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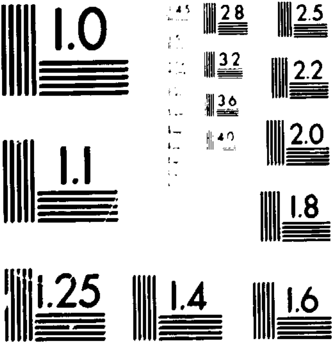
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INFORMATICS FOR INDUSTRIAL DEVELOPMENT

Richard J. Nolan

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INFORMATICS FOR INDUSTRIAL DEVELOPMENT

INFORMATIQUE AU SERVICE DU DEVELOPPEMENT INDUSTRIEL

INFORMATICA Y DESARROLLO INDUSTRIAL

ABSTRACT/SOMMAIRE/EXTRACTO

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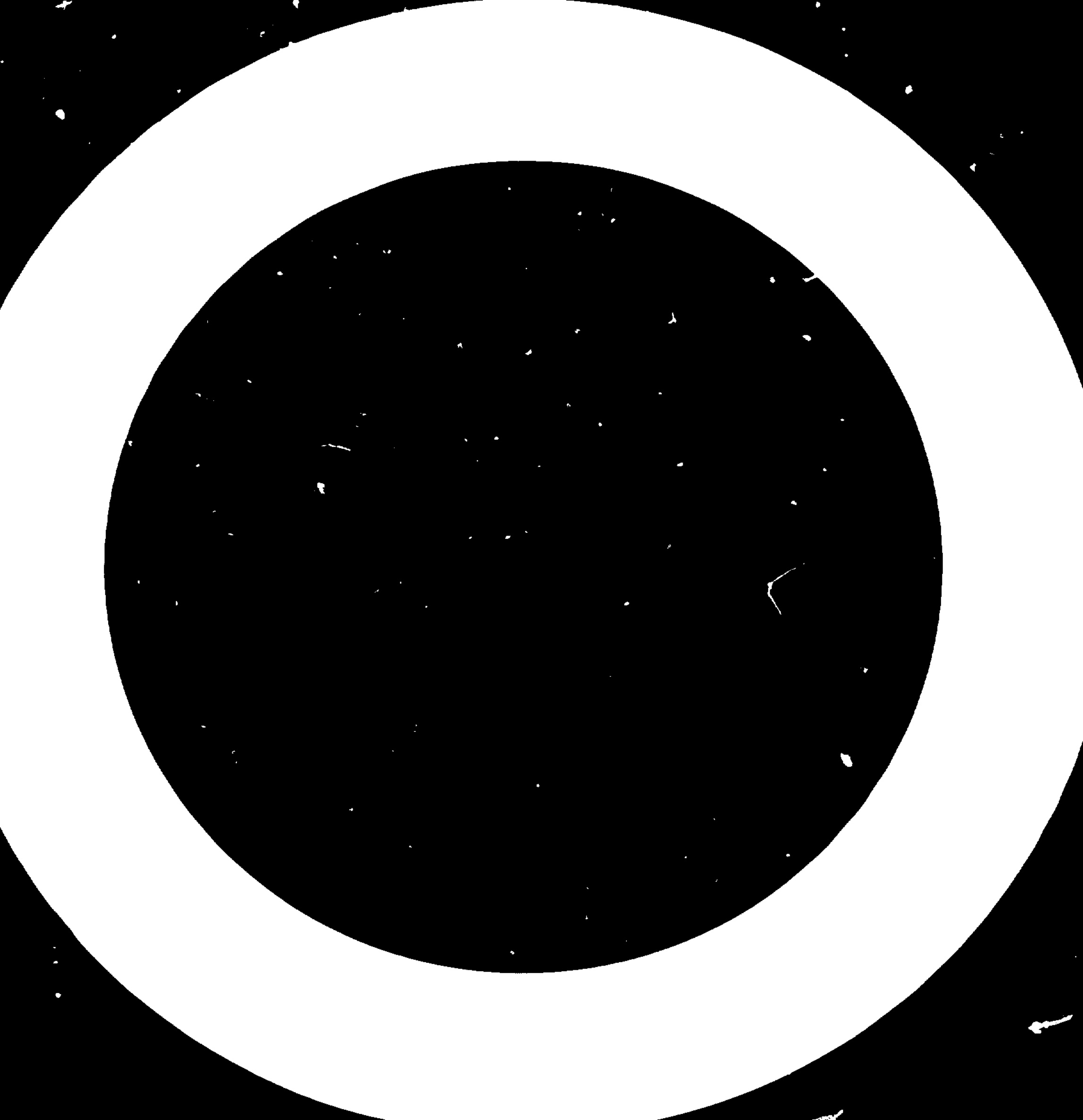


ABSTRACT

In the last few decades technologies for handling information have undergone rapid development, based on microelectronics. In the industrialized countries the impact of informatization, as it is called, is felt not only in organizations but also by society itself. This has important policy implications for development in the third world.

Informatics for Industrial Development, No. 22 in the Development and Transfer of Technology Series of the United Nations Industrial Development Organization (UNIDO), discusses the importance of informatics and its significance for the third world. The technology, its uses and its effect on productivity and employment are examined. The publication covers policies that the developing countries might want to adopt and action that could be taken at the international level. Finally, an 18-point check-list to help developing countries formulate an operational strategy for informatics development is presented.

SOMMAIRE

Au cours des dernières décennies, les techniques de traitement de l'information ont connu un développement rapide, basé sur la micro-électronique. Dans les pays industrialisés, les effets de ce que l'on appelle l'informatisation s'exercent aussi bien sur les organisations que sur l'ensemble de la société. Ce phénomène a d'importantes conséquences pour les politiques de développement du tiers monde.

Intitulé *Informatique au service du développement industriel*, le 22e volume de la série "Mise au point et transfert des techniques" publiée par l'Organisation des Nations Unies pour le développement industriel (ONUDI) considère l'importance de l'informatique et l'intérêt qu'elle présente pour le tiers monde. Il examine cette technique, ses utilisations et ses incidences sur la productivité et l'emploi. L'ouvrage définit les politiques qui pourraient être adoptées par les pays en développement et les dispositions qui pourraient être prises à l'échelon international. Il comporte enfin une liste récapitulative en 18 points destinée à aider les pays en développement à mettre au point une stratégie efficace de développement de l'informatique.

EXTRACTO

En los últimos decenios las tecnologías de manejo de la información han experimentado un rápido crecimiento merced a la aplicación de la microelectrónica. En los países industrializados el impacto de la informatización, como se la denomina, se hace sentir no sólo en las empresas sino también en la sociedad misma. Este fenómeno tiene importantes repercusiones sobre la política de desarrollo en el tercer mundo.

Informática y desarrollo industrial, Núm. 22, de la serie "Desarrollo y transferencia de tecnología" de la Organización de las Naciones Unidas para el Desarrollo Industrial (ONUDI), se refiere a la importancia de la informática y su significación para el tercer mundo. Analiza la tecnología, sus usos y sus efectos sobre la productividad y el empleo. Trata de las políticas que los países en desarrollo podrían adoptar y de las medidas que se podrían tomar en el plano internacional. Por último, presenta una lista de 18 puntos para ayudar a los países en desarrollo a formular una estrategia operacional de desarrollo de la informática.

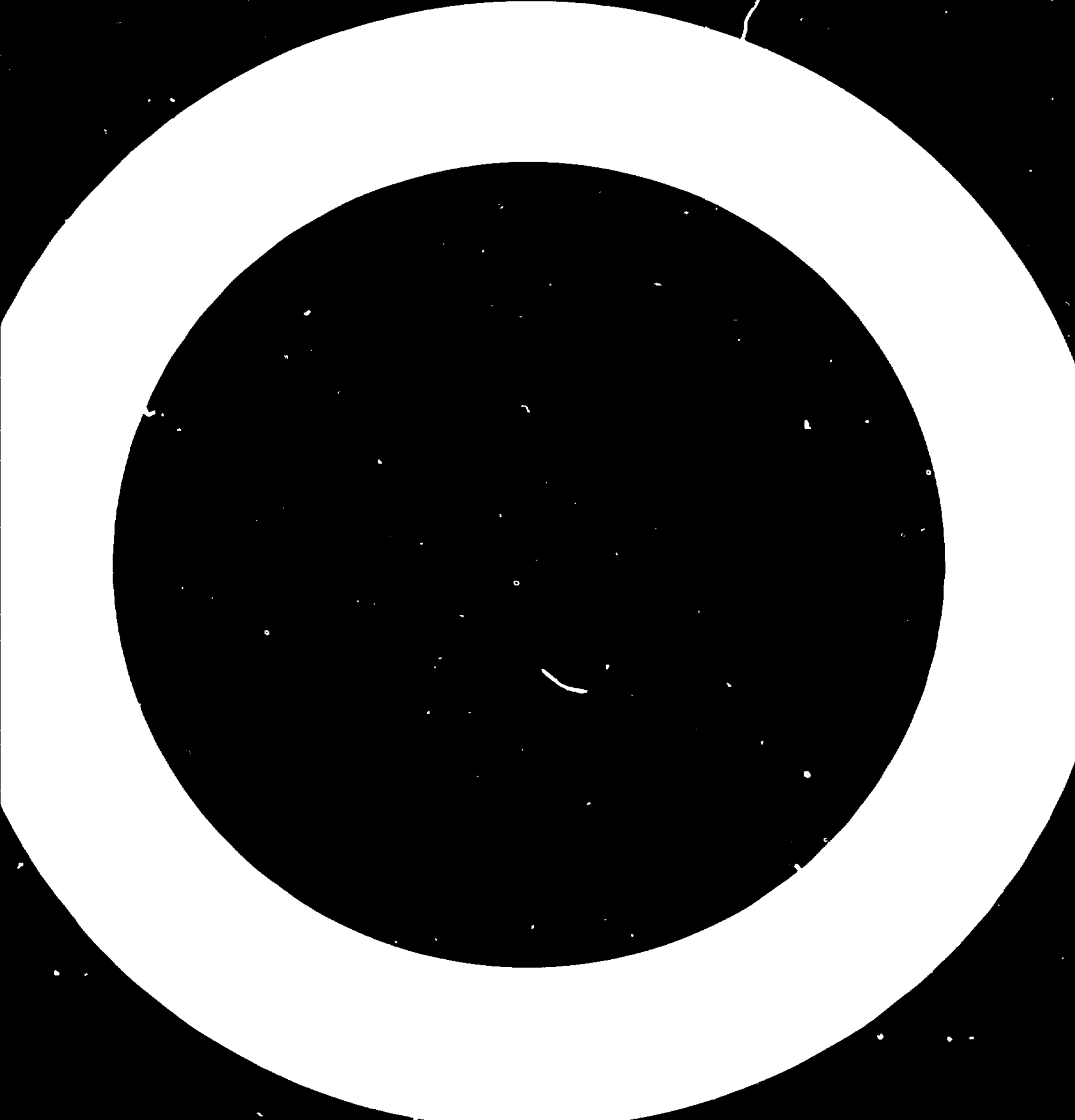
INFORMATICS FOR INDUSTRIAL DEVELOPMENT

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna

Development and Transfer of Technology Series No. 22

INFORMATICS FOR INDUSTRIAL DEVELOPMENT

UNITED NATIONS
New York, 1985



Preface

The present publication is intended to deepen understanding of the influence that information technology is likely to have on the industrial development strategies of developing countries and of the importance of building up technological capacity to enable developing countries to benefit from recent advances in that area.

It is hoped that the study will contribute to the development of operational strategies for the informatization of the third world. To this end, a check-list for national self-reliance in informatics is provided.

The publication is based on the work of Richard J. Nolan, Trinity College, University of Dublin, Systems and Data Studies. Much of the material is based on papers presented at the International Conference on Informatics and Industrial Development, held 9-13 March 1981 at Trinity College, Dublin, Ireland.

ABBREVIATIONS

AC	adaptive control
ARABSAT	Arab Telecommunications Union
bit	binary digit
CAD	computer-aided design
CIM	computer integrated manufacture
CITEL	Inter-American Telecommunications Commission
CMC	Computer Maintenance Corporation Ltd. (India)
CNC	computer numerical control
CP/M	control program for microcomputers
CPU	central processing unit
DNC	direct numerical control
EFT	electronic funds transfer
EPROM	erasable programmable read-only memory
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GNP	gross national product
IBI	Intergovernmental Bureau for Informatics
IC	integrated circuits
ILO	International Labour Organisation
ITU	International Telecommunications Union
JIRA	Japanese Industrial Robot Association
LED	light emitting diode
LSI	large-scale integration
MIS	management information systems
NC	numerically controlled
OECD	Organisation for Economic Co-operation and Development
PANAFTEL	Pan-African Telecommunication Network
PROM	programmable read-only memory
RAM	random-access memory
R and D	research and development
ROM	read-only memory
STI	scientific and technical information
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

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Introduction

The present publication examines the opportunities and threats, constraints and the necessary national infrastructure relating to the informatization of industry in developing countries. For the third world, industrial development is a priority. Studies have shown that informatics will profoundly affect the productive infrastructure and the international division of labour. Policy options for industrialization have narrowed, and a re-conceptualization of development strategies is called for. Developing countries must not merely copy the industrialized North but base their actions on an assessment of long-term comparative advantages.

Chapter I of the present publication defines informatics and gives an overview of its significance. Chapter II is a brief survey of infotechnology and its overall impact on industry and society, the hardware and software industries that are based on it, the development of new products and processes, and information systems. The potential economic effects on productivity and employment are of major concern, and this issue is discussed in chapter III.

