Information Technology for Development. Volume 2 Number 4.

Computer and Informatics Issues, and Policy for Third World Development

Mohan Munasinghe* World Bank, Washington DC

Abstract

This paper explains why the microelectronics and computer revolution has become a subject of extraordinary importance for the developing countries, because of the rapidity of technological change and the resulting global impacts on production and consumption. It stresses that a computer and informatics strategy must be developed in the national context, rather than piecemeal, and offers a framework for policy analysis in relation to fundamental national objectives. A basic decisionmaking model for assessing the demand for computer services is developed. The paper identifies the principal technical, national, and international issues arising from the information revolution, discusses the various policy options available, and describes how a practical computer policy might be formulated and implemented in a developing country. A case study of Sri Lanka is presented, involving the successful application of this approach to computer and informatics policy analysis and implementation. Finally, the emerging consensus in the informatics and international development community is outlined, to set up a new International Centre for Computers and Informatics (ICCI), based on the network principle, that will serve the urgent needs of the developing countries in this area.

I. Introduction

There is a revolution now under way, that will fundamentally transform human society in the coming years. Fortunately, this particular revolution does not involve weapons and bloodshed—it is the result of unprecedented developments in electronics and information technology over the last three or four decades.

The biological sciences show that a living organism may occupy a viable niche within the biosphere if it is able to successfully control the three principal aspects of its interaction with the environment, represented by flows of nutrients, energy, and information (Thomas 1974). Analogously, a study of the broad sweep of human history shows that it took many millenia for mankind to evolve

* The author is Chairman, Expert Group on Computers and Informatics for Development, Third World Academy of Sciences, Trieste, Italy, and Chairman-Emeritus, Computer & Information Technology Council, Colombo, Sri Lanka.

from the nomadic hunter stage to the early farming stage (by about 8000 BC). Societies were able to devote more time to relatively sophisticated pursuits, as food gathering became more efficient. The transition from the agricultural to the industrial phase (starting around the seventeenth century), was relatively more rapid, and mainly involved the control and use of energy for manufacturing and production. The most recent era involving the development of electronics and other modern technologies began in the 1950s, and has accelerated even more sharply. It is based on increasing manipulation and mastery of information.

Each age may be represented by a typical tool or implement: the hunter's spear, the farmer's plough, the industrial worker's lathe, and the brain worker's computer. The intrinsic capability of the modern-day computer to enhance and transform our thinking power, makes it a radically new instrument compared to the hunting tools, agricultural implements and industrial machines that chiefly augmented human muscle power in earlier times. It is this difference which provides the driving force for today's information based revolution.

The recent advances in solid state technology that have given the impetus to the worldwide information revolution are impressive (Scientific American 1986). Several generations of electronic computers have passed by with increasing rapidity, starting with vacuum tube technology (around 1950), and progressing through machines based on the discrete transistor, and small-, medium-, large-, and very large-scale integrated circuits (today). Consequently, computer hardware that would have filled a room 30 years ago, would now fit into a silicon chip smaller than a pea, while power requirements have also declined correspondingly. Reliability of operation has improved by a factor of 10,000, while maintenance is much simpler. Nominal costs of microelectronic devices have declined by a factor of about 150 over this same period, and the cost decreases are even more dramatic if the effects of steady inflation over the last 30 years were netted out.

Comparable reductions in cost, and improvements in both hardware and software capability are anticipated in the coming decades (Branscomb 1986, IEEE Spectrum 1987). Parallel processing architectures now being developed promise speeds and capacibities (for certain classes of computational problems) that were hitherto only available to supercomputer users and at considerably higher costs (High Technology 1987). A sampling of exciting potential developments for the future includes the

ultrafast light computer capable of trillions of operations per second, improved very large scale integrated circuits culminating in 'molecular' switches which are a billion times smaller than comparable devices today, and new digital and optical fibre based integrated communications services and systems (IEEE Spectrum 1986).

