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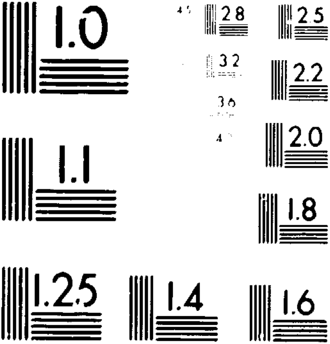

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OVERVIEW OF THE MICROELECTRONICS INDUSTRY IN SELECTED DEVELOPING COUNTRIES *

by

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PREFACE

UNIDO is publishing a series of country reports under the title "State-of-the-Art Series on Microelectronics". So far five countries have been published: No. 1: Venezuela (UNIDO/IS.489); No. 2: India (UNIDO/IS.492); No. 3: The Republic of Korea (UNIDO/IS.490); No. 4: Pakistan (UNIDO/IS.493); Bangladesh (UNIDO/IS.497).

This document is intended to provide a broad evaluation based on the five country reports with a view to identifying the type of approaches that developing countries at different stages of development could adopt in building-up a microelectronics capability.

Chapter 1 presents the state of the art of microelectronics technology, the dimension and nature of the industry and trade resulting from it, and policy measures employed by the Governments of developed countries to promote the industry.

Chapter 2 summarises the five studies.

Comments and conclusions on the difficulties and opportunities facing developing countries in benefitting from advances in microelectronics technology are then presented in Chapter 3.

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SUMMARY

Microelectronics technology is undergoing dramatic developments and associated industries are both very large and rapidly growing. These industries have a total world output in excess of US$400 billion at present. World production, consumption and trade in these products is dominated by the developing countries whose Governments promote research and development and market development. The newly industrialising countries of Asia are the only developing countries with a significant presence in the market.

The stage of development and the activities and programmes of Venezuela, India, the Republic of Korea, Pakistan and Bangladesh are summarised. There is a wide variation in the economic circumstances and the stage of industrialisation of these countries which reflects itself in their activities.

The analyses and recommendations propose a model for the development of national microelectronics industries in developing countries. It foresees three stages: (1) Implementation; (2) Assimilation; (3) Improvement.

It is important that countries select niches in the market and concentrate resources on these to develop a competitive advantage. Both the scope for developing an indigenous sub-supply capacity and competition as a stimulus are emphasised.

The role of foreign investment as an element in a strategy to develop an industrial sector is discussed. Joint ventures are identified as a useful developmental approach, but only where the firms involved are of comparable or complementary technological competence.

Governments should seek to develop the competence to apply microelectronic technologies and equipment widely in their countries. In contrast to component manufacturing, applications offer more immediate possibilities to developing countries since they are, in general, less capital intensive, less dominated by giant multinational firms and more controllable by local effort. Substantial priority attention should be given to software technology, I.C. design and systems engineering and design.

It is also recommended that governments preferentially build up innovative capacity in the technical areas underlying the selected industrial niche areas, identify actual industrial needs, build up innovative capacity in university and research institutes to meet these needs and establish effective mechanisms linking industrial needs and university competence.

It is suggested that developed countries can aid developing countries by providing training and assisting in the establishment of specialised technology infrastructure in the developing countries. Suggestions are also made for regional co-operation between developing countries at a comparable stage of development.

CHAPTER 1. MICROELECTRONICS TECHNOLOGY, INDUSTRY AND TRADE

1.1 INTRODUCTION

The microelectronics revolution could be said to have begun with the invention of the transistor in 1948 and the replacement by it of the thermionic valve as the basic electronic device. Since that time, semiconductor technology has developed dramatically and equally far-reaching advances have been made in that other basic technology - software.

The combination of semiconductor and software technologies have fuelled the revolution which has seen the creation of vast industries producing completely new products and services. The markets for these new electronics products and services -

- consumer products
- computer systems
- telecommunications systems
- industrial equipment, etc.

are large with high growth rates and are fiercely contested, primarily by the developed economies of the USA, Japan and Western Europe.

The widespread application of these technologies and their resultant products has fundamentally changed traditional ways of doing things. This change is all-pervasive and has effects in many areas of endeavour throughout the world - not only in the developed world, but also increasingly in developing countries.

Governments everywhere now recognise the importance of what is happening and the question is no longer 'Is this of interest to us?' but 'What must we do in our specific circumstances to maximise the benefits from this new technology and minimise its threats?'

In this chapter, we sketch the technological, industrial and trade background and address the issues

- What is the state of the art of this technology and where is it going?

- What are the dimensions and nature of the industry and trade it has created?

- What policy measures are employed by the Governments of developed countries to promote the industry?

1.2 TECHNOLOGY

There are many ways to segment the industry. In the present study, we shall discuss technology under the headings of: semiconductors, software, computer and communication systems and other applications.

Semiconductors

Electronic components are now based on materials with semiconducting properties - such as silicon, germanium and gallium arsenide. We may distinguish three categories of device:

i) discrete components such as transistors, rectifiers and diodes;

ii) integrated circuits, for example, microprocessors and memories;

iii) special purpose devices and circuits.

Advances in semiconductor technology may be illustrated by the evolution in the scale of integration of integrated circuits (see Figure 1).

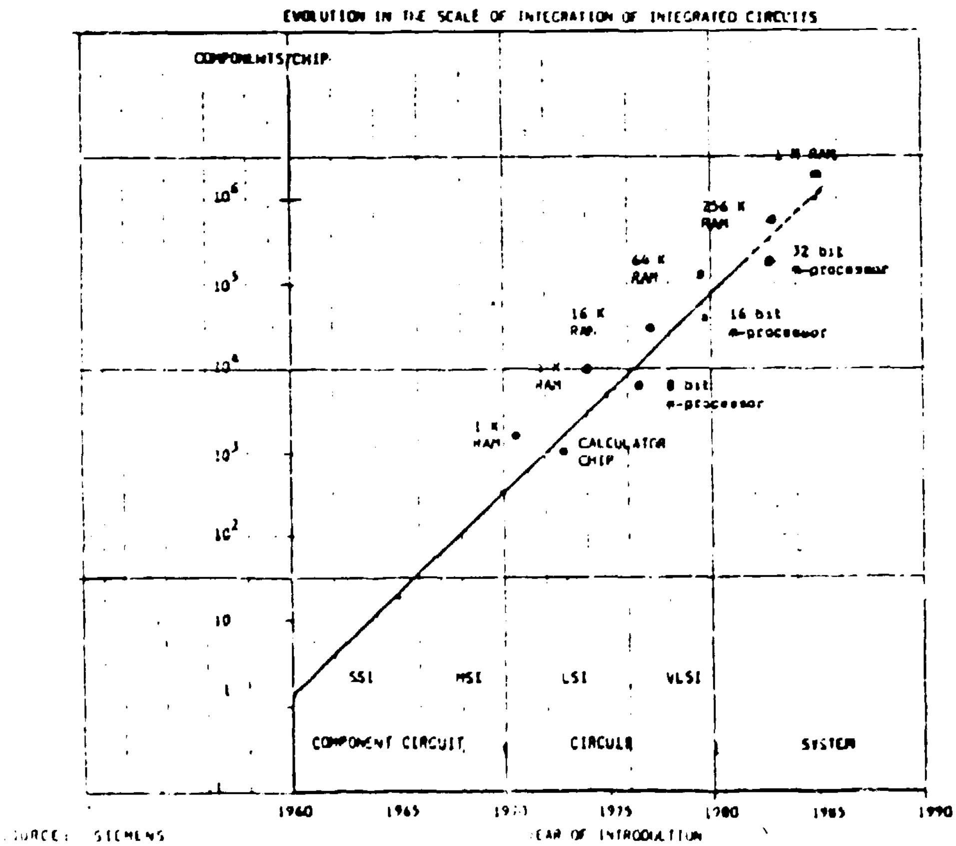


Figure 1

Different degrees of integration (number of transistors per chip of, for example, silicon) are described as follows: (Table 1)

TABLE 1

Degree of Integration -- Definition

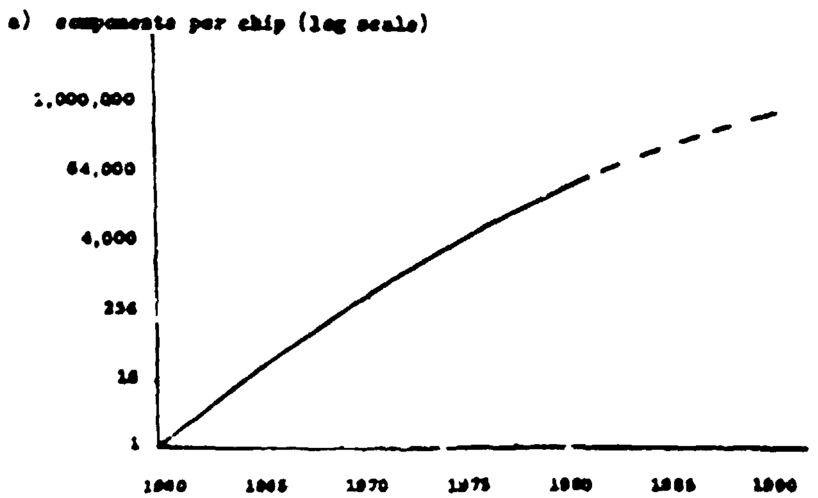
Degree of Integration		Transistors/Chip
Small Scale Integration	SSI	30 - 80
Medium Scale Integration	MSI	300 - 800
Large Scale Integration	LSI	3,000 - 8,000
Very Large Scale Integration	VLSI	30,000 - 100,000
Ultra Large Scale Integration	ULSI	about 1 million

In figure 1, 64K RAM, for example, means 64 kilobit random access memory - a device in which information may temporarily be stored. 256K RAMs will become commercially available in volume in 1984, and 1 megabit RAMs should be commercially feasible in the next few years.

