas of specialization. Pooling resources through regional cooperation could be beneficial for development of such methodologies and monitoring.

- Regional Cooperation through APCTT could be useful for:

  — Development of methodology for the assessment of national resource profile
  — Development of methodology for the assessment of national technological capabilities
  — Development of methodology for the assessment of gaps and levels of technology
  — Development of methodology for the assessment of national technological needs
  — Development of methodology for restructuring the national technological data-base
  — Forecasting and monitoring world technological trends and their impacts.

2. *Human Resources Development*

- Of the four components of technology, adequately developed Humanware can make maximum contributions to economic growth. Introducing planners to technological aspects and also orienting S&T personnel towards developmental aspects are needed. Again, pooling resources at a regional facility may be cost-effective for such training and may also reduce brain-drain.

- Humanware could be upgraded using APCTT as a regional facility, particularly for special courses in technological forecasting, technology assessment and other aspects of technology management.

3. *Exchange of experiences:*

- APCTT country studies on technology policies and planning and also the country profiles on technology climate could be used for exchange of experiences through national and regional level workshops.

North-South Cooperation

- If one accepts the fundamental premise that the primary responsibility for the development of technological capability and for proper use of external assistance for rapid socio-economic advancement in the developing countries rests with those countries themselves, then it is obvious that the matching of aid to needs should be looked into very carefully.

- Since the developed countries have already or are likely to concentrate more in the future in selected areas of technological specialization, it may therefore, be more useful for developing countries to be able to recognize this specialized expertise and thereby identify most relevant sources for techical assistance.

- In the case of "a developing country" requesting "a developed country" to provide technical assistance in any particular area, the following things may happen - (i) if the technology gap between the two countries is too large, assimilation of the Technoware and Inforware by the developing country is not possible; (ii) if the gap is too small, key Inforware will not be provided due to market competition; (iii) if the gap is medium, technical cooperation may be beneficial for both. Thus, it is important to identify optimal partners for cooperation on the basis of the gap with respect to any particular technology.

- Very often criticism of foreign assistance being linked with considerations other than the developmental needs of the recipient country, is due to the fact that the developing countries themselves may not be very clear about their own needs.

- When a developing country is not capable of identifying specific technological needs, a donor is likely to under-rate the capability of the recipient and hence provide some "aid" which may lead to inadequately qualified and/or experienced personnel being sent from the donor country to the recipient nation. Experience has shown that in many such situations the Humanware available in the recipient nations is far superior to that made available by the donors. Both the problem and the solution for such cases lie with the developing countries.

- For fruitful international cooperation, APCTT may be used as a common resource by the developing countries to

  — identify and monitor the areas of specialization;
  — develop methodologies for the selection of optimal partners in any specified technology area;
  — develop a north-south cooperation matrix.
  — establishment of international networks for continuous updating of information generated through the Technology Atlas project. Possible candidates for this linkages may be APCTT (Asian and Pacific Centre for Transfer of Technology), JICST (Japan Information Centre of Science and Technology) and KAIST (Korea Advanced Institute of Science and Technology).

Part VI
Workplan of the Technology Atlas Project

Workplan for the Implementation of the Technology Atlas Project (First Phase)