Meanwhile, computers and communications are so closely linked that telephone companies are offering new types of computer services and computer firms are entering the communications arena. The advent of the integrated services digital network (ISDN) concept underlines the potential of computers and informatics (Kitahara 1983, NTT 1985, Pitke 1987). ISDN combines audio, data, text and video transmission facilities in a single service, that is both faster and cheaper than comparable services today. At the same time, satellite links and international networks are becoming more commonplace and cheaper, and the developing countries cannot afford to lose the opportunity of gaining access to knowledge and services outside their borders (Quartermain and Hoskins 1986, Balson et al. 1987, Budd 1987). The critical importance of the telecommunications aspects of the informatics revolution, for world development, is becoming widely recognized (ITU 1985).

Software sophistication is also growing, but not at the same pace as hardware. New algorithms and languages are being developed for parallel processors. Expert systems which seek to mimic some of the basic judgemental skills of human experts in various specialized disciplines are already available, and are steadily improving capability. Finally, there is considerable interest in both the theoretical and practical potential of artificial intelligence devices. One particularly promising area of research concerns the so-called neural networks, which consist of large numbers of simple neuron-like logic devices connected in a network. These networks appear to have intriguing and unexpected characteristics, including heuristic behaviour.

In the industrialized nations, ambitious multi-billion dollar initiatives are under way to build fifth and sixth generation computers (ICOT—Institute for New Generation Computer Technology, Japan in 1982; MCC—Microelectronics and Computer Technology Corporation, USA in 1983; and ESPRIT—European Strategic Programme for Research and Development in Information Technology, EEC in 1984). These new systems will have greatly improved performance including quasi-intelligent capabilities (CEC 1985, Feigenbaum and

McCorduck 1983, ICOT 1984, IEEE Institute 1987). While the developed countries are already deeply involved in the microelectronics and computer revolution, the developing countries are also on the brink. Whether they like it or not, third world societies and economies will be compelled to live with these new technological advances, and all their widespread implications. Either the developing countries adapt and use the knowledge to enhance their drive for socio-economic development, or they fall back even further—this is the harsh rule of survival in an increasingly competitive world marketplace.

Although the technological advances are breathtaking, our feet must remain firmly anchored on the ground. Thus, policy analysts and planners generally agree with the need to rationally and efficiently allocate the scarce financial and manpower resources available to the developing countries, so that these new technologies can be harnessed to maximize socio-economic development (Munasinghe 1983). The dramatic declines in solid state device costs offer a golden opportunity for third world countries to close the gap between the rich and poor nations, through the wise and effective use of computers.

At the same time, we should also guard against exaggerated claims and expectations—actions must match the rhetoric. Unless the benefits of computer technology are brought to the people (especially the rural masses), scepticism and disillusionment might hamper further progress in this direction, as the scientific and technocratic leadership rapidly loses its credibility. Computers need not be confined to the elite—they should be accessible to everyone.

II. Why developing countries should be concerned about computers and information technology (Munasinghe et al. 1985)

Information technology is changing the world within which developing countries struggle for economic survival and growth. This change is a matter of great significance because computers can profoundly affect the central social and economic functions of an interdependent world economy. There are also elements of truth in both the glowing prophecies of computer benefits to mankind, and dire forebodings of the turbulent effects of information technology on markets, work, and lifestyles.

There is little doubt that this technology will change every country's development opportunities. How developing countries manage the computer driven process of change will influence whether their development goals will be achieved. The structuring of that process will determine who will benefit, and in what ways, from the technology. Therefore these change processes require

systematic consideration in the formulation and implementation of national computer and informatics policy.

A. Rapid technological advances and growth of computer use

More important than the absolute size of computer related investment is the rate of change in the technology and its applications. Computer technology is not at the moment the most important problem facing any particular country. But it may well be the fastest changing component of many economies. The technology is improving and costs are falling with great rapidity, the range of applications is very broad, and the impact of the technology on the relationship between labor and non-labor costs of production is significant in many industries (Munasinghe 1986). It is the breadth of potential impact and the rate of progress of the technology (and therefore its potential near-term economic impact), rather than the current economic importance of computer applications (as measured by aggregate statistics of installed computer investment and employment in the industry), that require developing country governments to give immediate attention to the formulation and implementation of national computer policies. The formulation of a national computer and informatics policy should recognize that a subject which currently is of secondary or even tertiary importance may soon be highly significant and therefore requires monitoring, preparation, and very probably substantial investment (especially in human capital).