Even as the scale of integration per chip has increased exponentially with time, the costs per chip have fallen drastically. Figure 2 shows two characteristic curves for the evolution of integrated circuits.

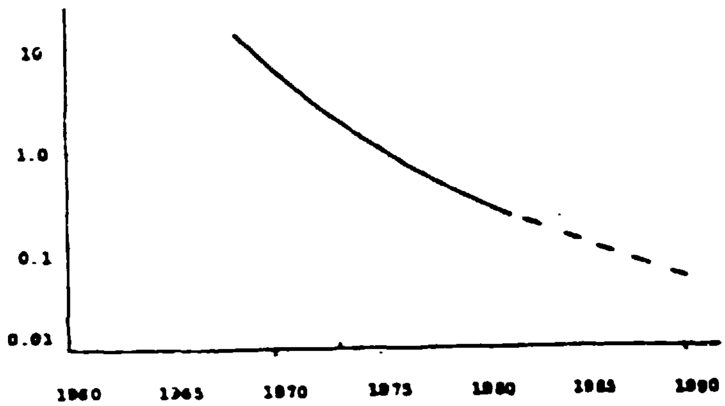
Figure 2

CHARACTERISTIC CURVES FOR INTEGRATED CIRCUITS



CHARACTERISTIC CURVES FOR INTEGRATED CIRCUITS

b) cost per chip (US cents) (log scale)



Source: Intel Corporation,

Figure 2

These advances have occurred following substantial investment by companies and governments in Research and Development on materials, and on the design and fabrication of devices. Typical industrial R&D investment would amount to about 7 - 10% of sales in the U.S. and up to 15% of sales in Japan.

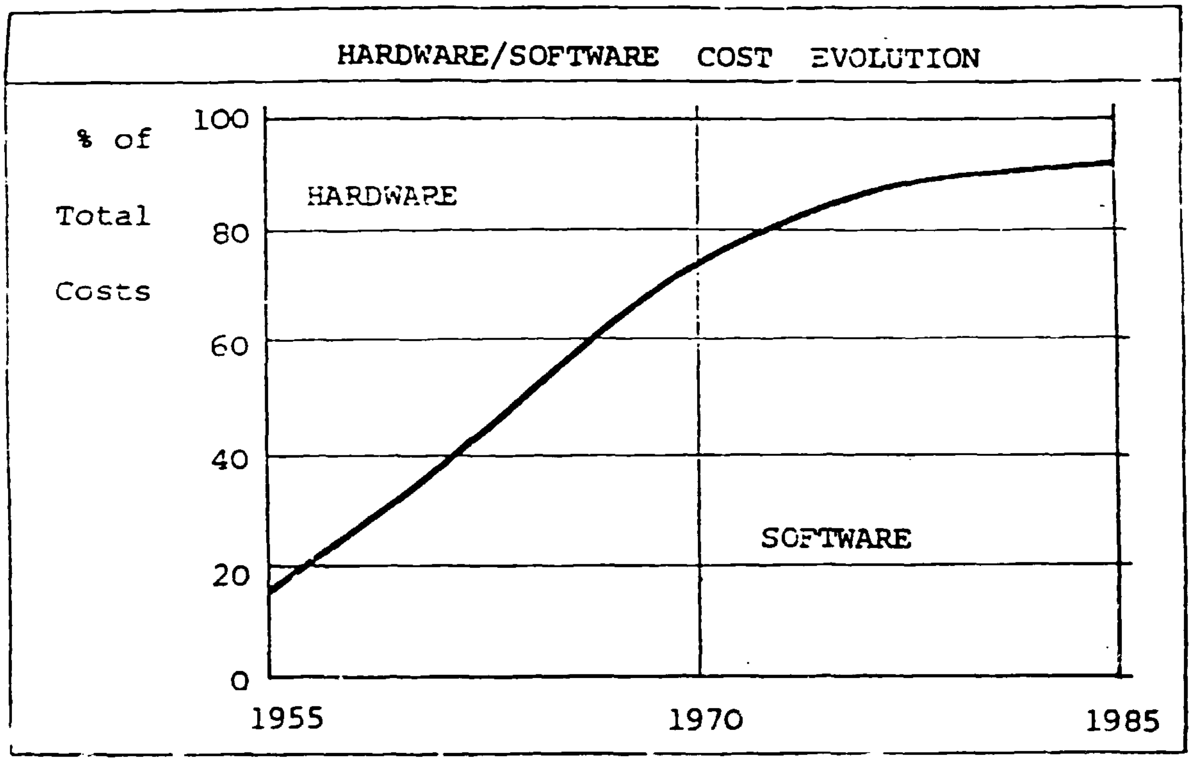
Software

To limit the analysis of microelectronics to the semiconductor industry would give a very inadequate picture of its scope. It is the combination of electronics hardware and software into systems and applications which give the sector its importance.

Software, defined as sets of purely conceptual data and instructions, is at the heart of all types and sizes of information technology applications. Computers and word processing systems, industrial automation systems, databanks, communication and telecommunication systems, electronic fund transfer systems, industrial products based on microelectronics, air, sea and road transport control systems and various national defence systems are all built around and operate via their software.

The scope and pace of microelectronics applications is limited by software state-of-the-art. There is much talk of a 'software bottleneck'. This is, perhaps, most graphically illustrated by the well known Figure 3, showing the evolution of the partitioning of costs of systems between hardware and software.

FIGURE 3



Source: Computer, 1983

Whereas the costs of components has fallen millions of times and of system hardware thousands of times, software costs have not fallen at all in the last two decades.

Software development is skill rather than capital intensive, but it is still very expensive with, perhaps, thousands of man years of development required for new major systems. Increasingly large sums are being spent by industry and governments in this area. The European ESPRIT programme will have a significant component dealing with software. The Japanese-sponsored "Fifth Generation Computer System" will make major and far-reaching advances in software technology over the next decade. The U.S. Department of Defence-sponsored STARS programme is expected to be a major driving force in the development of software technology in the next five to seven years.

Computer and Telecommunications Systems

Computers have become more powerful, faster, smaller, more reliable and cheaper over the last two decades. With the advent of the microprocessor, the new generation of microcomputers can today have comparable performance to some of the mainframe and mini computers of earlier times, while being many times less expensive. In general, it can be said that over the 20 years 1960 - 1980, the effectiveness of computers has increased by a factor of 20, whereas the cost has declined by 100 - a 2000 fold improvement.

Technical development continues apace and in the U.S., whose industry continues to dominate world markets and where companies typically spend about 7% of sales on R&D, new much improved systems will continue to be introduced. Japan is developing a new Super Computer with speeds 1,000 times faster than the current state-of-the-art.

Japan has also initiated a major long-term programme to develop the so-called Fifth Generation Computer System. The FGCS is, for the most part, radically new software implemented in VLSI. The proposed new concept exhibits artificial intelligence and will employ expert systems, using inference techniques. Where current computers can perform 1,000 to 10,000 of the inferences used in expert systems per second, the goal for the '90's is to perform 100 million to 1000 million per second. Another goal is to build a data flow machine comprising 1,000 to 10,000 processors, storage of 1 to 10 gigabytes and a speed of from 1,000 million to 10,000 million instructions per second.

Telecommunications developments currently involve digital switching and transmission, optical fibre technology and satellite systems. A wide range of new communications and information services are being provided. P.T.T.'s are planning to introduce over the next decade or so Integrated Services Digital Networks (ISDN) where all information in whatever form - voice, data, text and still or moving pictures - will be distributed to users over the same digital network.

Development costs for telecommunications systems are comparable with other electronic-based systems. For example, it has been estimated that the cost of developing a new digital switching system is about $1,000 million. This development cost is too large for even the largest European country to recoup with sales on its own domestic market.

Other Applications

Computer and Telecommunication Systems are applications of Microelectronics that have produced huge new industries. Such, however, is the nature of the technology that it can be applied, particularly since the development of the microprocessor, in an extraordinary variety of ways in many kinds of activity, manufacturing, service, commercial and social. The constraint on its application is largely the imagination of the developer rather than the technical potential.

Although many new products are introduced:- word processors, intelligent instruments, process controllers, games etc. etc., the process improvement resulting from microelectronics applications are seen to be at least as, if not more, important because of the enhanced efficiency maintaining competitiveness in a very wide range of conventional manufacturing and service sectors.

Much attention is being focussed on the manufacturing environment with computer aided design (CAD) and computer aided manufacturing (CAM) undergoing significant development. CAM encompasses

- numerically controlled machine tools,
- automated manufacturing systems,
- automatic monitoring and reporting systems,
- automatic warehousing,
- industrial planning and control and
- industrial robots.