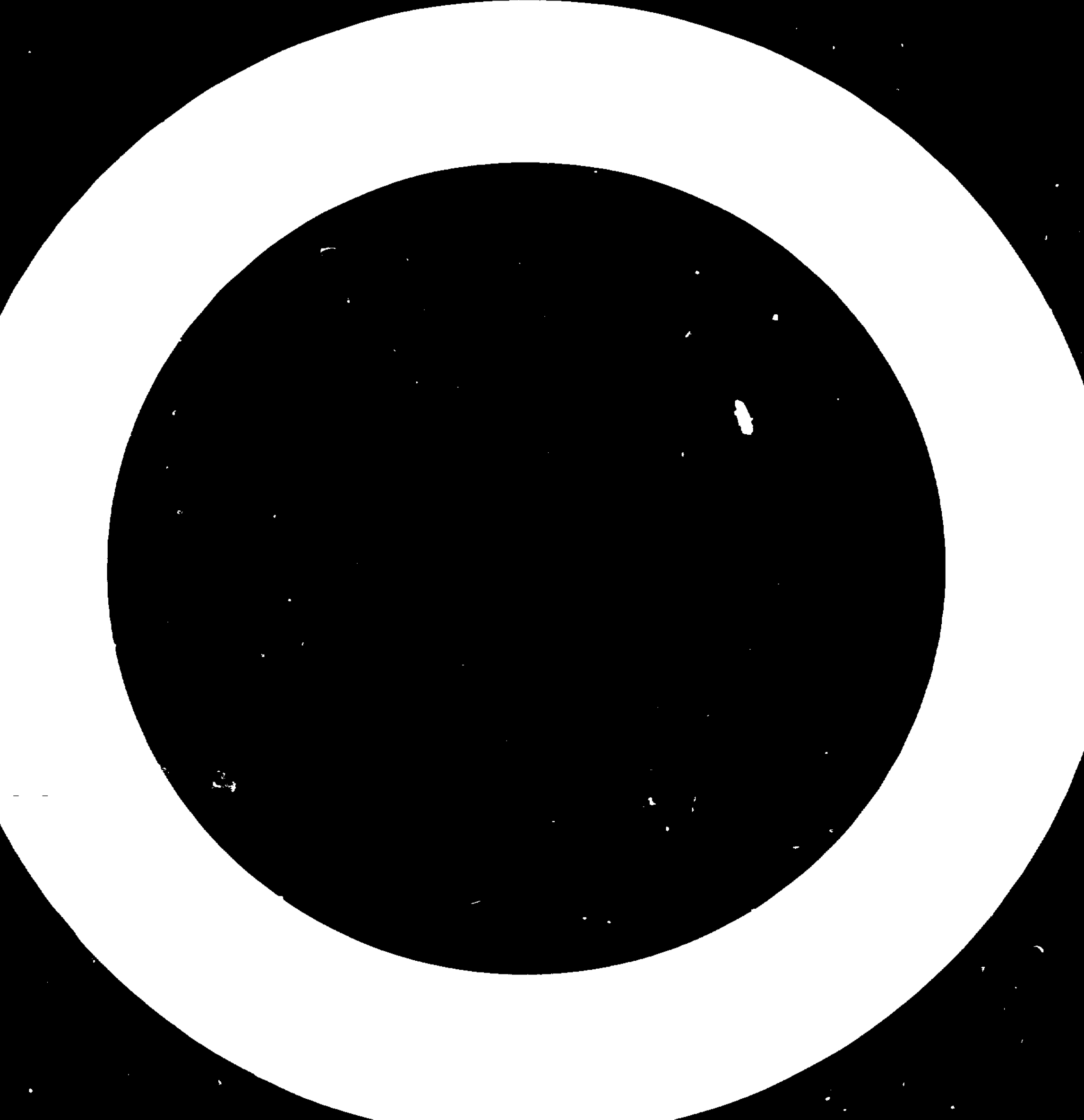
In chapter IV the development of informatics in the third world is reviewed; the use of informatics to promote self-reliance is proposed; and a conceptual framework for national informatics development is presented. Informatics development is a dimension of technological development which in turn is an integral part of national economic development. National policies and strategies are enumerated.

Since the informatics industry now ranks third in size, following energy and transportation, it must itself be a subject of study as an industrial sector. How the developing countries can participate in the industry is therefore an issue of major interest to policy-makers in developing countries, and the policy options, preconditions and constraints are examined in some detail in chapter V.

The infrastructure necessary for informatization in other industrial sectors and for supporting organic and self-sustaining growth are examined in chapter VI, with particular reference to education and training, industrial information structures, telecommunications and R and D.

International action will be essential to promote the development of informatics in the third world. Chapter VII therefore discusses the role of international bodies in the promotion of national policies and strategies; awareness, education and training; information infrastructures; communications infrastructures; hardware and software industries; new products and processes; and applications.

Finally, chapter VIII suggests a check-list of actions for individual countries for use in the formulation of an operational strategy.



I. The significance of informatics

What is informatics?

Over the last quarter of a century new powerful and integrative technologies, based on micro-electronics, have revolutionized the handling of information, and these technologies are still developing rapidly. The present publication is concerned specifically with the impact of these technologies on industry, with special reference to industrial development in the third world.

During the first phase of the development of the new information handling technologies, which started in the late 1940s, computers were used almost exclusively for scientific calculation. The impact was felt in the natural sciences, where new advances were made possible by the increase in computing power. From the 1950s to the present, new applications for computers were found as integral components of organizational systems for information and control purposes in the pursuit of productivity and economic growth. In the early days, only the largest organizations could afford to operate a computer. Recently, dramatic decreases in both unit cost and actual size of components, coupled with increased flexibility in handling, have brought computing power to even very small-scale enterprises.

In the industrialized countries the impact of computerization, or "informatization", is now felt not only within organizations but by society itself. The systems supporting modern society are increasingly computer-based, and this is affecting the ways in which society is evolving. It has been said that the final phase of informatization is now commencing; the impact will be on the individual, for whom the information technologies are creating new potential for self realization. The informatization of industry may therefore be regarded as but one aspect of a broader socio-economic development.

"Informatics" may be defined as the field of investigation that takes as its subject matter the variety of ways in which information flows and the manner in which information is processed, utilized, affects productivity and efficiency, is used for monitoring and control purposes and finally influences socio-economic development and society itself. The term also connotes the analysis and formulation of national and international strategies and policies for informatization. Thus, the field of informatics is trans-disciplinary and relates to established disciplines of computer science, management science, sociology, economics and political science, engineering and other technological disciplines.

In this publication, the information-handling technologies on which informatics is based will be referred to as "infotechnology". As in the case of other technological frontiers, infotechnology has the potential both for destruction and for peaceful uses. Other technologies have extended the muscular power and manipulative abilities of human beings. The significance of the integrated infotechnology of computers, communications and control is that it extends the nervous system and the brain. It is only the limitations in human will and creative imagination that restrict the extent to which the applications of this technology can support economic, social and personal development.

The importance of infotechnology for industrial development

Information is the life-blood of the modern industrialized State. Micro-electronic devices for receiving, storing and processing information and for control systems, together with telecommunications providing world-wide transmission capabilities, have resulted in radically new ways of handling information in all spheres of industrial and commercial activities. This has led to increased productivity and efficiency, lower costs and changes in employment structures.

Infotechnology impinges on industrial development in two ways: as a sector of industry and as a feature of industrial technologies in any sector of industry. As a sector of industry, the manufacture of micro-electronic equipment and components of all kinds, together with the production of software, now constitutes, after energy and transport, one of the three key world industrial sectors. Opportunities for the participation of developing countries in this sector need to be studied in depth.

Infotechnology as a feature of other industrial sectors—in the control of industrial processes, in innovative uses of microprocessors incorporated in new products and in information handling for decision support—is likely, in the shorter term, to have the more significant impact on industrial development and has the potential of becoming an effective vehicle for closing the North-South gap.

Informatics and the third world

Perhaps the most significant contrast that can be drawn between the industrialized North and the developing South is that the North is information-rich and the South information-poor.

To appreciate the connection between informatics and industrial development, it is useful to look back at the first industrial revolution in the North. Following the first industrial revolution, economic developments in the North were accompanied by a structural shift in employment from the primary and secondary production sectors to the tertiary or services sector. More and more specialization and professionalism were needed in the services sector, which expanded accordingly. Now information, and the means and techniques of acquiring information and control, are what this sector deals in. Information is itself a commodity that provides the basis for the livelihood of an ever increasing proportion of the work-force.

The proposition can therefore be advanced that, although in the course of industrial development in the third world the services sector will expand as an automatic accompaniment, an accelerated rate of development could be achieved if priority was given to the informatization of the services or information sector. The services sector is critically important to development, and the infotechnology applications that support activities in this sector are appropriate for speeding up socio-economic development in the third world.

Narasimhan (in [1]) discusses the importance of the services sector to developing countries, using India as an example. The industrial base in India is quite comprehensive, having as a constituent part every component of the primary and secondary production sectors. Why is India, then, not regarded as an industrially advanced country? The answer is that industrialization has not been accompanied by a structural shift of the labour force from the traditional occupational categories: industrialization has been grafted on to a society that continues to function to a large extent in its traditional mode. As a result many occupational roles in the services sector that could be contributing to the efficiency and productivity of the primary and secondary production sectors have not been created.

This is one basic aspect of the low level of information consciousness that is common to all socio-economic activities. No matter how it is measured (in terms of newspaper circulation, books, telephones, radios etc.), information consciousness is less, by several orders of magnitude, in developing countries than in developed countries.

In India, as in many other developing countries, the two major stumbling blocks to achieving rapid socio-economic development are massive illiteracy and poorly developed communications infrastructure to support information transactions between people living in geographically dispersed small communities. The provision of educational, health care and community services poses problems that only radically innovative and unconventional approaches can solve. Informatics has a vital role to play in extending the scope and improving the standards of functionally available systems in a society.

Summary

Informatics has immense potential, but there are many constraints that militate against setting up indigenous informatics industries in the developing countries, and these countries have at present only a tiny share in this vital sector. The development of this sector, however, is seen to be crucial for achieving technological self-reliance in the developing countries.

Severe structural and cultural constraints also hinder the effective implementation of even the simplest applications. Developing countries are heterogeneous and the circumstances of each will need to be considered separately. Specific pilot projects and case studies, and the dissemination of information on them, are urgently required. The problems are particularly acute because infotechnology is the prime example of a systems technology that only works effectively when many interacting components, people and hardware are brought into a harmonious relationship. Mechanical solutions to poorly understood problems must be avoided. Education and training should have the highest priority, and an effective informatics policy should be people-oriented—one that seeks to improve existing skills rather than to replace them.

The question of whether fundamentally new insights are still required for the promotion of self-reliance remains. The concept of an organizing principle, which Dedijer (in [1], p. 332) calls social intelligence, must surely be pointing in the right direction.

II. The technology and its impact

The technology

Infotechnology, as the technical support for human thinking and communication, has been evolving over thousands of years. New developments have been rapid over the last few decades, and it is important to be aware that the technology is still in a phase of very rapid change and development.

Information

Thinking and communication is information. Throughout the ages, the representation of information has been a basic human requirement, and various means have been used, along with devices for storing, transmitting and processing information and interfacing with users. Early examples of the technology are Stonehenge, the abacus, the printing press, Jacquard's loom and the mechanical calculating machines of Pascal and Leibniz.* The twentieth century then saw the development of the electronic computer.

The systems used to represent information in all these developments can be classified as either analogue or digital. In an analogue device, information is stored and transmitted in a form that has a direct correspondence to the form of the original information but in a different medium. The thermometer, slide-rule and the traditional gramophone record are examples. In a digital device, the information is coded, and the coded form bears no relation to the original. Any coding system can be reduced to a sequence of two symbols which can then be made to stand for anything and its opposite, such as "yes" and "no", the digits "1" and "0", "on" and "off" etc. These basic units are referred to as "bits" (binary digits). Examples of digital devices are the Morse code, the pocket calculator and the compact disc for the digital recording of music.

Logical processing

The system of coding using bits is known as the binary system. In the nineteenth century the Irish logician, George Boole, showed how to develop a symbolic logic, using the binary system, so that logical reasoning could be reduced to a calculus. In 1937, electrical switching circuits that embodied Boole's principles were developed—a significant advance in infotechnology, since it enabled the logical processing of information to be automated. The switching elements in the circuits are called logic gates. Logical functions embodied in the circuitry may be very complex, requiring thousands of such logic gates.

Integrated circuits (IC)

Initially, switching circuits were constructed using electromechanical components. Then, in the 1940s, thermionic valves were incorporated in logic gates. This led to the development of the first electronic computers.

These computers were huge and costly, and developments were slow until the first solid-state electronic switching device, the transistor, made from materials known as semiconductors, was developed at the beginning of the 1950s. This invention quickly led to the development of integrated circuits (IC) and the microprocessor.

The transistor was a discrete device, but a fabrication technology was developed whereby it became possible to combine a number of components in a single integrated circuit etched on a wafer of semiconductor material—silicon—as a substrate, using techniques of photolithography. By 1963, up to eight separate components were being integrated on a single "chip" of silicon. By 1970, the figure had risen to 2,000, and at present manufacturers are producing integrated circuits with a million components on a chip less than half a centimetre square.

Large-scale integration (LSI)

The fabrication of integrated circuits is known as large-scale integration (LSI) and is the culmination of the drive towards miniaturization. The goal of LSI has been to reduce the cost of devices through mass production of many circuits at a time and to reduce the elements and interconnections to the smallest possible size. The technology is generally referred to as semiconductor technology. The fabrication process is complex and

*For a historical survey see B. V. Bowden, *Faster than Thought* (London, Pitman, 1953).

demands extremely expensive and sophisticated equipment, which must be operated under carefully controlled conditions in an absolutely dust-free environment. In order to compete on the market, large quantities must be manufactured, and initial costs must be spread over a wide market.

The initial stages of the manufacturing process, namely the design and layout of the circuit, are still highly skilled, manual operations that may take several years for a complex circuit. Until recently the end stage, the final packaging, was labour-intensive, which led many manufacturers to locate operations in countries where labour was cheaper. Improved packaging technology is, however, highly automated, resulting in a recent trend towards repatriation.

The principle of the computer

The concept of the programmable universal computer goes back to the nineteenth century English inventor and mathematician, Charles Babbage, but its full realization had to wait for the invention of electronic switching circuitry and the vital concept of the stored program, put forth by Van Neumann in 1946. The stored program concept provided an evolutionary jump in the development of the computer, endowing it with its modern flexibility and the capability of performing tasks that are associated with "intelligence".

The computer is a device for automatically processing information. That it only performs calculations is a misconception: numbers are themselves coded information, and calculations are only one particular kind of information processing. Instructions can be stored in the computer in the same way as other data, which enables a computer to process its own instructions and modify them just as it processes the data that are the subject of the instructions. Instructions and data are put on the same footing as bits of information. The consequences have been far-reaching.

The basic elements in the design of a computer are:

(a) *Program.* Instructions specifying the operations to be carried out;

(b) *Input devices.* Keyboards, magnetic tape readers, light pens and sensors, with which the program and information on which it is to work can be fed into the machine;

(c) *Memory devices.* Receive and store the information;

(d) *Central processing unit (CPU).* Carries out the instructions;

(e) *Output devices.* Printers, TV screens and actuators to pass on the results to where they are required.

Memory devices

Devices for storing information are classified as primary or secondary storage devices. Primary memory devices are LSI devices, i.e. memory chips, which are regarded as an integral part of the computer. Secondary devices are external components consisting of magnetic discs, of either the rigid or "floppy" types, and magnetic tapes.

To date, primary memory has been more limited in capacity than secondary, but its advantage is that the time required to access information is faster, being a fraction of a millionth of a second. Primary memory is thus used for holding information that requires fast access or frequent access and in particular for holding instructions currently being executed.

Memory chips may be read-only memory (ROM), containing information that may not be altered and cannot be erased. Random-access memory (RAM) contains information that may be overwritten. Other types of devices are programmable read-only memory (PROM), which can be programmed only once by the user, and erasable programmable read-only memory (EPROM), which can be rewritten and modified by the user at will.

RAM chips with a capacity of 64,000 bits of information are common but chips with a capacity of 128,000 are now commercially available.

Secondary memory systems provide virtually unlimited capacity but with slower access times. While magnetic-based systems are currently in use, other systems are being developed that will be compact, faster and cheaper. These include magnetic bubble memories with no moving parts and laser-based optical systems. Such developments will provide even brief-case computers with virtually unlimited memory and increase their capabilities enormously.