NO. DESCRIPTION OF PROJECT ACTIVITIES C = COMPLETED P = PLANNED	ACTIVITIES IN 1986 A M J J A S O N D	ACTIVITIES IN 1987 J F M A M J J A S O N D	ACTIVITIES IN 1988 J F M A M J J A S
1. Formulating implementation scheme			
(a) List of activities and schedule preparation	C - - - - - - - -	- - - - - - - - - - - -	- - - - - - - - -
(b) Preparation of job descriptions and budget	C C - - - - - - - -	- - - - - - - - - - - -	- - - - - - - - -
2. Commencement of implementation			
(a) Approval of activities and budget estimates	- - C - - - - - -	- - - - - - - - - - - -	- - - - - - - - -
(b) Recruitment of long-term project personnel			
- Liaison officer (at ESCAP)	- - C - - - - - -	- - - - - - - - - - - -	- - - - - - - - -
- Statistical surveys specialist (at APCTT)	- - - C - - - - -	- - - - - - - - - - - -	- - - - - - - - -
- Systems analysis specialist (at APCTT)	- - - - C - - - -	- - - - - - - - - - - -	- - - - - - - - -
- Technology management specialist (at APCTT)	- - - - C - - - -	- - - - - - - - - - - -	- - - - - - - - -
- Technology assessment specialist (at APCTT)	- - - - - - - - C	- - - - - - - - - - - -	- - - - - - - - -
3. Preparation of country profiles			
(a) Review of relevant APCTT country studies	- - - - - C C - -	- - - - - - - - - - - -	- - - - - - - - -
(b) Preparation of detailed outline for profiles	- - - - - - C C -	- - - - - - - - - - - -	- - - - - - - - -
(c) Trial and testing for outline finalization	- - - - - - - C C	- - - - - - - - - - - -	- - - - - - - - -
(d) Existing data collection in ten countries	- - - - - - - - -	- - - P P P P - - - -	- - - - - - - - -
(e) Country missions for data validation	- - - - - - - - -	- - - - - - P P - - -	- - - - - - - - -
(f) Analysis of collected country data	- - - - - - - - -	- - - - - - P P P - -	- - - - - - - - -
(g) Preparation of draft country profiles	- - - - - - - - -	- - - - - - - - P P -	- - - - - - - - -
(h) Review, finalization and printing	- - - - - - - - -	- - - - - - - - - - P P	- - - - - - - - -
4. Conceptualization of methodologies			
(a) Technological capabilities assessment	- - - - - C C C	C - - - - - - - - - - -	- - - - - - - - -
(b) Technological gap and level assessment	- - - - - - C C	C C - - - - - - - - - -	- - - - - - - - -
(c) Technological needs assessment	- - - - - - - C	C C C - - - - - - - - -	- - - - - - - - -
5. Publications of interim results and revisions	- - - - - - - - -	- - C - - - - - - - - -	- - - - - - - - -
6. Identification of information needs for planning			
(a) Evaluation of existing data bases on S&T	- - - - - C C -	- - - - - - - - - - - -	- - - - - - - - -
(b) Checking feasibility of data restructuring	- - - - - - C C	C - - - - - - - - - - -	- - - - - - - - -
(c) Design and testing of classification format	- - - - - - - -	C C C P P P P P - - - -	- - - - - - - - -
(d) Printing of guidelines for data structuring	- - - - - - - -	- - - - - - - - P P - -	- - - - - - - - -
7. Technological capabilities assessment			
(a) Data collection in four selected countries	- - - - - - - - -	- - - - - - P P P P - -	- - - - - - - - -
(b) Testing and refinement of methodology	- - - - - - - - -	- - - - - - - - P P P -	- - - - - - - - -
(c) Country missions for data validation	- - - - - - - - -	- - - - - - - - - - P P	- - - - - - - - -
(d) Preparation of draft report	- - - - - - - - -	- - - - - - - - - - - -	P P - - - - - - -
(e) Review, finalization and printing	- - - - - - - - -	- - - - - - - - - - - -	- - P P - - - - -
8. Technological gap and level assessment			
(a) Data collection in five selected areas	- - - - - - - - -	- - - - - - P P P P - -	- - - - - - - - -
(b) Testing and refinement of methodology	- - - - - - - - -	- - - - - - - - P P P -	- - - - - - - - -
(c) Country missions for data validation	- - - - - - - - -	- - - - - - - - - - P P	- - - - - - - - -
(d) Preparation of draft report	- - - - - - - - -	- - - - - - - - - - - -	P P - - - - - - -
(e) Review, finalization and printing	- - - - - - - - -	- - - - - - - - - - - -	- - P P - - - - -
9. Technological needs assessment methodology			
(a) Testing and refinement of methodology	- - - - - - - - -	- - - - - P P P P P - -	- - - - - - - - -
(b) Review, finalization and printing	- - - - - - - - -	- - - - - - - - - - P P	- - - - - - - - -
10. Consultation, review and follow-up			
(a) Four meetings with project adviser	- - - - - - - - -	- - C - - - - - P - - -	P - - - - - P - -
(b) Two experts consultative meetings	- - - - - - - - -	- - - - - - - - - P - -	- - - - - P - - -
(c) Intergovernmental meeting and ESCAP Session	- - - - - - - - -	- - - - - - - - - - - -	- P - P - - - - -
(d) Preparation of second phase project document	- - - - - - - - -	- - - - - - - - - - - -	- - - - - - P - -

Please mail your remarks to:
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REMARKS

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