Once more the developed world of Japan, the U.S.A. and Western Europe, through national programmes and through the ESPRIT programme, are investing heavily in R&D in this area.

1.3 INDUSTRY AND TRADE

Semiconductors

World production and consumption of semiconductors amounted to about $20 billion in 1983.

The U.S.A. and Japan are net producers of semiconductors. The U.S.A. produces nearly two-thirds and consumes about one-half of world production. Japan produces more than one-quarter and consumes less than one-quarter.

Western Europe and the rest of the world are net consumers of semiconductors. Whereas Europe consumes about one-fifth of total production, it produces less than half of that amount. The rest of the world consumes less than 10% and produces about 2% of total world production.

The U.S. in fact imported $4 billion worth of semiconductors in 1982, of which $3 billion was from U.S. offshore facilities in four Asian countries: Malaysia, Philippines, Singapore and South Korea.

Electronic Equipment

Whereas semiconductors are critical components of electronics systems, nevertheless they may constitute a relatively small fraction of total equipment and systems cost. Telecommunications equipment, for example, will have sales in 1984 of about 59 billion $US (estimated 100 billion US$ in 1990), whereas the value of semiconductors used in this equipment is approximately 3.5 billion $US.

The total world market for electronic equipment is more than 400 billions $US today, and growing rapidly. U.S. consumption of electronic equipment, broken down by subsector for 1984 with projections for 1987 is given in Table 2.

TABLE 2 U.S. Consumption of Electronic Equipment (US$ billions)
Source: Electronics, January 1984

	1984	1987
Data processing & Office Equipment	79.0	125.0
Software	15.0	24.6
Consumer	21.3	23.8
Communications	11.5	15.3
Industrial and Military	57.1	70.6
TOTAL	184.0	239.3

The anticipated high growth rates in D.P. and office equipment and in software are particularly noteworthy.

Similar figures for Western Europe and Japan are given in Table 3.

TABLE 3 Western European and Japanese consumption of Electronic Equipment in 1984 (US$ billions)
Source: Electronics, January 1984.

	W. Europe	Japan
Data processing & Office Equipment	60.5	41.8
Consumer	15.8	11.2
Communications	12.8	3.0
Industrial and Other	15.8	21.6
TOTAL	104.9	77.6

1.4 POLICY MEASURES IN DEVELOPED COUNTRIES

In this section, we indicate briefly some of the policy measures used by the Governments of developed countries to promote the growth of their microelectronics industries. Three regions are discussed separately:- Western Europe (primarily the Member States of the European Economic Community), Japan and the U.S.A.

Western Europe

Western Europe is a collection of sovereign states, each of which promotes its own industry with its own national programme. In addition to this, the Member States of the European Economic Community (EEC) collaborate and coordinate their activities in certain areas.

The measures adopted by Western European Governments to promote their industries may be categorised under the headings:

- Funding of Research, Development and other industrial support
- Promotion of Awareness
- Use of Public Purchasing.

The governments of the ten EEC member states will spend about US$3.25 billion in support of its microelectronics industries during 1984. The national programme of France is particularly large, with that of the United Kingdom and the Federal Republic of Germany also large.

The support is directed towards the following categories of activity

- pre-competitive research
- product-specific development, and
- other industrial support.

with the sums directed to pre-competitive research being roughly one-tenth those devoted to product-specific development.

The areas of microelectronics receiving most of these funds are

- Components
- Optoelectronics
- Telecommunications
- Information Processing
- Software Engineering and
- Computer Integrated Manufacturing.

The necessity to raise the level of awareness of the value of the application of microelectronics in order to increase the efficiency of processes and the functionality of products is widely recognised by European Governments. Most countries have explicit Government funded programmes addressing this need. The programmes of the Federal Republic of Germany and the United Kingdom are the largest. A total of about US$300 million is spent by EEC member states on these programmes.

Most EEC member states use the substantial purchasing power of their public sectors to support the development of their national microelectronics industries. This is the case for computers and especially so for telecommunications equipment purchased by national PTTs. In fact, most European PTT markets are regarded as essentially 'closed', i.e. it is extremely difficult for foreign companies to break in to these markets.

It is recognised that, from the national point of view, there are positive and negative factors associated with these practices. On the positive side, the skilful and creative use of public contracts can develop new firms and improve the product range of established firms. On the other hand, the protectionism and lack of international competition for national firms in these markets can lead to inefficiencies and lack of competitiveness.

Public purchasing is one of the areas mentioned above in which EEC member states are coordinating their activities. There is a recognition that none of the internal markets of any Member State is sufficiently large to develop industries capable of competing internationally with U.S. and Japanese companies, in the long run. The internal market of the Community as a whole, however, is of a sufficient scale to develop a number of large internationally competitive companies. The coordinated use of the public markets across the Community is one approach to developing these companies.

The need for European firms to be competitive internationally with Japanese and American firms also motivated the EEC Member States to establish a cooperative Community-wide programme - ESPRIT - addressing pre-competitive research in the information technology field. This programme, which will cost US$1.5 billion (50% Community funds, 50% industry funds) over the next five years supports the following five research areas.

- o Advanced Microelectronics
- o Software Technology
- o Advanced Information Processing
- o Office Systems
- o Computer Integrated Manufacturing.

The programme is heavily industry-oriented. It involves international collaboration between firms and research institutes in different countries. It aims to complement and integrate national programmes. Its ultimate objective is to provide the technological basis for European industry to achieve parity within ten years in the trade of IT products between Europe and the rest of the world.

Japan

Although Japan would claim to be less interventionist in the affairs of business than, say, Western European Governments, nevertheless the powerful role played by the Ministry of International Trade and Industry in developing Japanese industry and the extraordinary degree of national coordination and cooperation between companies and Government gives the impression in the rest of the world of great coherence of policy and operation.

A major strength of the Japanese system is the ability to plan long term and to institute and execute programmes to carry the plans to success. Thus, the VLSI project brought Japanese industry to the forefront of IC technology at a cost (50%

industry, 50% government) of US$250 between 1976 and 1979, and a range of new MITI-sponsored projects are poised to have equal or more dramatic results in the next decade or so. These projects include

- The Fifth Generation Computer System (FGCS) - a ten year project established jointly by MITI and eight leading electronics manufacturers - is intended completely to transform the very concept of a computer in that period.

- The Supercomputer Project is intended to develop a computer 1,000 times faster than those presently available for scientific and technological use in eight years, at a cost of US$100 million.

- A robotic project to develop the next generation of robots over eight years with US$100 million of MITI money and involving a wide range of public and private research institutions.

Japanese firms cooperate readily in the pre-competitive phase of these projects, but once this phase is over they compete vigorously with one another and with the rest of the world in the marketplace.

In support of these activities, the Japanese have developed, over the last several decades, an extraordinarily sophisticated system for acquiring relevant technological information around the world. They have also developed high skill in the acquisition of technology through licenses, know-how agreements etc. with foreign technology leaders and in transforming this technology to their own use.

United States of America

The USA, both by explicit policy and by actual practice, intervenes less than most countries in the affairs of business. Government action is intended to create an appropriate environment within which individual and corporate enterpreneurial effort will flourish. The Government will intervene if the public good is threatened by, for example, monopolies or quasi-monopolies wielding an excessive amount of economic power but, for the most part, the market is seen as the best regulator and the determinant of success and failure.

This, largely true, view of U.S. policy requires some modification in certain high technology fields and notably in the field of microelectronics. It is widely acknowledged that the public purchasing efforts relating to U.S. space and military programmes have had far-reaching spin-off effects in this area. A number of substantial programmes can be mentioned.

- The U.S. Government invested some US$280 million in I.C. related R&D between 1978 and 1982.

- A military research programme - the Very High Speed Integrated Circuit (VHSIC) Project - will cost US$225 million in its six year period 1980-1985 and it is expected to have major spin-off benefits for non-military products in the telecommunications and computer fields.

- Another U.S. Department of Defence sponsored project - the STARS programme - while dealing with software development for military systems, is expected to have significant spin-off effects on software more generally.

For the most part, however, companies fund their own research and development and don't expect contributions from Government. The recently-created MCC consortium provides an interesting contrast to European and Japanese approaches. MCC is a consortium of major U.S. companies in the electronics field (not including IBM) who have come together to some extent in response to the European ESPRIT and the Japanese FGCS to collaborate and share expertise in advanced pre-competitive research in information technology sectors. Unlike the European and Japanese examples, however, MCC was initiated solely by private companies and receives no explicit U.S. Government aid.

CHAPTER 2. POSITION OF SELECTED DEVELOPING COUNTRIES

2.1 INTRODUCTION

This chapter is based on country reports, separately prepared by local experts in each of five countries - Venezuela, India, the Republic of Korea, Pakistan and Bangladesh. It aims to summarise and synthesise, without further analysis or comment, the findings of these case studies. The analysis and recommendations of this consultant are provided in the next chapter.