Microprocessor, microcomputer and mainframe computer

A microprocessor is a single LSI chip but having the function of a CPU. Limitations of a chip size mean that to date, microprocessors have only a single structure and a shorter word length than is customary in CPUs that use the older discrete circuitry.

A microcomputer is a complete processing system that includes a CPU, memory and input/output units.

Microprocessors and microcomputers are rated by the word lengths they employ. The 8-bit word length is common, but 16 bits and also 32 bits are now available. An 8-bit microcomputer can process only 2^8 = 256 bits of information in one instruction cycle. A 16-bit microcomputer is much more powerful; it can handle 2^{16} = 65.536 bits in the same time. On the other hand, it requires a correspondingly greater number of components per chip.

The mainframe computer has typically a word length of 32 bits. It still depends on discrete circuitry and is still necessary for applications requiring large-scale information processing or calculations. Increasingly, LSI technology is being used, where possible, to enhance capacity and reduce energy requirements. The technological race to make faster mainframe computers is still on, and it is to be expected that the demand for large computers will keep pace with the demand for the mini- and micro computers for the rest of the decade.

Communications

Revolutionary developments in communications technologies have resulted in telecommunications services that rely on equipment that simply did not exist 30 years ago: satellites, microwave, microprocessors and optical fibres. It was the introduction of the digital mode of transmission of information into telecommunications that has brought about the convergence in infotechnology of all the information-handling technologies of communications, computers and control and has facilitated the development of an integrated informatics infrastructure in a wide range of industrial sectors.

Communications technologies are of three basic types: transmission, switching and terminal. Transmission technology is concerned with the means of transmitting the signals over distance; switching technology is concerned with the mechanisms of exchanges for connecting users; and terminal technology is concerned with the user devices for initiating and receiving signals.

Technological advances in transmission have increased the options for transmission media while increasing the efficiency of each medium. Copper coaxial cable is the traditional medium of transmission. Improvements in cable technology have increased transmission quality and voice circuit capacity, and transmission costs per voice circuit mile have steadily fallen. In the 1940s microwave radio transmission was developed. This increased the options since coaxial cable cannot be laid in uneven terrain. On the other hand, microwave must travel on a line-of-sight path and relay towers, spaced at around 40 kilometers, are needed to boost the signals. The towers require maintenance.

Optical fibre cable is a third recently developed transmission medium, which is still in the initial phases. The cable consists of glass thread about the thickness of a human hair carrying concentrated beams of light. Two kinds of devises are used to generate the light, the light-emitting diode (LED) and the laser. LED are generally used for lower transmission volumes and lasers are required for high-speed transmission. Basic advantages over copper wire are that the material of the fibre, silica, is cheaper and more available than copper and the fibres have a much greater transmission capacity. Other advantages are that: they are more resistant to corrosion and require fewer signal boosters on long routes; they are also immune to electrical interference and are therefore much more reliable in environments where high currents may be passing; and they provide higher security against unwarranted tapping.

Rapid progress in optical fibre technology, combined with steep declines in costs, are expected to result in a large increase in the use and also in the range of fibre optic applications, for long-haul transmission and for distributing a broad range of communications signals, in addition to the traditional telephone, to the home: data, facsimile, voice and image.

Satellite communications are a special application of microwave systems. The microwave signal is reflected off a satellite stationed at an elevation of 22,300 miles (35.680 km) in geosynchronous orbit. The development of satellite communications has dramatically increased transmission capabilities, since the difficulties encountered in constructing cable or microwave networks are eliminated, and the distance has no effect on costs. Many countries now operate communications satellites with communications links to associated ground stations. The International Telecommunications Satellite Organization (INTELSAT)* provides a service designed for global use. Its first satellite (Early Bird) was launched in 1965. It weighed 39 kg and supported a band width of 50 MHz and 240 two-way telephone circuits. INTELSAT V (1980) weighs 1,000 kg and supports a band width of 2,300 MHz and 12,500 two-way telephone circuits.

Satellite communications have the potential to greatly increase global signal-carrying capacity for global TV transmission, person-to-person communications, electronic mail and all the other broad-band services. The main drawbacks at present are the high costs of construction and launching, but launching costs are declining with

*INTELSAT is an international organization comprised of over 100 countries that are parties to a treaty-like agreement.

the entry into operation of such launchers as the Space Shuttle and Ariane. At present satellite communications account for only a small proportion of global communications; although their use will be greatly extended, they are not expected to be a complete substitute for terrestial networks owing to constraints on "parking spaces" for geostationary orbits and the availability of radio frequencies.

Switching technology developed rapidly in the 1960s with the application of computer control to replace wired logic circuits. Early models using computer control were still partly electromechanical for the alignment of the circuits. Fully electronic switching, operating in a digital rather than analogue mode, became operational in 1970. The digital mode has significant advantages because it is compatible with integrated circuits and microprocessors and complements the developments in transmission media. All information—whether voice, video or data—is represented by a series of bits, so that the way it is switched or transmitted is independent of the original format. Through the digital mode, the merging of speech and data along the same cable, utilizing natural breaks in speech, became possible, as did packet switching to route traffic optimally through a network, resulting in cheaper and faster service. The digital mode also improves the quality of transmission.

Terminal equipment technology is in a stage of rapid development, especially with regard to increasing the speed, quality and reliability of equipment for image and text communications. This has led both to substantial improvements in the traditional business and private communications equipment and also to the development of completely new types of terminal equipment, including the following.

Data terminals. For direct communications between computers, or between terminals in one location and computers in another, data terminals have developed from the basic teleprinter of the 1960s. There are many types of terminals, to meet a range of requirements: high-speed terminals, lightweight portable terminals for field communications, text editing and video display terminals with graphic capabilities for scientific applications etc.

Facsimile machines. Such machines have been available since the 1930s for reproducing an image transmission, but technological advances have reduced the time required to transmit a 21 × 30 cm page to less than 30 seconds.

Communicating word processors. These connect machines capable of storing, retrieving and editing text.

Teletex. An updated version of the traditional telex service, teletext refers to work-stations (intelligent terminals) capable of exchanging letters.

Telewriting (Hiltz and Turoff, in [2]). A graphic tablet, light pen, keyboard and screen enables handwriting to be transmitted and reproduced. Applications include conferences, teaching etc.

Videotex (Ide, in [3]). Videotext systems provide consumer access to and retrieval of information in computerized data bases. The information available is of a business or social nature, identical to that normally distributed through newspapers, magazines and books, but the system provides selectivity in retrieval. Adapted television receivers display the information. Interactive functions may be included such as library services, teleshopping, computer-aided learning etc. Videotex was originally developed in the United Kingdom of Great Britain and Northern Ireland and rapidly attracted world-wide attention.

Teleconferencing (Dagnelie, in [2]). Through teleconferencing, people who are geographically remote can hold conversations. It would also be possible for them to see each other live on TV screens. This could be a significant development for business communications, particularly between branches of large-scale, geographically decentralized organizations.

Software

The physical components of computers and other equipment are often referred to as hardware. Software is a generic term for the sets of programs that control the functioning of any complex information system.

A computer has a set of operational functions engineered into its logical design. A program is a planned procedure for solving a problem or carrying out a task and consists of a list of instructions which, when read into the computer and stored, determine precisely the sequence of functions performed and the data on which they are performed. Instructions to the computer are sequences of bits and may be processed and modified by the computer's logical functions in precisely the same way as other data. As mentioned above, the stored program concept has opened the way to many developments, including what is referred to as "artificial intelligence".

Programs operate at different levels. At the highest level are the applications programs, which carry out a particular task such as payroll, accounting etc. The instructions of such a program will be coded according to a set of conventions that are helpful to the individual constructing the program. These conventions constitute the "language" of the program. Various languages have been developed, such as BASIC, COBOL and PASCAL, which resemble written language.

At the intermediate level the coded instructions are first operated upon by another program and translated into the language the computer understands. Programs that have the task of operating upon other programs in this way are called compiler or assembly programs and are generally supplied with the computer.

At the lowest level are the programs of the operating system, supplied by the manufacturer (for example Unix, a multi-user time-sharing system, or a control program for microcomputers (CP/M)). The operating system acts as general manager and ensures that all instructions and data arrive at the right place, at the right time and in the correct order.

More advanced computer languages will lead to greater efficiency in both writing and executing programs. Programming remains skill-intensive and defies mass-production methods. Computer architectures and languages are interdependent, developments in one area stimulating developments in the other. Thus, since most computers are sequential, most languages are also sequential, but much effort is now going into the development of so-called declarative languages which provide for parallel rather than sequential processing and have much greater power than conventional languages.

Special-purpose software is now required, not only in the conventional general-purpose computer but as an integral part of an increasing number of products, telecommunications switching gear, satellites, space vehicles etc.

The industry

The informatics industry includes hardware, software, electronic components and telecommunications equipment. These are discussed below.

Hardware

The hardware industry is characterized by rapid technological development and requires large R and D expenditures. An ever increasing number of phases of the production process are being automated: design (computer-aided design); assembly (robot use); testing (computerized) [4].

Hardware products must be competitive in world market terms because a high volume of sales must be achieved to finance the high levels of investment necessary. Manufacturers of core hardware and, to a lesser extent, manufacturers of peripheral hardware have been concentrated in a small number of highly industrialized countries. However, recent developments in microelectronics technology, culminating in the microprocessor, gave rise to the semiconductor industry and have enabled enterprises to enter into the production of hardware at a number of different levels. This means that more countries will be able to become hardware producers. Another effect of the new microelectronic technology is that the boundaries between the hardware sector proper and other sectors, where microprocessors are incorporated into products and capital equipment, will tend to become blurred [5].

*Software**

Partly because of rapid developments in hardware and also because the creation of software is highly labour-intensive, there is a worldwide lack of software. The development of "firmware"—fixed programs built into the computer at time of manufacture—has not, as was hoped, overcome this problem, nor has the encouragement of the use of high-level languages. The fact that software is not compatible with all types of hardware has contributed to the shortage of software.

The basic requisite for setting up a software industry is the availability of appropriately skilled manpower; large capital investments in plant and machinery are not required. It is likely that, in the future, less emphasis will be placed on general-purpose software and more attention will be given to specialized software that would be developed for particular applications [7]. This should encourage more countries to establish software industries.

Electronic components

The electronics components industry experienced spectacular growth following the Second World War (Braun, in [6]). The industry, now dominated by the semiconductor industry, originated in the United States of America. The largest and the most developed semiconductor industry is still in the United States, although France, the Federal Republic of Germany, Japan and the United Kingdom have developed their own semiconductor industries.

*The Directorate of Science, Technology and Industry of the Organisation of Economic Co-operation and Development (OECD) plans to publish a report on the software industry during 1984.

Licensing arrangements are often made because large customers generally need a second source of supply, and this contributes to the flow of information within the industry. The original character of the industry, with its diversity and many new ventures, is being replaced by a consolidated, mature industry of a few large, advanced firms surrounded by some satellite ancillary suppliers.

Telecommunications equipment

Advances in technology have stimulated rapid developments and change in the telecommunications equipment industry. This industry is concerned with three basic types of equipment: terminal equipment (e.g. a telephone set); transmission equipment (e.g. coaxial cable, microwave radio or communications satellites); and switching equipment to link the terminals as required. As a rough estimate, telecommunications equipment accounts for approximately 30 per cent of the output of electronics-based goods. The OECD countries account for the bulk of world production of telecommunications equipment. A small number of firms, most of which are transnational, accounts for the vast majority of world sales. The largest geographical markets for the equipment are North America and the industrialized countries of Europe. The geographical concentration of world production and sales reflects the international distribution of telecommunications infrastructure.

Since 1945, the industrial structure of the telecommunications equipment sector has been relatively static, with a near monopsony, or situation in which a single buyer dominates the market, being balanced by a stable supply oligopoly. Recently, the structure has begun to change under the impact of advances in technology [7].

Microprocessors

Semiconductor technology has an impact on virtually every sphere—home, office, factory, schools, hospitals, transport. Except in a number of specialized cases (see the section on defence, below), applications do not rely heavily on further technological developments for speed, size or reliability. The rate of development is not, by and large, constrained by the currently available technology but by economic and social factors and by the imagination of the potential innovators.

When looking at the applications of the technology in end-products, it is useful to distinguish between improvements in existing products and new products. In existing products, semiconductor technology is used to replace the older electrical circuitry or electromechanical technology, resulting in more flexible, "smarter" products with enhanced performance but having essentially the same functions as the older products and satisfying the same market. But the advent of semiconductor and associated technologies has also created the possibility of developing entirely new end-products, with new capabilities and for a new market.

Existing products

The clock and watch industry is a good illustration of an industry in which the rate of penetration of the new technology was extremely rapid, to the extent that most of the end-products now incorporate the new technology. Another example is the automobile industry, where a variety of microelectronic devices are being incorporated into vehicles for driver support and for control and monitoring purposes.

Other examples are domestic appliances such as washing machines; office appliances such as photocopiers and word processors; industrial instrumentation where electronic gauges, meters and displays have widely replaced their mechanical or electromechanical equivalents; and weapons systems such as ballistic missiles.

New products

The pocket calculator is often cited as the typical example of a new product made possible by semicond[illegible] technology (Clayson, in [1], p. 392). Altho[illegible] [illegible]chanical, electromechanical and electronic [illegible] calculators have been in existence for many years, the small size, flexibility and ease of use of the pocket calculator opens up a new market and an entirely new range of applications.

An example of a new product that, unlike the pocket calculator, has no predecessor is the plastic bank card that incorporates a microcomputer (Cremin, [1], p. 366). As pointed out below in the section on the electronic transfer of funds, the implications for the banking industry are enormous.

Other examples of new products are video games, home computers, "intelligent" paramedical products and devices used in health care delivery and to support the physically handicapped and communications satellites.

Innumerable useful products and processes are still waiting to be discovered. The pace of implementation is slow, and, in addition to the economic, social and infrastructural factors involved, there is a basic problem of two-way communications between the potential end-users and the manufacturers and component makers. Cremin (in [1], p. 366) discusses this issue in the context of the banking industry.

The number of products that could be developed incorporating the new technology is virtually infinite; such products are feasible in all situations [8]:

- Where a sequence of repetitive actions has to be carried out
- Where information has to be stored and retrieved
- Where monitoring, comparison or reaction to situations is required
- Where speed of response is important
- Where the environment is hostile to or uncomfortable for human operators
- Where sensors can provide feedback information and actuators can be triggered in response
- Where reliability, cheapness and small size are important

The impact of the technology on research and development

R and D is the traditional application of computers, which were invented to do the large-scale data-processing applications of scientific research. Infotechnology now constitutes a critical tool at the leading edge of the expansion of knowledge in every field and has an impact on R and D in a number of other fundamental aspects in addition to the original application of computation [5]. These include interactive computing in which the researcher can experiment in real time with theoretical formulations, the use of interactive visual terminals in design applications to explore alternatives, the use of graphics terminals, large-scale modelling and simulation applications and the use of data bases and computer networks for dissemination of new knowledge.

Industrial automation*

The number of applications for computers in the manufacturing industry increased greatly in the 1960s. The applications may be divided into on-line and off-line applications. An on-line application is one in which the computer is directly linked to the manufacturing operation. It processes state information to function as either *(a)* a control system or *(b)* a monitoring system. The monitoring function may also be a by-product of the control system. Its purpose is to register and report production data in order to provide management with current information for decision-making. Off-line applications are those in which the computer operates independently of the manufacturing system and processes pertinent textual information.

Control systems

Microelectronics-based control systems are used in industry for the direct control of manufacturing operations, such as: movement of materials, components and products; control of temperature, pressure and humidity; shaping, cutting, mixing and moulding of materials; assembly of components into sub-assemblies and finished products; and control of quality by inspection, testing and analysis. In each case the state of the manufacturing process variable is translated, by means of a sensor device, into an input signal. This information is processed and transformed into an output signal which may then be processed to determine, for example, a mechanical movement or adjust a temperature electrically by means of an appropriate actuator.

In certain applications the system may be programmed to achieve optimum operational conditions through the simultaneous control of a large number of variables; such programming is used in the petroleum and petrochemical industry, for example.

Process industries

The earliest applications of control systems were in the process industries—those industries that convert raw materials and energy into products such as chemicals, petroleum, metals, pulp and paper, food, cement, textiles and electric power. Instruments monitor process variables such as the flow rate, temperature, pressure, chemical composition and liquid level. A typical plant, such as one for manufacture of ethylene or ammonia, will have several hundred control values and more than a thousand measured variables. Changes are made in the operation of the process on a time scale ranging from a few seconds to a few hours (Evans, in [6]).

Manufacturing industries

In the manufacturing industries (automobiles, appliances, spare parts etc.), in contrast to

*For a detailed survey of how manufacturing industry's efficiency and productivity is and can be improved through the use of microelectronics, see Owen [9].

the processing industries, the geometries of the raw materials are manipulated so that discrete parts are assembled to form products. The methods of measurement and control are basically different from those used in the process industries, and the problems of automation are more complex, but highly automated plants are now in operation in Japan, the United States and Europe. These plants produce automobiles, engines, earth-movers, oil-well equipment, elevators, electrical products and mechanic tools.

One of the most significant early applications of automation in manufacturing was the introduction, in the 1950s, of numerically controlled (NC) machine tools. Coded numerical instructions controlled the fixed sequence of machine operations. Later, hard-wired conventional control was replaced by a minicomputer programmed to perform the control functions: this was called computer numerical control of machines (CNC). Other developments include the adaptive control (AC) of machine tools, in which the computer is used to measure, for example, cutting forces and speeds and to control the axis motion and spindle speed accordingly so as to maintain the optimal metal renewal rate, and direct numerical control (DNC) of machine tools, in which a general-purpose computer is connected directly to a number of NC machines [15].

Industrial robots

The concept of a control system leads on naturally to the concept of a universal machine that has the flexibility to perform a variety of tasks—the industrial robot.

Industrial robots are commonly defined* s manipulators that have a high degree of freedom and that perform versatile movement functions. The industrial robot involves an approach to automation that differs from the traditional approach: in the past technology was designed to perform a task in a manner that was not necessarily similar to that used by humans. By contrast, a "robotic approach" to automation follows human performance much more closely, since it reflects a move away from "purpose-built" machines towards universality (Zermeno, Moseley and Braun, in [6]). This has its advantages and disadvantages, and the economics of robotics must be carefully considered. The availability of highly developed off-the-shelf robots will facilitate the introduction of automation, but such robots would tend to be more expensive than purpose-built automatic devices when used for simple, common jobs. On the other hand, with a large enough market for robots, the design and development costs can be spread.

Development of industrial robots, which commenced in the late 1960s, has been given a considerable boost by the capacity and flexibility of microprocessors, and rapid progress has been achieved, which resulted in the practical application of industrial robots in the first half of the 1970s. It is estimated that there were 8,000 robots in use world-wide in 1978 [10], the most common applications being in coating, welding, pressing and injection moulding, particularly in the domestic appliances and automobile industries. JIRA, established in 1971, predicts that industrial robots will come into general use in the industrialized countries in the 1980s.

Manufacturing design and production

Manufacturing design and production systems are concerned with the off-line processing of textual or diagrammatic information pertinent to manufacturing design and production planning and control. They include:

Computer-aided design (CAD)

Requirements planning

Capacity planning

Scheduling

Purchase control, including replacement of raw materials, stock control and purchase order control

Production and assembly control, including materials control, load control, inventory control, tool control, job control and dispatching

Such applications are usually the result of replacing manual procedures with computer-controlled procedures; they permit the optimization and simulation of plans at a speed that would be impossible to achieve using manual methods.

Computer integrated manufacture

Industrial applications of informatics have inevitably taken place in a piecemeal fashion. Particular problems have been solved, but the contribution of the computer has often been less than that forecast. It has become apparent that it is not enough to superimpose computer technology onto traditional manufacturing systems and that a total systems approach would be desirable.

The name computer-integrated manufacture (CIM) has been given to such a total technology.

*Crossley (in [1], p. 351) gives the classification and definitions of industrial robots that were approved by the Technology Standardisations Committee of the Japanese Industrial Robot Association (JIRA) in 1974.

The technology will integrate all aspects of manufacturing activity from initial design to warehousing, sales and service; all stages are controlled by individual modules of computer software linked together in a hierarchical system. It is expected that CIM will make substantive software development necessary and will be evolved over a fairly long period of time.

Office automation

Curnow [5] estimates that, in the long term, office automation will be the main growth area for infotechnology and will have a radical impact on the efficiency of information flow within a company. All office procedures can be co-ordinated and rationalized and all transactions can be continuously monitored by applying the appropriate infotechnology. This will result in the so-called "integrated office" [11], and some of the components of the integrated office are quite advanced in the industrialized countries. Data-processing and word-processing applications are common. Other applications, such as image processing and audio processing, are at a relatively early stage of development.

Image processing enables complex data to be represented in visual forms. Products such as facsimile machines, display graphics etc. fall within the scope of image processing. This technology can play an important role in improving office productivity. Audio processing refers to electronic input and output mechanisms in the form of direct speech. Important developments are expected in the longer term in the area of electronic voice recognition [5] which will clearly affect office management in fundamental ways.

Word processors, based on the more traditional data-processing technology, consist of video display screens with keyboards, central processing units with internal and external memory and printers (Boddy and Buchanan, in [11]). Word processors have the following capabilities: information capture, information storage, information manipulation, information distribution and electronic control of typing and printing. Word-processing greatly improves typing productivity (Lamborghini, in [3]). Interconnections between word-processing stations, through telecommunications systems, will stimulate developments in the area of electronic mail. The optimum benefit of word processors will not be realized until full use is made of the potential for interconnections and access to central filing systems etc. to provide integrated filing, cataloguing and dissemination of information, both within and outside the office, is made available.

Computer-based corporate systems that are not related to any particular industry are now being widely used, for example in financial planning, wages and salaries and pensions systems The development of software for such applications has taken many years.

The electronic transfer of funds

Infotechnology is expected to have a great impact on the banking industry. At present, the industry faces a basic structural problem of uneconomic products and disproportionately high staff and premises costs, which is ample incentive to change from operations involving the movement of pieces of paper to electronic transfers and chequeless banking.

The term electronic funds transfer (EFT) covers all transactions using on-line computers that directly debit or credit accounts between banks or branches or between customers and branches or that transferring the cost of the purchases from the customer's to the store's account (point-of-sale transactions) [12]. Perhaps even more significant for the future of banking will be the development of personal plastic cards with an embedded low-cost microcomputer, for use as an electronic wallet, permitting value to be passed from card to card without bank intervention. Such cards are envisaged as personal, cheap, portable and powerful instruments of payment (Cremin, in [1]).

The change over from manual transfers to EFT requires reorganization, and few of the parties involved (State, banks, insurance companies) are ready for such reorganization.* However, there is a trend towards EFT [13] and fundamental changes in the financial structure of banking will occur, from the present labour-intensive service industry with high staff and premises costs to a decentralized, self-service, capital-intensive industry with very low premises and staff costs.

Decision support systems

In the industrialized countries the use of computer-based management information systems has become widespread in enterprises.

The management of an organization occurs at three functional levels: operational, tactical and strategic. The operational level involves routine day-to-day operations, the tactical level the con-

*For a detailed discussion of the issues raised by EFT, see *Communications of the ACM*, vol. 22, No. 12 (December 1979).

trol and evaluation of these operations and the strategic level long-term planning. In the industrialized countries, management information systems (MIS) have evolved through these three levels over a period of 30 years.

The first two levels contribute to the productivity of the organization. The third level contributes to its survival and growth: the contrasting concepts are "social efficiency" [4] and "social intelligence" (Dedijer, in [1]). While social efficiency is a product of a good management infrastructure that makes it possible to assess and process routine information cost-effectively, the building of social intelligence capabilities is still being debated on a world-wide scale.

In the industrialized countries, MIS have been used without difficulty at the operational and tactical levels for some time [14]. This is because people with the requisite experience and administrative skills became available to develop good operating procedures, and experience gained at the operational level contributed to development at the tactical level (Jorssen, in [15]). At the same time, hardware and software infrastructures were developing. Strategic level MIS pose deeper problems, and only recently has there been a move from the tactical level MIS to the strategic level MIS, or decision support systems [16], which provide a basis for building up social intelligence.

Government information systems

At the national level, the governmental decision-making processes must be able to react to the environment at the speed at which changes in the environment occur. The feedback process has to be well instrumented, and since the amount of information in the feedback process is so vast, infotechnology should play an essential role in the systematic capture of information and its organization, transmission and availability at the right time at all decision-making levels.

Infotechnology has been widely applied to administrative systems in government. Typical applications have involved high-volume transaction processing such as benefits payments (e.g., social security), tax collection, population census, trade statistics and accounting. Computers are also being used in the public administration area for planning, decision-support [16] and information retrieval [5]. The potential for office automation in this area is being recognized increasingly. Infotechnology offers wide scope for efficiency, for conservation of resources and for enhancing decision-making capability and organization structure in government services. In support of this view, Friedrichs (in [3]) indicates that about 75 per cent of the jobs in public administration can be formalized and 38 per cent can be automated. The increasing pressures on public finance will be an impetus to adopt infotechnology in this sector in the industrialized countries.

Defence and aerospace

Military applications of infotechnology have a basic significance (Rahman, in [1], p. 435); indeed, some of the earliest computers were used for military applications and the semiconductor industry had its origins in the United States principally in the defence and aerospace sectors. The demands of these sectors for devices with high performance and reliability led to the emergence of the silicon transistor and later to integrated circuits (Mackintosh, in [6]). Guidance and control for modern weapons, as well as military communications, command and intelligence, are highly dependent on advanced technology.

Factors that affect the diffusion of informatics in industry

Even in the industrialized countries the diffusion of informatics will be gradual, for a number of reasons:

- Large capital investment in existing plants
- Shortage of investment capital
- Industrial relations problems
- Shortage of skilled personnel
- Availability and cost of sensors and actuators
- Technological constraints

The motivation for informatic innovations is primarily economic, and the factors involved include:

- Saving of labour
- Saving of energy
- Saving of materials
- Improved production control
- Improved process and quality control
- Increased flexibility in products
- Improved products
- Improved stock holding
- Improved pollution controls
- Reduced need for labour in hostile environments

Costs

The costs of infotechnology have declined rapidly owing to the substitution of microelectronic components for discrete components. From 1973 to 1982, for instance, the cost per bit of computer memory for successive generations of RAM chips has been declining at an annual rate of 40 per cent (Noyce, in [6]). In addition to the decline in the price of the components themselves, less labour and materials are required for interconnections, less intermediate testing is required and components are cheaper to operate and maintain. Electromechanical devices have not experienced the same decline in price as electronic devices, and therefore peripherals, including sensors and actuators, are in many cases still quite expensive. This is reflected in the present overall low level of industrial automation. While telecommunications prices do not appear to have fallen as rapidly as other electronic-based products, the available data on price trends suggest that equipment prices have increased considerably less rapidly than prices for all manufacturing. Thanks to improvements in transmission and switching technologies, communication costs per circuit mile are steadily declining [7].

Impact on society

Many articles and books have appeared recently on the impact of infotechnology on society. Three views can be distinguished: the micro-sectoral, the macro-sectoral and the structural views [17].

The micro-sectoral view of the impact of infotechnology on society that is prevalent in North America emphasizes the role of telecommunications. By creating global information systems coupled with local decision-making, the trend towards urbanization can be reversed, and a fundamental change in society could occur.

The macro-sectoral view, which is prevalent in most of Western Europe and in parts of the United States, moves away from communications to the more general concept of information. Porat [18] found that over 50 per cent of the United States labour force was engaged in information activities and that these activities constituted 45 per cent of the gross national product (GNP). Similar results were subsequently obtained for other OECD countries. The inference is that the world is moving towards a global information society.

A wider view still, the structural view, which is prevalent in Japan and France, focuses on the changes in "process" arising from the application of infotechnology, including changes that are due to robotics, office automation etc. Changes in process have the potential to affect every aspect of economic activity and life style.

Bell (in [6]) has discussed what he calls the post-industrial society, the characteristics of which are: a change from a goods-producing to a services society; a shift in the nature of research from primary interest in products to primary interest in the properties of materials; and the emergence of a new intellectual technology as a key tool for managing complex organizations. Infotechnology is clearly basic to the post-industrial society.

III. The effect of informatics on productivity and employment

The use of infotechnology has led to significant reductions in labour requirements and increased productivity in the industrialized countries. Examples of applications of infotechnology are the cash register and telecommunications industries.

Narasimhan (in [1]) points out that technology plays two roles in an economy: an extensive role and an intensive role. In its extensive role, technology enlarges the sphere of industrial activity, creating new processes and products and thus new jobs. In its intensive role, it increases productivity and tends to reduce jobs (existing or potential). From the long-term point of view, both roles should be considered positive and desirable.

At the macro level, the effects on total employment of infotechnology are not straightforward. While technology is an important factor, the level and structure of employment is also a function of business cycles, economic policy, the economic system, demographic factors, the degree of resistance of workers to change, income distribution etc. It is difficult to separate these effects.

Infotechnology, by facilitating the production of new equipment and products and the development and improvement of services, creates employment opportunities at the manufacturing level and at the end-user level. However, the potential for employment in manufacturing may be small in the developing countries that import most manufacturing equipment, and the increased capital requirements may cause a greater concentration of industrial production in the developed countries. The employment that can be created through the indigenous production of informatic products (components, computers, word processors, software etc.) requires special consideration (see chapter V). The direct use of informatics equipment, such as computers, is likely to affect only a small part of the labour force (Rada, in [1], p. 199).