Three caveats need to be borne in mind when reading this chapter.

i) The selected countries are at radically different stages of economic and industrial development. At one extreme, the Republic of Korea is an advanced newly industrialising country with a well-developed and internationally competitive electronics industry. At the other extreme, Bangladesh is at the very early stages of industrialisation. The 'stage-of-development' issue is dealt with in Chapter Three.

ii) Although the case study experts worked from identical terms of reference, the interpretation differed from study to study, leading to a lack of uniformity and some gaps in the data presented and

iii) This summary is inevitably an incomplete statement of the situation in the selected countries. The reader is referred to the country reports for further detail.

The case-study findings will now be summarised under nine separate headings.

2.2 GOVERNMENT STRATEGIES AND POLICIES

In all of the countries in question, the Government has, both by statement and action, recognised the importance to their national development paths, and particularly to their industrialisation prospects, of acquiring and applying microelectronics technology. Only two of these countries, however, (Korea and to a lesser extent, India) have what could be regarded as an articulated strategy and related policies for microelectronics technology. In the Republic of Korea, the microelectronics industry is classified as a strategic industry and is given appropriate emphasis in the latest five year plan (1982 - 1988). In India, the area is also accorded special significance in national S&T and industrial policy efforts. In Pakistan, the profile of the electronics industry has been raised in the 6th plan (1983 - 1988). Within that country's scheme for Export Processing Zone industries, the microelectronic products industry has highest priority. The absence of a clear Government policy for microelectronics development, based on objective technical analysis is, on the other hand, perceived as a hindrance to the appropriate nature and pace of development in this area in Venezuela. Apart from petroleum-related research and development, no particular fields have yet been defined as priorities there. Bangladesh also has not yet defined its technology strategy and policies in the electronics area, but steps are being taken via a recently established national committee for Science and Technology and other relevant committees to frame a national policy and strategy in different technical fields.

The perception of Government's role in intervening in industrial development and the appropriate public/private sector balance varies from country to country. In the Republic of Korea, it is seen as essentially that of coordinating the environment for the industry with the primary thrust coming from the private sector. The Government also sets frameworks for the education system and for the national research laboratories. In Pakistan, while the mixed economy approach will continue, the public sector role is seen as a promotional one, with major emphasis on encouraging private investment.

The kind of environment within which private investment in high technology industries, including electronic industries, is to flourish is being cultivated in different ways, for example

- more liberal overseas interface with respect to foreign capital inducement and technology acquisition procedures (the Republic of Korea)

- guarantees of capital and profit repatriation (Pakistan)

- commitment not to nationalise industries (Pakistan)

- tariff restructuring (India and Pakistan)

- reduction in duty on capital equipment (India and Pakistan)

- tax exemptions or tax holidays (Pakistan).

Other elements of active 'environmental' promotion are discussed below under the headings of R&D, manpower and technology acquisition.

In Venezuela and in India, a role more substantial than environment setting is played by the Governments. These Governments intervene through the ownership of companies, the regulation of privately owned companies and the creation of a protected market environment.

2.3 ELECTRONICS MANUFACTURING INDUSTRY

The Republic of Korea is the only country whose output of electronic products is significant in world terms. Its share has grown from 1.3 per cent in 1977 to 1.8 per cent in 1982 and is growing at more than 30 per cent a year. Furthermore, it is the only country which is a net exporter of such products. It has widespread involvement in consumer products, industrial products and components The highest rate of sub-sectoral growth in recent years is in industrial products. Korean firms have a significant presence in the more advanced products of these industry sub-sectors.

In the Republic of Korea, all major corporate groups are investing heavily in the microelectronics industry and many small companies are also actively involved. Government is actively promoting the industry and the technology, as evidenced by the emphasis in the fifth five year plan 1982 - 1986, and in other longer term planning exercises, namely for the electronics industry (1983), the semiconductor industry (1982) and the computer industry (1984). The exercise of effective planning and promotion of the industry in the Republic of Korea is facilitated by the dominance of domestic investment in the industry, for example, in 1982, 58% of output was produced by domestic firms, 22% by joint venture firms and just 20% by foreign firms. The highest growth rate 1981 - 1982 was in the domestic sector.

India also has significant industrial activity in each of sub-sectors - consumer products, industrial products and components. It is not, however, self-sufficient in any of these areas.

Communication and broadcasting equipment and aerospace and defence equipment figure large in the industrial products category. The rate of growth in output of electronics products in India is high, averaging more than 20% (compound) over the past three years.

In India, certain Government plans are expected to provide a considerable boost to demand for integrated circuits e.g. the opening up of new TV stations, digitalisation of the communication network, the introduction of a public switched network, a circuit switched data network (and possibly packet switched data network) the modernisation of industrial sectors like steel, fertilisers, petrochemicals, cement etc.; the use of microelectronics in railways, agriculture and health care and the introduction of computers in schools and colleges. Preliminary estimates suggest that about two-thirds of the greatly increased demand could be met by indigenous production, providing appropriate investment is made in production, R&D, materials and manpower base. A Government Task Force on LSI/VLSI, set up in 1982, is preparing its final report, but it has already identified the gap areas and made recommendations for an investment programme covering R&D, production and manpower over a period of ten years.

In Pakistan, the annual requirements of all electronic equipment are estimated at some $300 million, of which consumer products constitute 38 per cent, industrial products 52 per cent, and components 10 per cent.

The annual proposed production in the 6th plan period 1983 - 1988 for manufacturing industry and products is expected to meet some 70% of requirements.

Investment in electronics is to be increased ten fold in the 6th plan, as compared with the fifth plan period and top priority is being given to electronics in the export processing zone scheme which allows foreign investment with added incentives.

Bangladesh is still at the assembly stage of consumer electronic products using imported components. These are mainly TV sets, radio receivers and radio cassette recorders for the domestic market. Only five companies are actually using integrated circuits in manufacturing and most are dependent on technical collaboration agreements with foreign companies. There is no manufacture of any of the basic components in the country. The national organisations for communications, aviation and airlines and meteorology all use integrated circuits in their equipment, but most of the equipment is supplied and maintained by Japanese and other suppliers.

In Venezuela, the pattern of industrial production is as follows:

- in telephone production, the country is virtually self-sufficient and, as of recent times, technologically independent. The telephone company's production is mainly oriented to meeting internal requirements (some one-quarter million new telephone lines per year);

- in the field of professional and consumer electronics goods, the market is dominated by many foreign based companies (e.g. IBM, Philips, Siemens and Hewlett-Packard). These are mainly dedicated to the sale of their own products with only one - Philips - having even a local assembly operation for TV sets and sound equipment;

- a number of recently-established indigenous electronic companies producing capital goods in the areas of telephones, electricity, control and instrumentation. Total assets of these companies are about 4.5 million US dollars; annual sales are about 11 million US dollars; and sales are increasing rapidly with rates of 20%, 50% and 66% being achieved in the years 1980 through 1983, respectively.

  The development of this last category is regarded as a very significant first step in the development of an autonomous electronic industry in the country.

2.4 APPLICATIONS OF MICROELECTRONICS

What is meant by 'applications' in this context is the use of microelectronics based equipment, instruments and devices in manufacturing and service activities other than in the electronics equipment manufacturing itself.

A wide range of such applications can be identified, including:

o Computing and Data Processing in e.g. public administration, finance and insurance, management information and control etc.

- o Manufacturing e.g. process control, CAD/CAM etc. - many applications throughout all sectors of industry.

- o Communications Services - both telecommunications over networks and broadcast media.

- o Other Public Services e.g. transport, energy, aviation, meteorology, medical services etc.

All of the countries surveyed have some appreciation of the value of the appropriate use of this technology. The actual use depends largely on the general state of development of the economy.

The Republic of Korea and India show the most widespread use, with the Republic of Korea showing increasing sophistication in industrial use and India a wide range of public services applications.

Pakistan and Venezuela show less sophistication and comprehensive use but some, and a growing, presence in all sectors above.

Bangladesh has as yet limited experience of microelectronic applications. What use there is, is largely in the public services area.

2.5 RESEARCH AND DEVELOPMENT

Not surprisingly, the pattern disclosed by the R&D status of the countries in question reflects the industrial profile in the preceding sections.

The Korean effort at both public, private and academic level is highly organised; the Indian effort seems set to benefit from improved organisation and specialisation as a result of several Governmental initiatives of recent origin. Pakistan's efforts are still very much at the initial stages of development, while in Bangladesh, the activities are extremely limited but steps to define a suitable national R&D programme are in progress. In Venezuela, there is a steadily improving base in the recently established FII and in some of the universities for the development of electronics R&D.

The position in each of the countries is summarised in the following paragraphs:

THE REPUBLIC OF KOREA

Who does it

Increasingly industrial R&D is carried out in the firms themselves. In addition, substantial industrial R&D activities is carried out in national research laboratories, mainly funded by Government or by public corporations. One of these laboratories, the Korean Institute of Electronics Technology (KIET) was established in 1979 and jointly funded ($29 million) by the Government and the World Bank. Limited research activities in the universities are funded by public and private sectors.

What they do

The national laboratories specialise to a large extent.

KIET focusses on microelectronic technology centred on integrated circuits from design to fabrication.

Korean Electrotechnical & Telecommunications Research Institute (KETRI) focusses on R&D activities for public telecommunications networks. Its main areas being

- advanced electronic switching systems
- fibre optics networks
- information networks such as ISDN.

Its programmes are carried out on a multiannual (5 year) basis.

A division of the Korea Advanced Institute of Science and Technology (KAIST) also carries out research activities in many areas of microelectronics.

INDIA

Who does it

Most R&D activities in the field are carried out in established national research institutes (one of which is Central Electronic Engineering Research Institute (CEERI)); in the R&D wings of two public corporations BEL and the recently established SCL; in the research laboratories of dedicated Departments (Atomic Energy, Space, Defence, Railways and Communications); and in five of the Indian Institutes of Technology which have fairly extensive facilities.

What they do

The Government is encouraging national laboratories and other organisations to conduct design and development work to suit specific industrial, scientific and other civilian needs recognising that, except for the captive R&D units of manufacturing organisations, the level of technology transfer has not yet been very effective.

For the CEERI, the basic interest lies in the NMOS process and it has already developed some circuits of LSI complexity.

The Tata Institute of Fundamental Research (TIFR) developed in 1971 the first integrated circuit to be made in the country. Its strength lies in IC design and fabrication, in CAD systems and software packages. It is currently working, inter alia, on CMOS metal gate and silicon gate technologies.

The R&D department of India Telephone Industries (ITI) has lso a strong group in design of LSI subsystems using CAD and is now piloting the fabrication of custom LSI circuits.

The five Indian Institutes of Technology (IITs) between them have an infrastructure capable of developing integrated circuits up to LSI level of complexity. A certain degree of specialisation in the building up of the respective strengths in various aspects of the technology is evident.

The recently stabilised Semi-conductor Complex Ltd. (SCL) is building up a comprehensive production and R&D base up to the level of LSI/VLSI. It will undertake LSI/VLSI design and projects aimed at establishing and upgrading the company's capability for meeting national needs. The Bharat Electronics Co. (BEL), largest in the field, has already been carrying out some R&D activities in addition to drawing a know-how of RCA.

While several institutes possess CAD facilities, competence for IC design is limited to a few individuals in each centre. The recent launch of a four year national CAD Programme with support of UNDP will provide training/education facilities for CAD and establish CAD software exchange systems.

The Government is also planning to promote a chain of decentralised design centres for IC, feeding centralised chip production facilities (eventally SCL and BEL).

PAKISTAN

Who does it and What they do

Government institutes of recent establishment predominate; the National Institute of Electronics, set up in 1980, commenced active research work in 1983. The main areas of activity relate to test equipment, computer/micro processor application, communication projects, control applications and medical instruments. The Carrier Telephone Research Laboratories set up in 1981, with Japanese collaboration, concentrates on various aspects of telecommunications requirements. A Silicon Technology Development Centre was set up in 1981, with assistance from UN. It will seek to transfer this technology and acquire indigenous skills and information. It will conduct research and have pre-production facilities to support the development of silicon micro chips and semi conductor devices, silicon based practices and solar cell technologies.

A limited R&D effort in application of microelectronic products and development of hardware and software in computer technology is carried out in a number of university departments.

Other Government organisations conduct a certain amount of R&D in microelectronic technology appropriate to their own needs.

Five institutes funded by private individuals and, in one case, sponsored by a bank, have also recently been established.

BANGLADESH

Who does it and What they do

University departments and two national institutes carry out what limited R&D is in progress.

The Institute of Electronics and Materials Science has the more relevant programme. The University of Dhaka has initiated a scheme for the creation of an Institute of Silicon Technology.

VENEZUELA

Who does it

Government and government-sponsored agencies and national universities are the main performers and funders of such research as is carried out in the field. The principal institution is the Foundation for Engineering Research & Development (FII), which has 70 researchers expected to grow to 200 by 1988.

The Venezuelan Institute of Scientific Research has a limited profile - mainly dealing with theoretical analysis of existing and new semiconductor devices.

The universities of Carabobo and Simon Bolivar also do research in the area, while activities at other universities are mainly concerned with microprocessor applications and software development for microchip systems design.

Major state-controlled telephone and telephone manufacturing companies have done little development (except that related to specialised instruments for their own use) and no research.

What they do

The FII, which covers other fields of engineering besides electronics, are increasingly directing attention to various aspects of microelectronics, particularly hybrid circuitry. Other projects are being developed at FII under contract agreements with confidentiality requirements. One of these relates to design and construction of an automatic machine voting system to be ready before 1989. Areas in which expanded R&D activities are foreseen include

- microstrip elements
- gallium arsenide technology
- fibre optic systems and components
- solar cells
- digital image processing (where personal expected to increase tenfold in next five years)
- software.

The main Government funding agency for R&D projects, CONICIT, still continues to apportion funds on the basis of technical quality rather than by reference to strategic priorities.

A proposal currently being considered by the government to introduce a tax on the productive sector to provide funds for the financing of local R&D activities is being hailed as a positive step in the country's development.

2.6 MANPOWER AND TRAINING

All Governments realise that skilled manpower is an essential prerequisite of an electronics industry that goes beyond mere assembly operations. The education and training of such manpower is universally accepted as a responsibility of Government.

Each of the countries surveyed has an active participation in this field and their programmes will be presented in turn below.

THE REPUBLIC OF KOREA

Manpower

There is sufficient manpower overall, despite rapid growth, but there are certain shortages of experienced personnel in management and engineering. Shortage of middle level managers and design engineers is acute. This is exacerbated by job-hopping and by engineers being promoted too early to management.

Training is provided by:

- educational institutes
- research institutes
- overseas.

Overseas training is common now, with many comprehensive technology acquisitive agreements including intensive training, particularly in manufacturing technology and maintenance. Training in design and project management necessary to develop next generation products is still inadequate. Recently concluded arrangements with AT&T and ITT will seek to remedy the inadequacy.

Instruction in junior colleges needs enhancement; facilities and instruction at graduate schools are generally out of date and inadequate, except at a few institutions.

Postgraduate training in-house and at national institutes is improving. Industry is paying more attention to in-house training. KAIST offers good training, but costs are much higher than universities.

INDIA

Manpower

The lack of adequate manpower of appropriate calibre has been a major bottleneck in development of composite technology for ICs. The good engineers who acquire basic training often go abroad to more lucrative assignments. There is also a lack of incentive among students to undertake IC technology as a major discipline. The situation is improving: in certain areas of the technology a high level expertise is now available and the major expansion of LSI production now enbarked on will provide greater opportunities. The need for incentives to promote and retain the indigenous competence is recognised.

Training

Several nationwide programmes are being launched:

- microprocessor training is being phased in in the graduate and undergraduate curriculum. About three thousand teachers will be trained in microelectronics by 1985.

- Computer education is being introduced on a pilot basis in about 50,000 secondary and higher secondary level schools.

- The Appropriate Automation Promotion Programme of the Department of Electronics funded by Government and UNDP/UNIDO is training engineers and scientists from industries and other organisations in the field of microelectronics and applications. Another such programme on microprocessor applications engineering is planned.

- Computer Maintenance Corporation offers training in various aspects of software technology under another UNDP assisted programme INTERACT.

- The Centre for Electronics Design offers specialised training to small industry sponsored personnel in all aspects (theory and practise) of electronics design. Another such centre is planned.

- Professional bodies also offer training.

PAKISTAN

Manpower

Qualified manpower in subjects allied to microelectronics is produced in abundance by the twenty four universities and polytechnics (400 professionals and 300 sub-professionals a year since 1978). Enrolment 1983/84 in professional disciplines of electronics is 500. Polytechnics qualify up to 300 high level technicians and up to 200 lower level each year.

The 1000 or so Pakistani engineers or scientists and up to 2000 technicians working in the field of electronics technology abroad are taken into account in concluding that sufficient manpower is available to undertake any electronic ventures in the country.

Training

In addition to degree courses, other institutes provide training in microelectronic technology and use of computers viz.

- recently established computer training centre with an emphasis on 'hands on' training in the facilities available in the centre

- various computer programming/data processing courses

- National Institute of Electronics (digital and microprocessor development)

- suppliers of foreign technology train Pakistani engineers in the maintenance/after sales service aspects of their products.

BANGLADESH

Manpower

There is a constant brain-drain from the country; engineers and scientists trained in the universities, including the Engineering and Technology University do not find attractive employment prospects at home; either from the point of view of facilities for application of their skills or the salary levels available.

Training

Existing facilities at University level and in-house training of the telephone and television companies etc. are insufficient to produce the numbers needed for the development of the industry.

Intensive training at technician and supervisory level is also inadequate. An integrated approach for delivery of such training is seen to be necessary. The need for inter-country or bilateral cooperation in this area is expressed.

Ad hoc arrangements with suppliers for training related to the maintenance and servicing of electronic equipment is insufficient.

VENEZUELA

Manpower

The number of professional engineers trained and the quality of their training is not a barrier to the achievement of indigenous technological development. However, the general picture is that their engineering skills are used minimally since they find jobs in management, sales and purchasing. In the specific instances of

- engineering consulting firms
- the petroleum industry
- the recently established indigenous electronic companies (manpower - 200 personnel)

there is a more appropriate exploitation of the engineering design skills available.

Training

- State support via graduate scholarships was significant in the training of a significant number of the founders of the indigenous electronic companies.

- The use of scholarships for the training abroad of graduate scientists and technicians in the early sixties was significant in establishing indigenous expertise in electronics. It continues to be used as such a tool.