From a national point of view, the use of infotechnology should be influenced by a number of considerations, for instance: the survival and reasonable growth of the firm through the production of competitively priced, high-quality goods; the employment of as many people as possible at socially acceptable wages; the improvement of working conditions; and an appropriate distribution of skills. To focus on a single consideration, such as the possible short-term adverse employment impact, may result in a distorted view.

To the extent that increases in production compensate for increases in efficiency and productivity, the application of infotechnology to industrial processes will proceed at an equal pace with an increase in employment. Of course, for given production levels, it may result in a reduced demand for labour. The question of whether production should be increased in step with increases in efficiency depends on whether a market can be found for the increased production.

The application of infotechnology in a particular firm or sector of the economy has, through linkage, implications for employment in other sectors of the economy (Stoneman, in [1], p. 262). Lower quality-adjusted prices should result. The consequential increases in demand should stimulate employment. If, however, a country does not take up the new technology as fast as other countries, it may have to rely on imports to meet the demand for consumer goods.

Changes in the global distribution of purchasing power as a result of increases in the price of energy and also as a result of wider access to technological know-how by newly industrialized and developing countries have radically altered world-wide patterns of demand. A factor that contributes to a narrowing of developing countries' options is the technological push of the developed countries and the consequential erosion of comparative advantages. Developing countries, therefore, being particularly dependent on foreign trade for economic growth, must orient productive capacity towards products and processes consistent with those changes in demand. Efficiency must be maximized in all sectors, and the role of product development assumes major importance.

A major difficulty is that some countries wish to maintain a surplus in the balance of trade.

Therefore countries that incur large deficits in their balance of trade become highly dependent on foreign loans and investments and the uncertainties that these entail. The result is that demand in all countries becomes weaker than it otherwise might be, and this adversely affects employment levels.

Many developing countries are fundamentally different in terms of supply of labour, capital, skills, foreign exchange, unemployment levels etc., as well as in terms of their political economic systems. These and other factors such as the size of individual markets, the extent of foreign control, including the degree of integration with local suppliers of intermediate capital goods etc. and the level of indigenous technological capability make it difficult to assess the impact of infotechnology on employment and productivity for the third world as a whole ([1], sect. 8, p. 430). Furthermore, many developing countries have dual economies, i.e. rural and urban sectors that are almost completely separate from each other. Historical circumstances and geographical position are also relevant, as well as the existing degree of specialization, which affects the ease with which infotechnology can be incorporated into production processes.

Factors in adopting infotechnology

There is really no choice as to whether or not to adopt infotechnology (Kuale, in [1], p. 222). Developing countries can only survive in the world market if they follow the lead of the developed countries and incorporate the new infotechnology into their products. One reason for this is that the economic system that prevails over large parts of the world today is characterized by a decentralized decision-making structure. The fact that both income and survival are closely tied to the actions taken by a company provides an incentive for constantly trying to increase productivity. As already pointed out, there is world-wide economic pressure for overall efficiency improvements, radical product innovation etc., which informatics technology facilitates. Thus it is reasonable to expect that the application of this technology will continue to expand.

Appropriately applied, infotechnology can facilitate qualitative and visual improvements in products, in particular through miniaturization. Such improvements can be a powerful factor in enhancing product competitiveness.

Even the sheltered sectors of the economy will not be able to avoid introducing infotechnology, since there is also a significant amount of competition in these sectors.

The innovative process and the diffusion of technologies to developing countries

As indicated in chapter II, informatics has a wide range of applications directly linked to manufacturing, for example, production management, process control, design and control of machinery (numerically controlled machines, robotics etc.). Innovations in manufacturing—in many cases involving infotechnology-based equipment—are usually responses to weaknesses in the manufacturing system: low labour productivity; machinery breakdowns; unavailability of skills; excessive energy consumption; inadequate quality of product; unsafe working conditions etc. Capital shortages, lack of foreign exchange, skill and knowledge deficiencies will retard the speed of diffusion of informatics-based technologies, especially in developing countries. The Dublin Conference on Informatics and Industrial Development ([1], sect. 8, p. 430) identified the shortage of skills as a major barrier to the successful introduction of these technologies.

Elements in the industrial environment other than the technology itself, such as production support, level of skills, training, industrial structure, management development etc., are relevant in industrial innovation. This does not mean that technology transfer or R and D are not of importance in the industrial sector.

A firm or an economy that is not positively committed to industrial innovation will usually decline. Even though the innovative process takes place primarily within the firm, public authorities have the power to influence the process in various ways: policies for and attitudes towards foreign investments, trade and tariff policies and fiscal measures and support for R and D.

Offshore industry

Offshore facilities are usually assembly operations and in general are not highly technical. Assembly operations are now being automated. Firms with large offshore manufacturing facilities will be able to compare the costs of producing in developing countries with low labour costs to the costs of home-based production using advanced technology. Much offshore production could become less attractive owing to the effects of rising domestic wages in developing countries, tariff barriers and infotechnology-based innovations in developed countries. On the other hand, it seems probable that some industries will choose developing countries as locations for establishing industries based on the new technology.

Transfer of technology

Improvements in the level of education together with the availability of technological information could enable developing countries to produce efficiently at a competitive level and thereby maintain an acceptable level of employment. The terms under which transfers of technology to developing countries occur and also the relationships and interactions between the centres receiving this technology in developing countries and the economy of those countries are the critical factors. Developments in infotechnology will lead to a demand for labour with the appropriate skills, which requires appropriate training.

The garment industry—an example

The impact of infotechnology on employment and productivity in developing countries can be seen by taking a specific industry as an example: the garment industry is important to many developing countries in terms of employment, exports and development. The impact of infotechnology on this industry from the perspective of developing countries has been discussed by, among others, Rush and Hoffman (in [1], p. 252) and Rada (in [3]). The industry has traditionally been highly labour-intensive and very fragmented. The systems of management and organization have been at a basic level and the degree of technology used to support the production process has been limited. A variety of wearing apparel is produced, and, owing to low wage rates, developing countries have enjoyed a significant degree of comparative advantage in a number of high-volume subsectors. The infotechnology to automate many production processes in the garment industry is available, and recent advances in microelectronics, based on the microprocessor, will increase the scope and flexibility for applying infotechnology in this industry and make it more economical to implement. This will lead to changes in the skill and investment requirements of the industry. Labour costs will become a less important factor. It is important therefore that developing countries take the potential impact of infotechnology into account in the elaboration of their development strategies for the garment industry.

Structural shifts in employment

During the industrial revolution in the last century, it was feared that replacing people with machines would lead to widespread unemployment, and some labour displacement did indeed occur. However, productivity increases generated real income increases, demand expanded, and new industries and service activities were created. Overall employment rose, although its composition changed, with a shift from agriculture to industry and services.

Now, industry and services are prime candidates for the application of infotechnology. Unless there is a massive expansion of new industrial products and new services, the industrial and services sectors will not be able to absorb labour displaced by industrial and office automation. The large increase in population since the industrial revolution, as well as the present sluggishness in economic growth, reduce the prospects for absorbing displaced labour.

Rapid structural transformation between sectors provides the basis for desirable productivity and employment improvements in general but may also lead to social stress. Global changes in the pattern of demand together with developments in informatics are likely to contribute to a general failure by the labour force to recognize and positively respond to the need for such transformations. The main feature of developed countries in this area has been the reduced significance of the agricultural sector and the corresponding growth in the services sector. These structural changes have occurred as a result of low growth in demand and large increases in efficiency in agriculture, together with the reverse situation in the services sector, i.e. rapid growth in demand and sluggish increases in efficiency. If the efficiency increases in the services sector had been greater, the structural changes between the sectors would have been less. The use of the microprocessor to automate and improve the efficiency of the services sector would be an aid in reducing such rapid transformations and would also help the sector to play a catalytic role in relation to the development of organic and self-sustainable industrial development generally. The movement between sectors could then to some extent be replaced by less socially disruptive movements within the secondary sector to meet changing patterns of demand for manufactured goods.

However, if developing countries were to import entire industrial processes on a turnkey basis, islands of high technology could result, and the social and economic strains of accommodating the type of imbalances that would then be a feature of the economy would not be easy to predict.

Conclusion

The scope for applying infotechnology to increase productivity in industrial processes is large, and the potential impact of such applications on labour and skill requirements is significant. At the national level, it is difficult to separate out the employment effects of infotechnology from other determinants of employment. While the rate of diffusion of infotechnology will vary, there are compelling forces for adopting it to improve efficiency and enhance productivity so as to maintain competitiveness. It is therefore essential that appropriate provision be made for infotechnology in the elaboration of industrial development strategies.

IV. The development of informatics in developing countries

International action to promote policies and strategies

There are many obstacles and constraints to technological development in the developing countries. These include: massive illiteracy; poorly developed communications infrastructure to support information transactions; lack of financial resources; massive unemployment; scattered rural communities; rapid population growth; general lack of infrastructure; lack of organized procedures to adapt technology transferred from abroad; and lack of basic capability for decision-making and implementation in development matters.

Comparative statistics point up the problems. The third world (including China) has some three billion people—nearly three-quarters of the world's population—who earn one-fifth of the world's income and have only 10 per cent of the world's manufacturing industry. Illiteracy is typically around 50 per cent, ranging up to 80 per cent in a number of countries. The World Bank estimates that (excluding China) 800 million people are destitute and (optimistically) that the figure will still be 600 million by the year 2000.

Narasimhan (in [1]) proposes that radically innovative, unconventional solutions will have to be tried in deploying infotechnology in education to eradicate illiteracy, health care to improve the standard of living and community services to upgrade the quality of life for the geographically dispersed small communities of people in countries such as India. The magnitude of the problem renders conventional solutions infeasible.

Constraints on the diffusion of systems technologies

One fundamental constraint to the development of infotechnology in the developing countries is that it largely belongs to the category of "systems technologies". For systems technologies to be effectively implemented, a large number of interacting components to operate as a system must be co-ordinated (Barguin, in [1], p. 84). In addition to economic and technical feasibility, social and cultural feasibility must also be considered, and this may be the more constraining (Banerjee, in [1]). A systems technology can be contrasted with the successful type of technology transfer in which a discrete innovation that requires few new skills to operate, such as a pocket calculator, is introduced, and at the same time skills are mobilized towards new applications (Clayson, in [1], p. 392).

International action

Owing to the numerous obstacles and constraints, international action will be essential to assist in promoting the adoption of appropriate policies and strategies for informatics development, together with the establishment of appropriate national institutional arrangements, in individual developing countries.

Technological self-reliance

The principle of technological self-reliance for developing countries is now widely accepted as an essential prerequisite not only for the rapid acceleration of their social and economic development but also to overcome their excessive technological dependence on the industrialized countries.

Technological self-reliance is defined as the autonomous capacity to make and to implement decisions and thus to exercise choice and control over areas of partial technological dependence or over relations with other nations. The need for operational strategies in this regard is pointed up by the fact that at present research on problems directly relevant to the third world accounts for only about one per cent of the total research expenditures of the industrialized countries [19].

Self-reliance must be concerned with the long-term development of skills and resources and the independence to use them to meet national objectives (Gupta, in [1], p. 109). It should not be seen as simply a drive towards self-sufficiency in response to immediate pressures, such as a shortage of foreign exchange. The development and implementation of a strategy of technological self-reliance is a complex problem. It involves much more than the creation of national technology centres, improved access to foreign patents and know-how and the availability of capital to exploit them. Social, economic and cultural interactions play an important role, and there must be a will to communicate and co-operate at all levels [19].

An appropriate programme of indigenous research and development is an essential component of a strategy of technological self-reliance. Such a programme would not seek to duplicate the efforts of industrialized countries. To be cost-effective, it should be very selective and concentrate on a limited number of assignments most relevant to the situation in the country concerned (Deodhar, in [15]).

The role of informatics in achieving self-reliance

The use of informatics in promoting self-reliance has not yet received general recognition in international forums.

Informatics has cross-sectoral impacts. Its main concern is with the modalities of providing the right information to the right person at the right time, cost effectively; the medium of transmission can be formal and infotechnology-based or informal and word-of-mouth. The processes of information flow that support productivity are subtle and complex and not yet well understood or modelled. It is here that the deepest informatic problems reside and not in the simpler task of automating an information system on the basis of a well-structured model.

Services sector

Industrialization and economic development have always been accompanied in the developed countries by a structural shift of labour from the primary and secondary production sectors to the tertiary or services sector [18, 20, 21]. The critical importance of building up the services sector in developing countries is pointed out by Narasimhan [1]. The services sector deals mainly with information in the fields of banking and insurance and in agencies, industrial consultancies etc. With increased development, the demand for specialized information services of all kinds will grow; the occupational categories in the services sector will, in turn, become more specialized and professional and there will be increased "information consciousness". In the early stages of industrialization the service occupations are in-house, but, as industrialization advances and the service occupations become more specialized and professional, they will become industries in their own right.

According to Narasimhan [1], however, over the 50-year period during which a comprehensive industrial base was built up in India, there was virtually no structural shift of the labour force from the traditional occupational categories. As a result, a large proportion of industries operate without the benefit of specialized information service inputs that would normally exist in a services sector. The missing occupational categories are the ones that would contribute to the efficiency and productivity of the primary and secondary production sectors.

Thus in India, as in other developing countries, the industrial sector remains isolated and unintegrated into the national socio-economic system. Many occupations that should accompany balanced industrialization and provide diverse employment opportunities do not exist. There is also a low level of information consciousness in the entire spectrum of socio-economic activities.

In regard to the development of the services sector itself as a sector of the economy, it is an interesting point that increases in productivity in the services sector come about mainly through the application of infotechnology, in the form of microelectronics equipment [22]. The technology results in a decrease in labour growth and is most evident in office automation. Since the occupational roles in this sector in developing countries still have to be provided and since productivity increases in this sector are essential in expanding economic activity elsewhere, such a so-called "intensive" role for informatics activity should be considered positive and desirable. The development of the information-intensive sections of the services sector is one of the most fundamental ways in which industrial growth can be stimulated [23].

Social intelligence

At the heart of the concept of informatics is information and feedback control within an appropriate time frame, whether the automated control of an industrial process or, at the other end of the spectrum of applications, the strategic control of a corporation or a nation (Banerjee, in [1]). Information and power are two sides of the same coin and are basic to self-reliance [24].

A basic informatic problem, in both industrialized and developing countries but acute in the latter, is the attitude towards information [25]. If the attitude towards information is indifference, then the contribution of information resources to productivity will not be fully effective. In other words, more basic than providing the answers to the questions is stimulating the questions to the answers [26]. When problem solvers are convinced of the value of information, they will be motivated to develop the appropriate information networks as a basis for the generation of a social intelligence [27, 28] and effective decision-making [16] at every level.

Models for informatics development

The Brandt Report [29] states: "A refusal to accept alien models unquestioningly is in fact a second phase of decolonization. We must not surrender to the idea that the whole world should copy the models of highly industrialized countries."

There is no reason to expect that the normal informatics applications in the industrialized countries would be relevant to the problems of the developing countries. In the past much harm was done in third world countries because informatics developments were based on the transfer of ready-made solutions to unstructured problems. Often value systems and ways of thinking of the developed market economies were also transferred.

Appropriate models will have to take into account the factor endowments and relative abundance of labour and scarcity of physical capital and skills of the developing economies and the need for a policy of self-reliance, i.e., the long-term development of skills and resources and the independence to use them to meet national objectives (Gupta, in [1], p. 109).

Revolutionary advances in infotechnology create new possibilities in all sectors of the economy. Informatic products can change the entire structure of an industry. A good example in the developed market economies is the banking industry which is in the process of radical restructuring (Cremin, in [1], p. 366). But in the developing countries new and innovative applications are still waiting to be discovered.

An industrial strategy of decentralization becomes feasible owing to the capabilities of decentralized information systems with connections, where appropriate, to major centres. Production in a larger number of smaller decentralized units becomes economic and may be advantageous where the size of the market is also small. A strategy of bringing industry to the people in rural areas would ease the increasing problems of urbanization.

Again, informatics products can enable an unskilled person to perform a sophisticated task that otherwise could be performed only by a highly skilled person, which could be a short-cut to acquiring skills in developing countries (Hahn, in [1], p. 39). In this way, instead of replacing workers with machines, informatics applications can increase employment and enhance skills.

The priorities in particular developing countries must also be taken into account in selecting models. Different criteria will apply in different countries, but, in general, because typically three-quarters of the labour force is employed in the rural sector, the highest priorities will be increased decentralization, balanced economic growth and employment. Priority will also be given to informatics applications in small-scale industrial enterprises, which in a developing country might typically account for 50 per cent of total industrial production. More specifically, efforts must be directed towards developing the services sector to serve small-scale enterprises as a channel of appropriate infotechnology transfer [1].

Information-handling capabilities constitute the nervous system of a society, and information is the ignition key to innovation and self-sustaining development which draws upon the inventiveness and adaptiveness of local artisans, small entrepreneurs etc. in a national development effort. In-depth studies will be required to develop detailed models of appropriate information services and systems and of national information networks to meet the needs of a variety of end-users, who include R and D personnel, technologists, engineers, industrial managers, economists, planners, investors, financiers, entrepreneurs, market analysts, sales personnel, industrial consultants and government decision-makers.

Models for national communications systems must allow for changing telecommunications technology and changing costs. These changes increase the available options, ranging from very low-cost systems, based for example on a combination of subscriber radio point-to-multipoint microwave system and buried cable, to the highest technology, based on satellite transmission.

A conceptual framework for national informatics development

Informatics development is a dimension of technological development, which in turn is an integral part of national economic development for which national policies and strategies should be developed. While patterns of economic development will vary from country to country, depending on a number of factors including resources, geography and skills of the population, it is now recognized that economic development causes a transformation of the entire economic and social structure [29]. Economic development means creating a more diversified economy whose main sectors become more interdependent: thus, overall national policy objectives might include:

Promotion of national self-reliance
Creation of employment
Development of education and training
Industrial growth

Technological development

Technology is recognized in industrialized countries as a central, critical factor in development, and technological development is built into national development strategies to achieve policy objectives, whether military, economic or social. In developing countries, on the other hand, the importance of technology as a factor of development is largely unrecognized. As a result, technological development strategies have been lacking, with the consequence that in the developing countries industrialization has tended to be accompanied by growing technological dependence on foreign sources [30].

This contrast in attitudes towards technology between industrialized and developing countries suggests that the reduction of technological dependence should be central to national development policies in the developing countries. Technological development should be a dimension of overall development, and this means essentially building up a basic capability for decision-making and implementation in technological matters [30].

Technological development policies within overall national development policy should include:

(a) The promotion of national capability for the production and dissemination of technologies;

(b) The promotion of national capability for technological innovation;

(c) The development of an organized process for technological transfer from abroad.

Informatics development

Informatics is not a single sector of technology that can be considered in isolation; it is rather a dimension of technological development with cross-sectoral impacts (King, in [37]). In line with the technological development policies above, more specific policies relating to informatics should be drawn up, on two levels: operations and infrastructures.

Policy objectives at the operations level are:

(a) The promotion of indigenous hardware and software industries;

(b) The identification and promotion of priority application areas;

(c) The promotion of innovative applications;

(d) The development of management decision-support systems;

(e) The development of governmental information handling systems.

Policy objectives at the infrastructures level are:

(a) The promotion of awareness, education and training;

(b) The development of national communications;

(c) The development of national industrial information services and systems;

(d) The promotion of the industry-related services sector.

Strategies at the sectoral or national level, as appropriate, will be required to attain each of these policy objectives. One major national development strategy should be to set up appropriate institutional arrangements for the promotion, coordination and review of the specific informatics policy objectives and corresponding strategies, national or sectoral.

V. National action: policies for the production of hardware and software

The principle of self-reliance (see chapter IV) is fundamental to the question of developing indigenous production of hardware and software in the third world. The principle does not imply that efforts must be made at all costs to achieve the greatest possible degree of indigenization. What it does imply is that the competence should be developed that will enable a country to make informed decisions regarding the sectors of the informatics industry that it would be desirable to develop on the basis of carefully selected objectives.

The development of an operational strategy for indigenous manufacture is of special importance because of the rapidly changing technology: options must be constantly re-examined in the light of the priority needs of the particular country.

Consequences of an indigenization policy

There are three considerations to be borne in mind in formulating an indigenization policy for informatics. First, there are the direct economic benefits accruing to a country through participation in an industry that has become, as a result of rapid growth, one of the three largest world industries (alongside energy and transportation). Second, the risk that a country's industrial sector depends too heavily on imported informatics products can be reduced. Third, and most fundamental, informatics products actively marketed by the industrialized countries are not appropriate to the needs of developing countries (the needs of the developing countries have hardly been examined as yet).

An examination of areas for priority application would show quite different needs in developing and in industrialized countries. Individual developed and individual developing countries would also have different needs. Kalman (in [1], p. 137) contrasts, in a number of examples, priority applications in the industrialized and developing countries. The approach to the promotion of indigenous capabilities in the production of informatic products should be based upon the need to ensure that the supply of such products is geared specifically to local requirements.

A selective approach

The changing structure of the informatics industry (see chapter II) provides opportunities for enterprises to enter into the production of hardware at a number of different levels, corresponding to the key decision stages in the manufacture of a product: the components, boards, enclosures and full systems.

A country can adopt a policy of selectivity in regard to imports and need not necessarily try to manufacture everything. Since manufacturers in many countries offer high-quality and low-cost components and equipment, a country can pursue an optimal policy of selection. Thus, without becoming too dependent on one country or one manufacturer, imports of an appropriate mix of components, subsystems, equipment etc. can be purchased. A selective policy contributes to self-reliance through the long-term development of skills and resources and the independence to use them to meet national objectives.

Gupta (in [1], p. 109) cites application areas that contribute directly to Indian national development: process control, freight wagon identification, power systems control and flood warning systems. Computers are an integral part of such dedicated systems. Today in developing countries most systems are supplied on a turnkey basis by a limited number of manufacturers from the industrialized countries. While the hardware costs are going down, the costs of labour and software are increasing. There is no reason why the activities that make up the bulk of the cost—systems integration, interfacing, installation, commissioning, maintenance, software development, training etc.—should not be carried out locally on a national basis. A systems engineering approach has the advantage of obtaining the latest and most reliable hardware and yet depends to a large extent on national resources and skills (depending on the availability of technical skills in a country). India, for instance, has people with the skills to perform many of these activities.

An institutional basis

The development of an indigenous capacity for the production of hardware and software requires an institutional base that is national in character and independent in approach and has the capability to render total support. Again, India provides a case study.

The Government of India set up the Computer Maintenance Corporation Limited (CMC) in 1976 to provide one-point total support to computer users (Gupta, in [1], p. 109). CMC now works closely with the Central Electrical Authority, the Meteorological Bureau etc. to introduce computers for control and monitoring purposes. The system could be extended to any large-scale applications in order to integrate the best hardware available, imported if necessary, while developing the software internally, thus retaining full independence, flexibility and control and at the same time reducing costs. All support services including maintenance for imported hardware are provided by CMC. These services include site consultancy, site preparation, installation and commissioning of systems, software support, systems advice, user training and applications development.

Hardware

The development of hardware calls for large-scale investment and requires government support, which may take the form of such measures as import controls and subsidies to protect indigenous producers in the home market. However, these measures impose an additional cost on either the taxpayer or the final purchaser, and at the same time the advantages of a wider choice of hardware on the home market through a less restrictive import policy are foregone. Government support may also take the form of assistance with research and development, grants for training and upgrading of skills, assistance in defraying operating costs etc., which are more directly aimed at making the products of indigenous producers competitive with imports. In the case of even small computers, the costs to the indigenous supplier of providing user support and assistance in order to penetrate the home market are significant (Arcaraz, in [1], p. 115). A successful producer will build up an installed equipment base sufficiently large for specialized firms producing "plug-compatible" products and services (terminals, application packages, software, maintenance etc.) to grow around it; the producer will not have to supply the whole range of hardware and associated products and services alone.

A joint arrangement between a developing country and an industrialized country to manufacture hardware is worthy of consideration. Such an arrangement can range from labour-intensive offshore assembly to a more genuinely joint approach where some of the strategic production areas such as research, design, marketing, manufacture etc. are carried out in the developing country. If foreign companies become more integrated into a host country's economic structure, the quality of the employment they provide and their capability to become more innovative in the host country will increase, and they will become, in time, a training ground for local entrepreneurs [61].

In joint arrangements, however, the developing country is inevitably the junior partner, which is not a fully satisfactory situation. Offshore assembly, for instance, does not usually lead to genuine integration in host countries.

Regional co-operation is another option. Arcaraz (in [1], p. 115) refers to the Latin America Free Trade Association (now the Latin American Integration Association (LAIA)) where the role of producing and exporting machinery for information processing was assigned to Brazil, computers were then imported duty-free by the other member countries.

The wholly indigenous manufacture of hardware is very expensive, and the likelihood of a manufacturer in a developing country reaching a self-sustaining level of operation is slim, particularly where the country does not have a sufficiently large home market for domestically produced informatic hardware. Maintenance, systems integration, commissioning, installation and interfacing are activities that should be actively encouraged instead of an attempt to manufacture a full range of hardware products.

Software

Indigenous software production is more immediately attractive than hardware manufacture. As Hanna (in [1], p. 134) points out, the software industry does not require large direct capital investment or extensive physical infrastructure (with the exception of educational facilities and, in some circumstances, telecommunications), and the industry is expected to grow extremely rapidly in the future.

Developing countries have special requirements in relation to informatics applications. Jain (in [1], p. 130) characterizes these special requirements as deriving principally from the important position of the rural sector in the economy, the small scale of industrial units and instability in the supply of basic industrial inputs. Therefore, simply transplanting applications software from developed to developing countries will not in general be appropriate.

Governments can take effective measures to promote an indigenous software industry. Kalman (in [1], p. 137) lists some specific measures including:

(a) Direct financial support by Governments to assist software firms in acquiring computer hardware and undertaking training;

(b) Reducing the tax liability of firms by an amount sufficient to meet the cost of maintaining locally produced software;

(c) Legal copyright protection for software;

(d) Establishing registers of software in order to avoid unnecessary duplication.

Suitable institutional arrangements to manage and co-ordinate indigenous software production (including training arrangements for labour) and to ensure that the software produced is high-quality and fully compatible with national application priorities are a prerequisite.

Singapore is an interesting example of a country that is taking steps to reduce reliance on labour-intensive industries with low productivity by promoting high-technology sectors: infotechnology is one of the high-technology sectors earmarked for development (Iau, in [1], p. 121). In particular, a major drive is underway to build up significant local capability in software production. Software was chosen in preference to hardware because of the difficulty involved in attempting to compete with the major industrialized countries in an established area of infotechnology such as the manufacture of hardware. A massive training programme in software skills is being launched in order to ensure a steady supply of skilled labour. Curricula are being reviewed and new training structures established. Incentive schemes to encourage industrialists to undertake software production are being formulated. There is provision for external assistance, where appropriate. It is too early to assess the effectiveness of the strategy being adopted by Singapore. However, it should be noted that Singapore is not typical of developing countries. In areas such as education, literacy and employment, it is on a par with highly industrialized countries. For this reason the experience of Singapore will require careful interpretation before it can be drawn upon in the development of models for developing countries.

VI. National action: policies for informatics infrastructure and social development

A national informatics infrastructure determines a country's capacity to harness infotechnology for the benefit of social and economic development. It is the essential link between national strategies and policies (together with international considerations), on the one hand, and individual applications in the industrial, rural, government, services and other sectors, on the other. Education and training is a pivotal element in infrastructural capacity. Other important elements include information services, communications and research.

Constraints

A number of factors that contribute to the development of appropriate infrastructure in industrialized countries are not present in developing countries (Mufti, in [1], p. 147). A technical environment characteristic of a developed country includes, for instance, a high degree of competence among users of infotechnology, at least some local production of informatics hardware and software and high-level technical support and maintenance services; in addition, software and associated documentation are written in the languages of the developed countries. The smooth evolution of informatics applications to progressively sophisticated levels, in step with technical and industrial innovation such as occurs in developed countries, is unlikely to occur in developing countries. The social and administrative systems of developing countries are often characterized by decentralized, small-volume data capture, on the one hand, and centralized decision-making, on the other, requiring specially tailored informatic systems.

Factors that inhibit the development of informatics in developing countries are, for example, instability of electricity supply, poor quality data transmission lines and climatic conditions. Informatics hardware manufacturers sometimes provide only basic representation in developing countries and do not provide comprehensive maintenance services. Structures and systems must be developed to ensure an adequate level of maintenance, repairs and spare parts. Back-up facilities must be incorporated in informatics applications, and attention should be given to quality and reliability of systems. This is very important in the technically least advanced developing countries.

In developing countries, an informatics data collection and preparation application may not be replacing a manual mode of operation (Miligi, in [1], p. 158)—quite often it will be a completely new application. Most personnel will not be familiar with the disciplines necessary for such work. The nucleus of a work-force has not evolved in many developing countries. Because of this, the informatics training given in industrialized countries must be modified to meet the needs of developing countries.

Awareness, education and training

Various international conferences and reports have underlined the importance of the planned application of infotechnology for national development [15, 31, 32]. However, the applications in developing countries have been, compared to developed countries, extremely limited.

As part of a move to make educational systems more relevant to socio-economic development [25], there is scope for imaginative and innovative programmes in formal education designed to increase the level of informatics awareness. In developing awareness programmes, the steps that have already been taken in many industrialized countries should be studied.* These steps include seminars, publicity materials including specially commissioned video films and books, substantial media coverage, consultations with trade unions and introduction of small computers in schools. Awareness and education are needed, in the first place, in order to create the political will to develop the massive training programmes that will be required in the developing countries if the potentialities of informatics are to be realized.

*See, for example, E. Brown, K. Hoffman and I. Miles, "Microelectronics and government policies: the case of a developed country" (ID/WG.372.2).