- The National Telephone Co. operates a training centre for telephone engineers.

- Training in the maintenance of Hewlett Packard products is given to sizeable groups of Venezuelan technicians and engineers.

- All of the major academic institutions offer microprocessor courses in the regular electrical engineering study programmes.

- Major state R&D organisations are also a major source of trained personnel.

2.7 THE ACQUISITION OF TECHNOLOGY

Technology can be acquired from abroad by a country in a number of ways:

- by direct foreign investment
- by licencing packaged technologies
- by licensing unpackaged specific technologies
- by know-how agreements for specific technologies
- by training abroad
- by joint venture agreements and
- by comprehensive agreements including the outright purchase of proprietary technology.

The means with which technology is effectively transferred to a country is critically dependent upon the indigenous expertise or the capacity of the host country to receive it. The approaches adopted by the surveyed countries is now presented in turn.

The Republic of Korea is by far the most successful of the surveyed countries in this regard. It has used all the above approaches. Chapter 3 gives an analysis of the various stages of development the country has undergone in this connection.

Most technology acquisitions are financed by domestic funds, but some have been carried out with loans from the World Bank, the EXIM Bank and the Asian Development Bank.

The country is currently in the process of changing from a positive to an automatic acquisitions policy. Companies can acquire technologies automatically by simple submission of an application form, unless Government decides to seek further information.

India has used the direct foreign investment route and the licensing of both packaged and unpackaged technologies. Indians trained abroad and returning to their own country constitute a valuable source of technology transfer. The country has been less successful in joint venture arrangements or comprehensive acquisition.

Technology importation is strictly Government controlled.

The conventional methods of transferring technology have not worked well in Pakistan in this field, due to the difficulty of absorbing the technology with its high rate of obsolescence.

The Government has, therefore, sought through the export-processing zone industry scheme to acquire technological know-how, training of professional manpower and establishment of industrial infrastructure to improve the capacity for indigenous absorption and adaptation of technology. The microelectronics industry has the highest priority within the scheme. Joint ventures with reputable foreign firms are seen as a desired future path.

A global approach to technology acquisition has not yet been defined for Venezuela. Only a few examples exist of technology genuinely transferred to indigenous use from multinational companies. Training of Venezuelans abroad over the last two decades has, however, been valuable and has led to the growth of the emerging indigenous electronics sector. There is a consciousness of the need for a more systematic approach to technologies acquisition in the field.

The electronics industry in Bangladesh, being mostly limited to assembly operation, the transfer of technology is limited. Those companies using imported microelectronics in TV production mainly rely on technical collaboration agreements with reputable foreign companies (e.g. Japan, Thailand). Another company manufacturing electronic fences has entered in a joint venture with a Swedish company.

2.8 FOREIGN SUPPLIERS OF EQUIPMENT AND TECHNOLOGY

The information is most easily presented in the table which follows:

THE REPUBLIC OF KOREA

Table 4. Suppliers of Equipment and Technology in the Republic of Korea

Equipment/Technology	Suppliers
Semiconductors including: NMOS, CMOS, linear, hybrids; process, design and fabrication technology; 32K ROM, 64K RAM, 8 bit microprocessors etc.	Japanese and U.S. companies including: VLSI Tech. USA, ITT, AT&T, Zilog, Tosniba, Northern Telecom
Telecommunications including: electron switching systems, private branch exchanges, electromechanical switching systems.	AT&T, ITT, Ericsson, NEC, Rolm, Northern Telecom, Siemens.
Computers and Industrial: including CAD, robots, monitoring and control systems	Hitachi, NEC, AT&T, DEC, Honeywell, Prime, Hewlett Packard, Mohawk Data Systems. Fujitsu, IBM and Sperry are 100% owned local firms in Korea.

INDIA

Table 5. Suppliers of Equipment and Technology in India

Equipment/Technology	Suppliers
Computer Systems	USA, UK, USSR, Netherlands
Computer Peripherals: including floppy drives tape drives, hard disc, drives etc.	USA, UK, Japan, West Germany
Process Control Equipment: digital equipment & computers	USA, UK, France, Sweden, West Germany
Data Acquisition & Control Systems	USA, Japan, France, UK
Communication Equipment	France, USA, Switzerland
Electronic Instruments including special applications	USA, Europe, (U.K., Netherlands and others)

PAKISTAN

The microelectronic technology and equipment has mostly been imported from USA, Western Europe and Japan.

Table 6. Suppliers of Computers in Pakistan

Manufacturers	Nos.	Percentage
IBM	60	58.8
ICL	19	18.6
NCR	17	16.6
Others	6	5.9
Total	102	100

Products from Japan, the area of Hong Kong, the Republic of Korea and Singapore are now finding wider acceptance in Pakistan and also those of other Asian countries.

BANGLADESH

NEC Japan are the main foreign suppliers of microelectronic technology and equipment.

VENEZUELA

The main suppliers of electronic consumer and professional goods are foreign-based companies operating in the country e.g. IBM, Philips, Siemens and Hewlett Packard.

2.9 RAW MATERIALS AND THE INFRASTRUCTURE FOR SUB-SUPPLY

Raw materials, particularly for IC production (e.g. IC grade silicon, high purity chemicals, high grade metal products, fine ceramics, specialised resins etc.) are mostly unavailable from local sources and must be imported. The Republic of Korea and India are building capacity for the indigenous production of certain essentials.

The infrastructure for the supply of materials, components and subassemblies to local electronics equipment manufacturing units is poorly developed in all countries. Once more, the Republic of Korea and India are making the greatest strides in this connection.

2.10 AREAS FOR INTERNATIONAL COOPERATION

Suggestions made for international cooperation in each of the country case studies are summarised sequentially below:

The Republic of Korea identified needs/opportunities in the following areas:

- IC Design Centre with CAD
- Joint large-scale R&D programmes
- Training Centres for managers and engineers
- Regional Computer networks
- Pilot plant for wafer production for custom chips
- Consultancy and systems study.

The partners in such cooperation and the methods employed were not identified.

The Indian case study identified the following areas where that country could offer assistance to others in the region:

- Design and fabrication facilities for custom/semi-custom chips
- Hosting a regional centre for IC design and technology
- Creation of a centre of Electronic Design Technology in Thailand
- Expertise in microelectronics application engineering
- Expertise in applications software
- Expertise in programmes promoting the use of microelectronics
- Consultancy skills in certain areas
- Exchanges of scientists and engineers
- Student training.

India has need for assistance from more advanced countries for:

- software for LSI design
- skills in system software
- exchanges of scientists and engineers
- student training.

Pakistan identified the following areas where it could offer expertise:

- education and training in electronics and computer science
- R&D collaboration in computer hardware and software and component technology.

Areas where it needs assistance include:

- CAE/CAD/CAM/Robotics
- Fibre optics
- LSI/VLSI design and fabrication technologies
- On the job training in advanced countries
- Equipment and system design.

Regional cooperation agreements are seen as the preferred approach.

Bangladesh identified needs for

- industrial support for proposed National Institute for Electronics
- instructors and equipment for Institute for Scientific instrumentation.

It sees scope for sharing facilities with India and Japan and is particularly interested in the recommendations of an international symposium in New Delhi (1983) to establish an Asian Institute of Electronics Technology in Bangladesh.

Venezuela sees scope for technology agreements between middle-tier developing countries in Latin America and for trade agreements, political treaties and natural resource supply contracts between developing and developed countries.

It is particularly interested in a proposal to UNIDO to establish a Regional Centre for Applied Microelectronics centred on the FII in Venezuela. Activities of this centre could include

- R&D directed towards design and applications relevant to the needs of partially developed countries
- technical assistance to new industry establishments
- technical training
- technical information focus.

Such a Centre could be networked with other similar institutions in cooperating countries.

CHAPTER 3. ANALYSIS AND RECOMMENDATIONS

3.1 A MODEL OF DEVELOPMENT

In order to facilitate analysis, a model of the development of a national microelectronics industry is described in this section. The stage of development of selected developing countries is then, in the next section, discussed by reference to the model. Finally, in section 3.3, recommendations are made aimed at advancing these countries along the path of development.

The model (see Reference 1) envisages three stages:

- Implementation
- Assimilation and
- Improvement.

Implementation

This stage presumes no indigenous innovative capacity.

Production at this stage is merely the assembly of foreign components and parts with equipment purchased from overseas. Technology is acquired through direct investment or through 'packaged' technology from overseas. Packaged technology includes assembly processes, together with product specifications, production know-how, technical personnel and component parts.

The focus at this stage is either import substitution or, if the firms are off-shore production units of MNC's, exports to markets developed by the parent company overseas.

In this stage, the technological task is the implementation of the transferred foreign technology in order to produce products whose technology and markets have been tested and proven elsewhere. For this purpose, only limited engineering efforts are required.

By means of this stage, a country can establish an industry where none existed before. It cannot yet, however, develop new products or new markets.

Assimilation

The assimilation stage is a stage in which firms get a certain mastery over the production technology and become capable of producing modified or differentiated products for differentiated markets. This stage requires indigenous effort to assimilate the foreign technology. Technical emphasis is placed on engineering and limited development rather than on research.

A cadre of experienced technical personnel is created or spun-off from existing companies and the mobility of these experienced people leads to a diffusion of production technology within the country.

Competition may develop on local markets and, perhaps also influenced by foreign market developments. Entrepreneurs will develop the capacity to use technology for competitive advantage by lowering production costs and making limited product and quality improvements.

This stage can develop an industry which is organically growing and is, to some extent, under the control of the indigenous entrepreneur. It does not, however, result in an industry developing completely new products for existing and new markets.

Improvement

This stage, which sees the improvement of foreign transferred technology and the production of significantly improved or new products, requires significant inputs of local technical efforts. It is characterised by training and education programmes to produce highly-skilled people and significant national research and development efforts. It may entail further inward technology transfer but, at this stage, the technology will be 'unpackaged'. Licensing, know-how agreements and joint ventures with foreign technological capacity will be pursued.

In this stage also, it is likely that local sub-supply of materials and components will be the practice. Competition on local markets will be stronger and foreign markets will be pursued, probably through national export promoting schemes.

Successful transition through this stage may see an internationally competitive industry, capable of taking on world leaders in certain niche segments of the market.

3.2 STAGE OF DEVELOPMENT OF SELECTED DEVELOPING COUNTRIES

This model will now be employed to characterise the stage of development of microelectronic activities in selected developing countries in the following regions

- the NIC's of Asia
- Latin America
- Southern Asia

The Newly Industrialising Countries of Asia

The Republic of Korea, Taiwan province of China, the area of Hong Kong and Singapore, account for 80% of all electronics exports from the less developed countries. When they started developing their electronics industries within the last 20 to 25 years, they were faced with the problems of working from a very low base of technology, skills, international marketing capability, a lack of organisational strength in existing indigenous electronics firms, and poor infrastructure for the industry in terms of suppliers of parts and services. They are also located at a considerable distance from the most advanced countries, the United States and Europe, and so from the sources of technology and the largest markets.

Initially, the indigenous firms entered the industry by producing the simple products which were at the mature stage of the industry life cycle, especially the simpler consumer products such as radios, black and white TV sets, and audio equipment. The technology for these products was easily obtainable and was changing slowly, so that there were low technological barriers to entry. The firms competed on price using their extremely low labour costs as a competitive advantage. The technology was imported in a "packaged" form, with the licence deals involving product designs, production specifications, supply of parts, and import of foreign technical personnel to oversee production start-up. The products were usually marketed abroad by the technology suppliers under the suppliers' own brand labels.

Later, as the firms' technical capabilities improved through learning the simpler technologies, they developed the capability of imitating foreign technologies and of modifying the technologies imported through licensing. They were gradually able to move to more complex consumer products such as cassette players and colour TVs. The larger firms began to develop their own international marketing capabilities which helped to overcome some of the major problems of peripheral location by feeding back information on market and technology developments to the home country. The industry has grown dramatically in the most successful countries; in the Republic of Korea, for example, employment grew from 30,000 in 1970 to 250,000 or 13% of the workforce in manufacturing, in 1983.

The success of their industrialising efforts has resulted in higher labour costs, so that other developing countries such as the Philippines and Sri Lanka began to pose a competitive threat in the products with low barriers to entry. This has forced the firms in the NICs to move to products which are at an earlier stage of the industry life cycle where the technological barriers to entry in particular are higher, such as video cassette recorders, instruments, telecommunications products, and computer-related products. However, the companies have now run into a major problem. Foreign firms are refusing to licence the relevant technology since they do not want to encourage direct competition, in products which they are still producing themselves, especially from the by now more threatening firms in the Republic of Korea and the Taiwan province. This has forced the NIC firms to do their own R&D work but this is difficult since the technologies concerned are changing fast. The products which they painstakingly develop are quickly made obsolete by advances in the developed countries.

The larger firms have adopted a number of strategies to overcome the obstacles. They have mounted large R&D efforts at home, have bought into small high technology firms in the U.S. in order to transfer the technology back home, and have set up R&D facilities in the most advanced locations such as Silicon Valley, employing highly skilled researchers at very high salaries. However, only the very large firms in the Republic of Korea and the Taiwan province have been able to afford these strategies. The smaller firms such as those in the area of Hong Kong have run into major hurdles. In the past, they managed to compete in products with mature technologies where the technology made small-scale assembly economically viable, notably radios, watches and calculators. These firms also competed on price with low labour costs. They have tended to remain in a very dependent technological position without any R&D of their own, depending on technology transfer from foreign firms which marketed their products. They cannot afford the costly strategies open to the larger firms.

Of these countries, Taiwan province and especially the Republic of Korea have firmly moved into stage three of the development model described above. They are significant forces in the world's electronics marketplace. Their continued success in consolidating or advancing their position will be watched with interest.

Latin America

The NIC's of Asia discussed above may be described as advanced developing countries. Latin American countries such as Mexico, Brazil and Venezuela are in a middle developing category. Although these countries are at present suffering severe economic difficulty including crippling foreign debt, they are nevertheless resource-rich, with substantial potential for development in the future.

The manufacturing sectors of these countries are characterised by considerable protectionism of the internal markets, low product and process innovation, and lack of experience on export markets. Many firms are, as a consequence, inefficient and their products of lower quality and expensive by the standards of international competition - despite labour cost advantages.

Mexico has an indigenous electronics sector which is large but uncompetitive in the consumer subsector and fragmented, but improving in the professional subsector. Joint venture companies with MNC's manufacturing locally supply the national PTT market. In very recent years, Mexico has taken positive action to attract foreign investment in the professional electronic field and a number of the world leading computer companies have established modern production plants. The Mexican policy - which is being implemented - is to negotiate arrangements with these firms to:

- procure a well-defined, and growing with time, percentage of subsupplies (component, sub-assembly, etc.) from local Mexican companies;
- employ a number of practical measures (R&D levy, training etc.) to transfer state-of-the-art technology to indigenous enterprises and
- target exports.

An important part of this policy is to build up the technological, manufacturing and managerial competence of the indigenous sub-supply firms.

Venezuela's electronics industry is again of three kinds:

a) Large firms, partially state-owned, supplying the national PTT market with licenced foreign technology.

b) Private firms associated with foreign companies, mainly selling imported products or assembling consumer electronic products, and

c) Venezuelan privately-owned firms in the professional electronics subsector. These are small firms with varying degrees of technical sophistication. The total sales of these companies is still small, but is rapidly growing.

In both of these countries, state scientific and technological support services, although containing pockets of excellence, are fragmented, largely uncoordinated and relatively poorly oriented towards the needs of industry.

These countries are, therefore, for the most part largely in stage one of the development model, with some and increasing inroads into stage two and no presence in stage three.

Southern Asia

The countries of Southern Asia - India, Pakistan and Bangladesh - have significantly lower GNP per capita than the previous two groups, and significantly less natural resource-based wealth than the Latin American countries discussed. They, nevertheless, have an important resource in their sizeable numbers of highly trained and well-educated people.

Their electronic industries are, for the most part, based on the simple consumer products of radio, T.V.s, and tape recorders. Recent years have seen in India the growth of a significant professional sector involving computers, communication equipment, process control equipment and instrumentation. In very recent times, India began production of small volumes of integrated circuits.

India has been attempting to build its electronics industry and the supportive technological infrastructure on the model of large industrialised countries like the U.S. and Japan. It has been attempting to create, largely from internal resources, a self-sustaining, integrated and self-sufficient sector covering most if not all product areas.(2)

The main objective of industry in these countries is to supply their national markets and avoid the need for imports. This objective is, however, not achieved in most cases. Experience of international competition is limited. Technology levels significantly lag, in general, behind the world state-of-the-art and rates of indigenous innovation are relatively low.

The industry in these countries is, therefore, largely in stage one of the model with the exception of India and, to some extent, Pakistan.

3.3 RECOMMENDATIONS

The model of development outlined at the beginning of this chapter is considered to be broadly valid and is recommended to Governments as a framework for planning the development of their electronics industries.

It is characterised by:-

- three stages; implementation, assimilation and improvement. Each of these stages must be taken in turn. It is not possible to move to stage three without going through stages one and two.

- The key to moving successfully from one stage to another is the development of sufficient indigenous competence (technological, manufacturing, managerial, marketing etc.) to do so. This applies whatever the origin of foreign expertise or the modalities employed to transfer it to local use.

Of the countries surveyed, the Republic of Korea is by far the most advanced in terms of this model. Whereas it is accepted that not all countries would aspire to, or would be likely to achieve, the success of the Republic of Korea in developing an internationally competitive electronics sector, nevertheless it is confidently proposed that each of the other countries considered can significantly improve their present positions.

A number of recommendations will now be made under a series of headings. The focus of these recommendations will largely be on the development of indigenous competence. The scope of the recommendations is broad and general. The details of the specific application of these recommendations would depend on local conditions and circumstances.

The Development of an Indigenous Manufacturing Sector

Expertise and experience in technology, manufacturing practice and the key business functions must be painstakingly acquired - there are no short-cuts.