The countries of the third world generally suffer from shortages of personnel trained in critical skills required in the industrialization process: engineers with agricultural expertise and managerial skills, industrial designers, production and process engineers, engineering craftsmen, food technologists, quality-control personnel and management accountants. For most of these people, informatics-related training is desirable. Systems analysts, organization and methods experts, programmers, operators and data preparation staff need training in computer skills; professional training in this area has not generally reached a high standard in developing countries. The type of training required is often not recognized, and the decisions about training may even be left to the hardware manufacturer. The result can be that operational skills are emphasized and management skills neglected.

The performance of a system depends on the one hand on its concept and design and on the other hand on the environment in which it operates (Miligi, in [1], p. 158). The operating environment includes, in particular, the human element interacting with the system in various aspects. Education and training are the means by which the efficiency and effectiveness of the vital human component of a system is optimized.

There is a lack of information on the type of education and training in informatics needed in individual developing countries (Scott, in [1], p. 164). This makes it difficult to formulate appropriate programmes. Informatics is a new field; many of those engaged in it were previously concerned with some other area. This has led to inconsistencies and lack of clarity in subject nomenclature which further adds to the difficulties of formulating a programme (Miligi, in [1], p 158).

In order that the expenditure of scarce resources on education and training will not be negated by the "brain drain", Governments may have to promote policies that will ensure adequate remuneration at local public sector and university-level institutions so that these institutions will be able to retain informatics staff of sufficient calibre (Scott, in [1], p. 164). Another area for government consideration is the regulation of private informatics training schools in order to optimize the contribution of such schools to national informatics development. A national framework of informatics education is required at all levels, including advanced courses for specialists, in order to avoid unnecessary duplication of resources. In some cases a regional framework may be advantageous.

Education and training centres must be equipped with appropriate hardware and software. The use of individualized teaching packages may be very effective. Adequate library and reference facilities should be provided to support informatics programmes.

A balance between theoretical and practical orientation should be adopted in education and training. Programmes should keep up with developments in infotechnology. Procedures for assessing competence in the area of informatics should be developed. Where aptitude tests are used, they should reflect local and regional circumstances (Scott, in [1], p. 164). Training in the key areas of data entry and data control needs to receive special attention since many of the people involved will not have been previously exposed to the type of discipline required.

While expatriate expertise has a role to play in selecting, developing and implementing informatics applications, in the final analysis, in order for the high investments in such applications to be fully economic, local expertise must be available to resolve the day-to-day problems that arise in operating even the best designed applications (Miligi, in [1], p. 158).

The ratio of education to training will be different for different categories of personnel (Miligi, in [1], p. 158). Education is primarily concerned with the development of character or mental powers; training, on the other hand, is generally more specific, of a shorter time span and concerned with bringing a person to a desired state of efficiency by instruction and practice. Personnel for data preparation, machine operating, programming etc. require a high degree of training and a more limited amount of education. Personnel for research, design, management etc. require a high degree of education, supported by a more limited amount of training. The distinction between training and education is also relevant in making institutional arrangements for implementing educational and training programmes.

Training new personnel

Scott (in [1], p. 164) points out a number of features of education and training for new entrants to the informatics profession in Africa:

(a) Most new entrants to the profession attend only computer vendor courses;

(b) There has been considerable implementation of post-secondary level courses and also the emergence of some activity at the secondary school level;

(c) There has been considerable implementation, at the undergraduate level, of service courses in informatics for science and business students;

(d) The main developments have been at the post-graduate level, and a number of scientifically and business-oriented post-graduate diploma courses have been implemented;

(e) Training courses in systems analysis and design are being run at the regional level;

(f) User education appears to be comparatively neglected.

External support

External consultants have a role to play in the development of informatics education and training programmes in developing countries. For instance, they might be called upon with advantage to identify the present and potential availability of suitable local informatics personnel, to compare the costs of various training strategies and to engage informatics training specialists from other countries to implement selected strategies.

The consultants' role should not extend to setting the objectives that the training strategies are designed to achieve. The setting of objectives and the choice between individual training strategies and broad programme options is a matter for the government agency charged with informatics policy (Ryan, in [1], p. 174). The appropriate government agency may feel that it does not have sufficient experience to elaborate the objectives required. If this is the case, external consultancy support will be necessary. Strategic decisions must, in due course, be accurately reflected in executive decisions on, e.g., the number and size of training centres, the balance between general and specific training, the broad thrust of the disciplines to be taught etc.

Foreign training personnel

In order to secure training personnel of the appropriate calibre, it may be necessary to engage foreign personnel, usually on a contract basis. Costs associated with employing such personnel include: the drain on foreign exchange; the cost of the higher salary levels (over those in industrialized countries and local levels) necessary to attract appropriate staff; overheads, for example owing to the short turnover period of foreign staff; and the impact of the high standard of living of foreign personnel on the local community.

Prior to engaging foreign training personnel a full cost-benefit exercise should be carried out (Ryan, in [1], p. 174).

Training vis-à-vis line management

In the context of a national programme of indigenization, there might be a need to modify the traditionally supportive and subordinate role of training personnel *vis-à-vis* line management. Management's attitude to the trainers might be conditioned more by the fact that it is their own replacements that are being trained rather than by the potential contribution of training to the success of the enterprise (Ryan, in [1], p. 174).

Industrial information infrastructures

Information handling capabilities, whether formal or informal, are crucial to industrialization. In the industrialized countries such capabilities have grown hand in hand with industrialization in all sectors (see chapter IV). Developing countries need to promote information handling activities, which have generally not emerged and which firms often have to develop internally, leading to duplication and excess capacity.

Information services and systems of national information networks are required to co-ordinate sectoral growth and meet the needs of a variety of end-users. The type of information needed covers socio-economic data, financial opportunities, market situations, equipment availability, management practices, patents, legislation etc. The information has to be continuously updated and obtained from a variety of sources, at the national, regional and global levels. It is transmitted to end-users in many forms, ranging from oral communication to computer printouts.

Sozen (in [1], p. 182) points out that, in the case of Turkey, the required information often exists, but it is not readily available because it is scattered throughout a number of unrelated bodies; the most economical approach would be to link the information from these bodies in one new central agency.

Communications infrastructures

In the process of development, social forces must be carefully balanced, and, in order for interrelationships to function effectively, efficient communications systems are necessary. Infotechnology, from the printing press to electrical communications devices to modern telecommunications systems, has played, and continues to play, a crucial role in providing efficient communications capabilities. However, the gap between successive major developments in infotechnology-based communications has shortened considerably. For instance, the gap between the development of the printing press and the development of the telegraph and the telephone was much longer than the gap between the development of the telegraph and the telephone and the development of world-wide satellite-based data transmission systems. If the maximum benefit from successive infotechnology-based communications advances is to be realized, social groups and organizations must make appropriate adjustments. The process of social adjustment is traditionally very gradual, but the pace of recent developments in communications has been very rapid. As a result, adjustments in social organizations are lagging behind. For instance, modern and inexpensive energy-efficient communications systems can lead to small and effective decentralized decision-making units (Byrnes, in [1], p. 153), yet the trend towards vast industrialized urban sprawls continues. Policies are necessary to accelerate the pace of organizational adjustment so that the maximum benefits from infotechnology-based advances in communications systems are harnessed for the well-being of nations.

In order for telecommunications to be integrated into an economy's infrastructure, it is necessary to consider institutional arrangements, adopt a systems approach and develop a planning framework. Adequate funding must also be ensured as the investment costs are high. The institutional arrangements should not be unnecessarily bureaucratic and should be sufficiently flexible to allow for an imaginative approach to be adopted. A plan is important because the payback period can extend to several decades.

Research and development

An adequate R and D capacity is an important prerequisite for realizing a measure of self-reliance in the field of informatics. It provides a means of keeping abreast of technological developments and facilitates the cultivation of innovative entrepreneurship. Most R and D takes place in the developed countries. Because of severe resource constraints, developing countries should select a few areas for R and D that are most relevant to their requirements and allot available resources to funding them (Deodhar, in [15]). R and D efforts should not simply reproduce the efforts of the developed countries. Their aims should be based on an assessment of long-term advantage. Most R and D is government-sponsored; there may be scope for promoting some industrial enterprises for R and D through the use of carefully designed financial incentives.

Scott (in [1], p. 164) proposes that an information R and D programme appropriate to the needs of developing countries could begin with selected projects such as: the implementation of dial-up telecommunications facilities for data transmission purposes; the automation of national university libraries; the application of portable microprocessors, e.g. in the fields of computer-assisted instruction, medical diagnosis and farm management; and the impact of word processors on traditional urban employment.

Shortages of qualified advisory informatics personnel, in particular in higher education and central government informatics centres, is seriously impeding the application of informatics in technical areas, for example, in the creation of medical data bases and the processing of satellite data.

Institutional infrastructure for R and D in informatics technology must be provided. This might involve attaching laboratories to university-level institutions in different regions of the country, with each laboratory being allocated a clearly defined area of interest.

VII. International action

The scope for international action

National self-reliance depends on the availability of informatic infrastructure, and international action will be essential to promote the development of such infrastructure.

Actions at the national level are interrelated, will be mutually reinforcing and should be approached in a systematic manner (Barguin, in [1], p. 84). They include the promotion of:

(a) National policies and strategies, including institutional arrangements at the national level;

(b) Awareness, education and training;

(c) Information infrastructure, including industrial and technological information transfer services and systems, R and D, industrial extension services and the services sector;

(d) Communications infrastructure;

(e) Hardware and software industries;

(f) New products and processes;

(g) Applications, including governmental information handling systems, management decision support systems and innovative industrial applications, with special reference to small-scale industrial enterprises.

Global studies

At another level, international organizations could usefully carry out global studies and organize seminars and workshops to assess needs. In this way in-depth knowledge about models for informatics development that are appropriate for the third world may be generated (as pointed out in chapter IV, models that have been developed in the industrialized countries should not necessarily be transferred). Such studies are also required to identify programmes and to pin-point where action should be taken to achieve maximum results. Co-operation with non-governmental organizations in carrying out such studies can often be advantageous.

Categorization of developing countries

A categorization of developing countries may be required so that action can be tailored to groups of countries. Countries can be categorized by region, e.g. the Andean Group or regional country groups in Africa and Asia, or by their stage of industrial development, e.g., Brazil, India and Mexico could be grouped together. For certain types of action, groups could be based on a simple typology using population size, geographical area and population density, per capita income, economic growth rate, internal income distribution and availability of natural resources [33]. With reference to the development of informatics, typologies of developing countries have been suggested in literature on the subject [34, 35], but such typologies would not necessarily have operational significance in the present discussion.

Global co-operation

To achieve any effect it will be essential for the United Nations Industrial Development Organization (UNIDO), with its focus on industrialization, and other international organizations that are concerned with aspects of informatics—the United Nations Conference on Trade and Development (UNCTAD), the International Labour Organisation (ILO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Bank, the International Telecommunication Union (ITU), and the Intergovernmental Bureau for Informatics (IBI) etc.—to mount a global onslaught aimed at the national Governments, educational systems and R and D and industrial infrastructures.

National policies and strategies in the context of international action

In 1971 and 1973 it was recommended in United Nations publications that each developing country should formulate a broad national policy, consistent with its national goals, on the application of computer technology, and recommendations were set out [34, 36]. Since that time IBI has been active in promoting the development of national strategies and policies. In co-operation with UNESCO, IBI organized a world conference in 1978 on the subject. The Department of Cooperation of IBI provides assistance and co-operative missions for policy planning for its member countries.

The view of IBI is that informatics technology plays a key role in the promotion of self-reliance and endogenous development and must therefore be subject to national policies. Information is perceived as a natural resource to be utilized, and informatics is concerned with the design and implementation of appropriate systems to utilize it. At the national level, informatics is the study of the nervous system of the nation. It is therefore concerned with the basis for the generation of a social intelligence [28] and effective decision-making in any sphere: hence the need for a national policy.

The national policy of any country is individual to that country and depends on many factors, including the stage of development. However, the following would necessarily form the substance of any policy:

Awareness, education and training

Identification of application priorities

Acquisition of hardware and software

Informatics infrastructural arrangements, including maintenance

Communications

Research and development

Informatics industry developments

Within a broad national policy that covers economic, social, cultural and political aspects, industrialization provides a special focus for the developing countries. An industrially oriented policy would, above all, be concerned with identifying applications that would increase productivity and create employment [37].

Further studies are needed at the international level, based on an appropriate typology of developing countries, to elaborate national policies, and international action is required to promote the adoption of policies in individual countries and the establishment of national bodies to be responsible for informatic developments.

Awareness, education and training

A major constraint to the development of informatics is the world-wide shortage of skilled labour. Set against a 30 per cent annual growth in end-user investment in hardware, this constitutes a serious failure of the education sector to come to terms with informatics. More resources need to be devoted at the international level to increasing the level of awareness of informatics in national Governments, through carefully planned programmes of action followed by assistance to government departments in setting up support programmes to alert management to the industrial scope and potential of informatics and to assist in retraining staff.

As an integral part of a national informatics strategy, education and training needs have to be established on the basis of employment projections and the range of education and training provided that is appropriate to the specific needs of the country and to its level of development. An educational and training strategy of this scope can be achieved in developing countries only through international co-operation.

Education and training in informatics is within the mandate of UNESCO and is being given much attention by that body. Several recommendations of the first conference on strategies and policies for informatics underlined the importance of education in informatics and stressed that UNESCO should strengthen its programme to enhance informatics education at different levels, including post-university, university and pre-university levels, as well as public awareness education. The 1981-1983 triennium programme provided for increased support to be given to post-graduate training courses and the establishment of centres of excellence in many countries. Regional networks are being established to encourage lateral transfer of infotechnology through the exchange of personnel and training. A special study was planned to compile information on informatics information centres, educational and training establishments and courses offered, research and experimental development institutions, research opportunities and fellowships. A pilot project to establish microcomputer laboratories in developing countries is also foreseen; it will include purchase of equipment, transportation, installation and training of staff. Support will be given to institutions in developing countries especially teaching and research institutions, or the establishment of minicomputer centres, and advisory services will be provided (Owolabi, in [1], p. 53).

It will be essential for UNIDO to co-operate with ILO, UNESCO, IBI and other bodies in order that priority is given to training programmes that will lead most rapidly to informatic applications supporting increased productivity and employment in the short term and the development of endogenous capacities in the longer term.

In the development and implementation of long-term, co-ordinated training strategies, international bodies should evaluate the usefulness of a number of large, manufacturer-independent, national training authorities in the industrialized countries that are able and willing to offer training services and materials to developing countries (Platts, in [1], p. 73). Efforts should also be directed towards the development of regional training centres in selected third world countries to operate on the basis of technical co-operation between developing countries, as described by Chico (in [1], p. 291).

Information infrastructures

The processes of information flow that support productivity are certainly not yet well understood or modelled, and it will be necessary for international agencies to be involved in global studies in order to identify the specific information-related factors affecting industrial growth and the priority areas for the development of information infrastructures. The scale of the undertaking is enormous, and only a highly selective, cost-effective approach will be feasible. For economic, operational and cultural reasons, the wholesale informatization of a society as a means of providing a general infrastructure for industrialization is not feasible in the shorter term.