Such is the scale of the growing world market in this area, such is the dominance of certain countries and firms and such is the cost and rate of development of technology that no newly industrialising country could expect to develop national competence which would be internationally competitive across the range of information technology products and services. It would, for example, be foolish for a newly industrialising country to try to develop a new digital telecommunications public switching system. It will be necessary for industrialising countries to select their niches in the microelectronics sector. Niches are relatively narrow or specialised markets, and the markets can be specialised in any of the following ways: by product, by customer, by geographical area or by a combination of these. Once the niches or specialised market segments are selected, national, developmental resources can be concentrated on them in the form of state R&D funding, specialised manpower development, public procurement measures, development contracts etc.

This niche or selectivity policy is recommended for all countries surveyed, including the Republic of Korea and the smaller countries, but also and especially India. No policy of self-sufficiency in all products will succeed and the pursuit of such policies (by, for example, India) is likely to dissipate available resources over too wide a range, with the possibility of no great success in any segment of the sector.

In the earlier stages of development, a focus of indigenous effort might usefully be on the creation of a healthy and competent sub-supply sector. Indigenous firms in this sector would supply the (probably foreign) electronic consumer and professional equipment manufacturers operating within these countries with materials, components and subassemblies. In this manner local, probably small, firms could gain experience within their own country of sophisticated high technology business. It would be important to ensure that the local firms meet the standard of technology quality and delivery of their products which apply generally in the industry. They could be assisted in this regard both by Government policy measures and directly by the equipment manufacturers whom they are supplying.

In a later stage of development, local innovative effort will have mastered and improved existing technologies in the selected niche areas to compete on the national and international markets with new or improved products.

The role of competition, as a stimulus to enterprise and as a method of ensuring efficiency, should not be neglected. Countries who protect their internal markets from foreign competition and allow a monopoly supply position from preferred national companies on that market inevitably find inefficiencies developing in the forms of low quality, high cost, lack of innovation and a general falling behind vis-a-vis the standards applying to similar products in the outside competitive world. Countries who must protect their internal market might consider one of the following approaches:

i) Allow a certain fraction of their national market in certain product areas (e.g. telecommunications equipment) to be open to competition between a foreign firm (possibly manufacturing locally) and national firms, the rest of the market being closed to foreign suppliers.

or

ii) Build competing national firms to supply market segments and use Government policy measures (e.g. through public procurement contracts) to foster competition between them.

It should go without saying that countries who wish to enter foreign markets must get experience of international competition. This could start either on their own markets or in selected foreign markets in their region and probably in both.

The Role of Foreign Investment

Direct foreign investment could be an important element in the development of a sector. It is by no means a sufficient means of developing a thriving and organically growing industrial sector, but the benefits which derive from it may be of significant value. These benefits include:

- the capital resource invested
- the employment generated
- the imports substituted
- the exports generated
- the work experience gained by operatives, technicians, engineers and management and
- the somewhat intangible but very important "manufacturing ethos" created. (The value of the experience of the manufacturing environment and practices - including the maintenance of standards, quality control etc. - prevalent in developing countries should not be underestimated).

On the other hand, the foreign investor is not normally motivated by altruistic intentions of benefitting the host economy, but by other interests such as gaining access to the local market. The host Government will, therefore, have certain leverage which it will seek to exploit in the interests of its national economy.

It is recommended that this leverage be utilised to ensure the maximum transfer of expertise to the host country.

In an early stage of development, with limited indigenous competence, the focus could be on ensuring that the foreign investor contributes to:

- the development of relevant national technological infrastructure

- the development of the technological competence of indigenous sub-supply and service firms through, for example, training programmes, technical assistance, giving know-how, development contracts etc.

These initiatives could be funded by a levy on the sales of foreign-owned firms. The host Government will wish to ensure that schemes they adopt in this connection are relatively simple and easy to administer, monitorable against targets to determine success or failure and are directed towards the practical achievement of clearly identified national needs.

Joint ventures between indigenous companies and foreign companies may be a valuable approach in a later stage of development. It is important to realise that technology will not generally be successfully transferred in a joint venture arrangement unless both partners are of roughly comparable technological competence. Many joint ventures between firms from developed and developing countries are not of this nature and are undertaken because of a Government requirement for local equity participation in foreign manufacturing enterprise. In the view of this consultant, these are less beneficial arrangements than ones in which real competence is transferred.

The Development of Local Applications

The electronic equipment sector is advanced, rapidly changing and fiercely competitive. Most developing countries will not succeed in creating an internationally competitive industry of any substantial proportions in the sector. A compromise, determined by local circumstances, between importing equipment and local production will have to be arrived at in almost all cases.

The question of the application of this equipment and technology in the local environment is, however, a different issue. Because of the specificity of local need and the local control over how this need is to be addressed, the balance of advantage lies with indigenous effort rather than foreign competence in this area. It should be remembered in this connection that the cost of the basic equipment, e.g. a mini computer or a microprocessor, may only be a small function of the cost of the application e.g. air traffic control or industrial process control. There is frequently very substantial scope for local value added.

This is not to say that the necessary application competence is easily acquired, but it is:

- less capital intensive
- less dominated by giant multinational firms and
- more controllable by local effort.

All countries should, therefore, seek to develop their microelectronics applications competence to the full within their available resources. It has been stressed before that the benefits which accrue from this activity come from the added efficiency and effectiveness of all industrial and service sectors and by no means just from the electronic sector itself.

Areas of basic technology which should, therefore, get priority Government attention include:

software:

- which is at the heart of all applications and, while not capital-intensive in its creation, is nonetheless an extremely sophisticated business;

design:

- integrated circuit design, particularly for customised I.C.'s to meet specific applications. The necessary infrastructure to fabricate and test, at least on a prototype basis, I.C. designs should also be considered even by countries who do not intend to have a significant semiconductor manufacturing industry of their own;
- systems engineering and design is another necessary competence to develop in each country.

In addition to the development of these basic skills, there will be a need to promote the appropriate application of microelectronics technology throughout the industry, commerce and administration in each country. This frequently requires state-supported institutions to raise awareness, provide information, assist in feasibility analysis and sometimes implement applications in particular environments.

Research and Development and Skilled Manpower

No form of technology transfer to a country will succeed without the presence of an indigenous innovative capacity and the skilled manpower necessary to absorb, assimilate and apply it to local conditions and national needs.

The ideal location of industrial innovation, including industrial R&D is in the firm itself. Governments encourage firms to invest in innovation through various environmental measures such as tax concessions, the subsidisation of in-firm R&D and sometimes by subsidising the cost of the acquisition or retention by firms of skilled manpower.

In addition to these firm-oriented measures, Governments build national innovation capacity through the support of basic and applied research and development in universities, the education and training of skilled manpower in universities and technical colleges, and the build-up of applied research and development capacities through the establishment and support of mission-oriented laboratories and institutions.

To complete the picture, some Governments provide positive measures and mechanisms to link the expertise of the largely state funded universities and institutes to the needs of industry, whether private or public.

All Governments are aware of these issues and approaches. What varies are the measures used to orient the national innovation capacity - wherever it is located - to national needs, and the success of the measures employed.

In many developing countries - including those surveyed - the national innovative capacity in the universities and research institutes is not well planned. It is frequently poorly coordinated and inadequately linked to real industrial needs.

The criteria that decide research priorities in universities and institutes take only limited account of the actual present and short term future innovation requirements of industry in their regions. Mechanisms to make university expertise available in a meaningful way to industrialists are either non-existent or poorly functioning. Industrialists may be unaware of or suspicious of universities' and institutes' research efforts and researchers in these establishments may be uninterested in practical industrial problems. This is a quite unsatisfactory situation.

It is recommended therefore that Governments:

* preferentially build up innovation capacity, both R&D and skilled manpower, in the technical areas underlying the selected industrial niche areas;

* identify actual industrial need;

* preferentially build innovation capacity in university and research institutes to meet these needs;

* establish practical and effective mechanisms - such as University/Industry Liaison Offices - to build bridges between industrial need and university competence.

These ideas are by no means novel but, in practice, much improvement can be made in the existing procedures adopted by the surveyed and other countries to apply them to best effect. These approaches - as distinct from technology and market development generally - are under the control of national authorities.

The Scope for International Cooperation

Cooperation (as distinct from aid) can only work well between partners with comparable or complementary abilities. Ways in which developed countries can assist developing countries are:

o training of engineers and technologists from developing countries in the universities, institutes and industrial laboratories of developed countries, and

o assistance from the developed countries (either bilaterally or through the medium of international organisations) in establishing, training expert manpower for and funding technological infrastructure in developing countries.

Regional cooperation between developing countries at a comparable stage of development can assist these countries achieve a critical mass of effort through sharing tasks and sharing experience and information. Some practical suggestions in this regard include:

- common and/or networked regional facilities for I.C. design

- common regional facilities for the fabrication of customised integrated circuits

- centralised production and/or procurement of special or strategic raw materials and components

- common and/or networked centres for software development

- common and/or networked centres for systems engineering and design

- networked centres for information, advice, feasibility studies and assistance to industry on microelectronics application.

References

1. "Stages of Development of Industrial Technologies in a Developing Country: A Model"
Linsu Kim, Research Policy 9 (1980) p. 254
North Holland.

2. An interesting critique of India's Policy in this area is provided in:
"Indian Electronics: The Technological Dilemma of a Middle Power" by Erik Baark - a paper presented to the Eighth European Conference on Modern South Asia Studies in Tallberg, Sweden, July 1983.