Studies should be based on the concept of information handling capabilities as the nervous system of a society and of information as key to innovation and self-sustaining development which draws the inventiveness and adaptiveness of local artisans, small entrepreneurs etc. into a national development effort (Dessau, in [1], p. 49).

Global studies carried out at the international level should result in the development of detailed models for information services and systems of national information networks to meet the needs of a variety of end-users (Banerjee, in [1]). These include R and D personnel, technologists, engineers, industrial managers, economists, planners, investors, financiers, entrepreneurs, market analysts, sales personnel, industrial consultants and government decision-makers. As discussed in chapter VI, the type of information needed and the forms of communication used are very diverse. It must be emphasized that such models would be much broader than the development of conventional documentation and abstracting services and scientific and technical information (STI) networks.

UNIDO plays a unique role in the promotion of information infrastructures. The Industrial and Technological Information Bank was established within UNIDO with a mission "to make available a greater flow to the developing countries of information permitting the proper selection of advanced technologies" [38]. The functions of the Bank include the provision of assistance in the technology selection process and also the provision of assistance in the setting up of matching industrial information structures in individual countries [39].

Industry-related services sector

As was pointed out in chapter IV, the development of the information-intensive sections of the services sector could be one of the most fundamental ways in which industrial growth could be stimulated. The modalities of such a development should be studied.

Social intelligence

The most basic problem in informatics is to show the problem-solvers the value of information, which will create a demand for information networks as a basis for the generation of a social intelligence and effective decision-making at every level. This area also requires study at the international level. The long-term solution involves the remodelling of the educational system [25]. The short-term strategy consists of *(a)* identifying the "gate-keepers" (Barguin, in [1], p. 84); *(b)* specifying the information services and systems most appropriate to their needs; and *(c)* devising crash training to create information-conscious cadres of problem-solvers [25].

Communications infrastructures

The General Assembly, in its resolution 36/40 of 19 November 1981 on World Communications Year, recognized "the fundamental importance of communications infrastructures as an essential element in the economic and social development of all countries". In most developing countries inadequate communications infrastructure is one of the biggest obstacles to economic and social progress. The imbalances in communications are striking: 75 per cent of installed telephones are in eight developed countries and the developing countries have only 7 per cent altogether. Many rural areas lack electrical communications of any kind. Good communications increase social efficiency, that is to say, they shorten response times for administrative and decision-making procedures. When travelling is used instead of the telephone, efficiency is lost; when no one knows how long it will take to bring a procedure to a conclusion, efficiency is non-existent. Improved telecommunications both within and between developing countries will be essential for collective self-reliance and economic integration and a prerequisite for industrialization.

Studies in selected developing countries have shown that, for various sectoral interests, the indirect benefits of telecommunications are ten times higher than the cash return. For example, the ITU investigated the impact of telecommunications on the performance of a number of business enterprises in Kenya. The enhanced economic performance resulting from better telecommunications was estimated to be 110 times higher than the total cost of providing the improved service. Evidence indicated that the benefits were greater in the remote areas.

The planning of communications development must take into account rapidly changing telecommunications technology and also changing costs. These changes mean that technology is available at different levels and costs for countries with different basic characteristics, such as geographical features, size, population density etc. and in different stages of development. Thanks also to the new satellite communications technology, direct South-South communication has become possible. Various options should be investigated and studies should be undertaken of the existing examples of recently developed national communications systems.

International action will be required to facilitate the preparation of national and regional programmes and to assist countries in undertaking in-depth review and analysis of their policies on communications.

Pilot projects

Recent technological developments, e.g. in the use of digital telephone exchanges, satellite transmission and fibre optic cables, should be reviewed. A categorization of developing countries, based on characteristics that would have a bearing on communications infrastructure, could be developed so that countries could be grouped together according to their communications problems. As a pilot project, field surveys could be carried out in one or two countries in each country group selected. In the selected countries, national communications needs could be studied, with special reference to the demands in different sectors of industry and the projections of growth in demand. The potential for developing an indigenous telecommunications equipment industry could be investigated. For each country studied, a number of communications systems options—covering technical, economic, operational and financial feasibility—could be developed.

The next stage would be to equip the countries concerned with the capabilities to proceed with the development of plans for communications systems. As a first step, appropriate training programmes in communications would be developed for personnel selected from country groups. The training programmes would be individually tailored to the needs of each country group and designed to match the technological information requirements and the communications systems options developed for that country group.

The output of a pilot project carried out at the international level would be a technical report, together with an integrated package of technical and cost data and a methodology, on the basis of which a range of options for a national communications system appropriate to the needs of any individual country could be specified in broad outline. The options developed would range from very low-cost systems, based, for example on a combination of subscriber radio point-to-multipoint microwave system and buried cable, to the highest technology, based on satellite transmission.

Existing models

Models of existing, recently developed national communications systems can be studied. This should be done within the framework of an integrated international development strategy. Developments in telecommunications in Latin American countries are reported by Galli [40]. Hahn (in [1], p. 39) describes an inexpensive communications system that would be economical for a low-density population, based on a combination of subscriber radio and cable. Ireland is an example of a recently industrialized country not burdened with old industry and traditional infrastructure that has decided to invest £800 million in an integrated telecommunications system based on digital switching and transmission to integrate voice, data, text and pictures for transmission through the system (Byrnes, in [1], p. 153).

These and other such models should be studied within the framework of an integrated international development strategy. ITU, in collaboration with the United Nations Development Programme (UNDP), has directed a major part of its development co-operation towards the interconnection of national networks of developing countries and their integration into a global telecommunications system and has promoted many regional projects for bringing the developing countries together [41]. Examples of these projects are the Pan-African Telecommunication

Network (PANAFTEL),* the Inter-American Telecommunications Commission (CITEL), the Asian Telecommunications Network (in collaboration with the Economic and Social Commission for Asia and the Pacific (ESCAP)), and the Arab Telecommunications Union (ARABSAT). UNDP is also involved as a partner in a project to establish the development information network through technical co-operation between developing countries. This project will be linking, in the first stage, 60 developing countries with the existing interregional network via satellite as well as linking other developing countries to sub-regional redistribution centres terrestrially; it is intended that news agencies be the primary users (Dessau, in [1], p. 49).

The informatics industry

The considerations that would lead a developing country to adopt an indigenous informatics industry policy have been set out in chapter V. The elimination of dependency may often override considerations of comparative advantage. The benefits of interaction with applications, servicing and maintenance are also often important [4].

International organizations can play an essential role in promoting the creation of appropriate national policies and strategies and co-operation between developing countries. The early stages could focus on sharing experience and expertise in building up the institutional structures, capabilities and techniques [42].

New products and processes

There are many important problem areas for developing countries in which the industrialized countries have no readily available knowledge or experience. Innumerable new products and processes are waiting to be discovered, for example in agricultural applications or in the form of cheap, rugged and portable electronic medical equipment for use in static or mobile rural health-care delivery systems.

The development of new products and processes will require international action and co-operation and the sharing of experiences among developing countries [42].

*For a survey of developments in Africa, see Intergovernmental Bureau for Informatics, *For an African Management Infrastructure* (Rome, 1982).

Applications

As was pointed out in chapter IV, the normal informatics applications in the industrialized countries will not have much relevance to the problems of the developing countries. These problems have to be looked at afresh in the light of the advances in informatics technologies which create new possibilities for applications in all sectors of the economy. This again requires the co-operation of the international agencies.

Government information systems

No country has as yet fully solved the vast information handling problems involved in analysing and synthesizing the national accounting, statistical and demographic data required for sound national management and for national planning for the development of regions and resources, land, water, forest, crops and livestock and the efficient employment of people. The appropriate information systems again will differ for developing countries at different stages of development and with different characteristics. A series of comparative studies at the international level are required to identify suitable models. Many government information systems are in operation, in both developing and developed countries, so that the opportunity to study the best practice and to transfer appropriately modified models to new situations exists.

Governmental applications are an area ideally suited to stimulating the indigenous development of software. Software packages specifically tailored to national planning needs in developing countries have enormous potential; international organizations can encourage many projects for the design of software for national management of electric power and railway freight, meteorological early warning systems and communications and language systems [43].

Decision support systems

In developing countries social intelligence capabilities to assess and evaluate raw information will be absolutely crucial to building self-reliance and industrialization. The most pressing needs are to obtain market intelligence and to keep track of new technologies and current thinking on technological forecasting [44]. This requires the development of management information systems oriented towards long-term planning. As discussed in chapter II, management of an organization is at three functional levels—operational, tactical and strategic—corresponding to routine day-to-day operations, the control and evaluation of those operations and long-term planning.

The development of management information systems in the third world need not necessarily go through the same evolutionary stages that were experienced in the industrialized countries (see chapter II). The reason for this is that changes in the technology have increased flexibility and enhanced the capabilities of potential management information systems; thus all three levels can be developed at the same time. Nevertheless, such development is dependent on overcoming the lack of experience that is gained during the evolution of the operational, tactical and strategic level systems. It is necessary to develop an expanded programme of education and training, involving universities and technological institutions and to establish R and D institutes, information centres, industrial extension services and industrial consultancy services.

Bearing in mind that there can be difficulties in implementing even the simplest application, international organizations must work to strengthen managerial skills through industrial training centres, industrial extension services and consultancy firms, both nationally and regionally.

Small-scale industrial enterprises

International organizations should give priority to the promotion of informatics applications in small-scale industrial enterprises which, as pointed out in chapter IV, might typically account for 50 per cent of total industrial production. More specifically, efforts should be directed towards encouraging the growth of the industry-related services sector to serve the small-scale enterprises as a channel of appropriate informatics technology transfer [1].

VIII. Check-list for national self-reliance in informatics

The formulation of an operational strategy for informatics development for a particular country is individual to that country and depends upon conditions, requirements, priorities and stage of development. The specific set of actions suggested in the check-list below is therefore only illustrative.

Check-list

1. A high-level committee should be established at the level of the office of the President or the Prime Minister. This committee would promote the need for awareness of informatics as a major concept, and it would develop the concept of social intelligence generally, including associated infrastructures.

2. Consultations should take place with international bodies on development of policy. In this connection, access to other country models can be obtained through international agencies.

3. Study groups should be set up to consider topics such as training of labour, industrial policy etc.

4. A policy report should be prepared. This would set priorities for policy implementation and provide terms of reference for national bodies. It would also set indigenous informatics industry developments within national industrial policy.

5. Appropriate institutional arrangements should be made to set up a national body or bodies, e.g. a national informatics authority, to plan and regulate developments.

6. The national informatics authority should plan and implement national awareness campaigns on the value of information. The need for awareness of the value of information must be emphasized.

7. The appropriate government department should carry out national surveys of resources in equipment, labour and administrative, managerial and entrepreneurial skills.

8. The national informatics authority should investigate financial resources, nationally and internationally, and availability of funding sources for special projects (e.g. the United Nations Industrial Development Fund, UNDP, UNESCO, IBI, regional and national development banks etc.).

9. The national informatics authority should plan the industrial and technological infrastructures. This would cover industrial extension services, information centres, technology transfer centres, national information networks and ensure that existing bodies are brought fully into the overall plan, that new bodies are created where necessary and that appropriate links with UNIDO and other international information clearing houses and other national and regional centres are forged.

10. The national informatics authority should promote relevant applied R and D activities in third-level colleges and universities, and if necessary special centres, covering administrative sciences, management information and decision support systems, information science, studies of the information needs of industry including in particular those of small-scale industrial enterprises, microelectronics hardware and software technology and studies of innovative microelectronic applications in priority areas.

11. The national informatics authority should promote, in co-operation with the appropriate national bodies (or if necessary by setting up new bodies), an integrated national plan for education and training in all aspects of informatics and documentation as well as related administrative and management functions.

12. The national informatics authority, in co-operation with the appropriate government departments, should plan appropriate measures to stimulate the development of the industry-related services sector, with particular reference to engineering and industrial consultancy, in developing their technology transfer functions and expertise in implementing information systems in industry.

13. The national informatics authority should ensure that special legislation for the regulation of the inflow of informatics technology, licensing arrangements etc. comes within the general governmental framework for regulating and promoting the transfer of technology in accordance with a proper policy implemented by a national technology transfer regulatory agency [45].

14. The national informatics authority, in co-operation with the appropriate government departments, should plan a national communications system, integrating it into planning at regional and global levels, in consultation with ITU and other relevant bodies.

15. The national informatics authority, in co-operation with the appropriate government departments and other national bodies concerned with industry, should co-ordinate the development of a comprehensive industrial strategy for informatics hardware assembly and manufacture, software production, maintenance and support services within the framework of the national development plan, integrating the strategy at the regional level as appropriate.

16. With the dual objective of increasing efficiency and using government purchasing power as a substantial stimulus to developments in the informatics industry, the national informatics authority should promote a strategy for the development of information systems and data bases in government departments and public utilities, to be implemented through the further development of existing bodies or the creation of new bodies at the national level as appropriate.

17. The national informatics authority should promote the development of sectoral plans for applications in, for example, agriculture, transport and energy. These plans should be co-ordinated with an overall plan.

18. The national informatics authority should promote informatics applications in the private sector through the information infrastructures set up for that purpose and through developments in the services sector.

Comments

The informatics policy that is developed will be conditioned by a number of factors such as the degree of state intervention, the country's industrialization policy (for example import substitution or export-led) and other basic country characteristics. The following issues would necessarily form the substance of any policy:

- Institutional arrangements
- Awareness, education and training
- Government support, promotional measures and policy instruments
- Priority applications
- Hardware and software acquisition
- Informatics industry developments

The two greatest obstacles to implementation in most developing countries will be lack of awareness of the value of information and lack of management skills and experience. These can only be overcome by integrated and sustained action at the national, regional and global levels.

It should be borne in mind that at each stage in the national development of informatics, from the initial creation of policy to the actual implementation of operational systems, a nation can obtain a great deal of information, guidance and sharing of experience through the international agencies. General referral points would be the Industrial Information Section of UNIDO and the Department of Co-operation of IBI.

It should also be borne in mind, in studying the check-list, that informatics is not "just another mystification" (in [1], sect. I) or "just another technology" [58] (King, in [3]) and that integrated development must take place in harmony with clearly defined development goals and using existing governmental agencies and policy instruments and the capacities of existing institutional infrastructures, creating new entities only where necessary.

The development of informatics must be set within the broader framework of a national policy for economic and industrial development. The need for special and careful consideration of informatics arises because it cuts across and interacts with almost all other strategic areas and sectors of a nation. A prerequisite for the success of any national strategy for informatics development will be the creation of a lively awareness at the highest levels of the value of information and of the concept of informatics as a major concept in development. If self-reliance is the first major concept in the formulation of development goals, then informatics, meaning all the problems and the infrastructures involved in the promotion of social efficiency and social intelligence, is in turn a prerequisite to self-reliance.

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