There is also a more basic and equally important reason for policy level consideration of information technology, that is, the need for formal recognition that computer technology is part of the common heritage of mankind, not the exclusive province of more developed countries. So long as the technology is foreign and elitist, it will be perceived as another dimension of dependency and another mechanism for manipulation and widening the gap between rich and poor. Once the technology is understood by some and used by many in the developing countries, it becomes domesticated, familiar, non-threatening, and therefore capable of being harnessed to meet one's own needs. Furthermore, innovative applications to local problems in hitherto neglected areas such as agriculture, education, energy, and health, which affect the large majority of rural and poor third world citizens may be pursued, rather than relying solely on the urban, industrial uses of micro-computers that are already well known from the experience of the developed countries (Carroll 1985,

Deer and Lauria 1985, Galvis 1987, Harsh and Weber 1985). Ensuring a nation's fullest participation in the available opportunities, requires a widespread base of human resources on which the technology and its application can be built (Resnick 1985).

Few, if any, developing countries can exploit information technology opportunities without a number of complex and difficult decisions. Such decisions are not necessarily easy to arrive at in countries beset with a multitude of urgent economic and other problems and constraints. Understanding how the technology is affecting the international economy is difficult for specialists in the field. Even gaining an appreciation for what is going on within one's own country, presents serious problems. For example, it is difficult to think about a 'computer sector' of a developing country economy in the same way one envisions an agricultural or industrial sector. Social and economic data are not organized to facilitate the observation of developments in the computer sector and their effects on society.

Not only is the sector difficult to isolate and describe, but its development can be problematic. The computer and information industry or sector is fully as complex and intricate in requirements and application (e.g., trained manpower and differentiation of products and services) as other sectors now economically far more important in most developing countries, such as industry or agriculture. Thus the sheer number of things needed to be done to lay a base for the exploitation of information technology may be substantial.

Developing countries need to commit a critical mass of human and capital resources to computer and informatics development in the near future, in order to exploit the benefits of the technology. That critical mass may have to be specially developed by deliberate policy intervention as a pre-condition of computer sector development, because normal growth driven by the existing level of economic activity and resources in the informatics sector is likely to be too slow.

The need for laying an industrial and human resource base for future computer and information technology development (rather than addressing an existing large scale computer sector base) has a significant effect on the substance and process of national policy formulation. Lacking the immediacy if not the importance of concerns in critical sectors such as agriculture industry or trade, computer and informatics policy tends to be dominated and constrained by policies in these other sectors. Thus

computer policy is now an area which must start off with the handicap of coping with given policy constraints in more mature areas. But the balancing of policy interests should be done in a way which accords due respect to the needs and future significance of computer and informatics policy concerns relative to these other sectors.

B. Basic model of demand for computer and informatics services

In order to start the process of computer and informatics policy formulation, national planners and decisionmakers need to make a preliminary assessment of the present state of computer development in a given country, and then decide on a feasible and desirable future scenario or evolutionary path for computerization. Therefore we present below, a simple aggregate model that might be useful to policymakers, to determine a set of broad indicators and parameters concerning computer-related activities in a country.

Starting from the well established microeconomic foundations of consumer theory and producer theory, it is possible to build up an aggregate economy-wide functional relationship that seeks to explain the factors underlying the demand for computer services in any given country (for details of this model, see Munasinghe 1983). Thus we may write:

$$C_t = C_t(P_t, Y_t, Z_t) \qquad (1)$$

where, in any given time period t,

C_t = the demand for computer services;
P_t = unit price of computer services;
Y_t = level of economic activity or income;
Z_t = vector of other explanatory variables, such as the population, and indices of reliability, computing speed, component size, etc.

The model is specified as simply as possible to allow for the data weaknesses in many developing countries, where it would ultimately be used. The model could be first estimated for those countries where data is relatively easy to find, e.g., USA, Japan and Europe. In the next step, some of the middle income developing countries, as well as other industrialized nations might be selected, based on data availability, e.g. Korea, Taiwan, Singapore, Brazil, India, Eastern European countries, Soviet Union, and so on.

One important goal might be to develop a set of normalized curves that would assess the market for computer services as a function of income level, with other

supply and technology-dependent factors like cost, reliability, speed and size acting as parameters. These normalized curves would give third world policymakers a feel for the size of computer markets in their countries, and the potential for computer application—even on an order of magnitude basis.

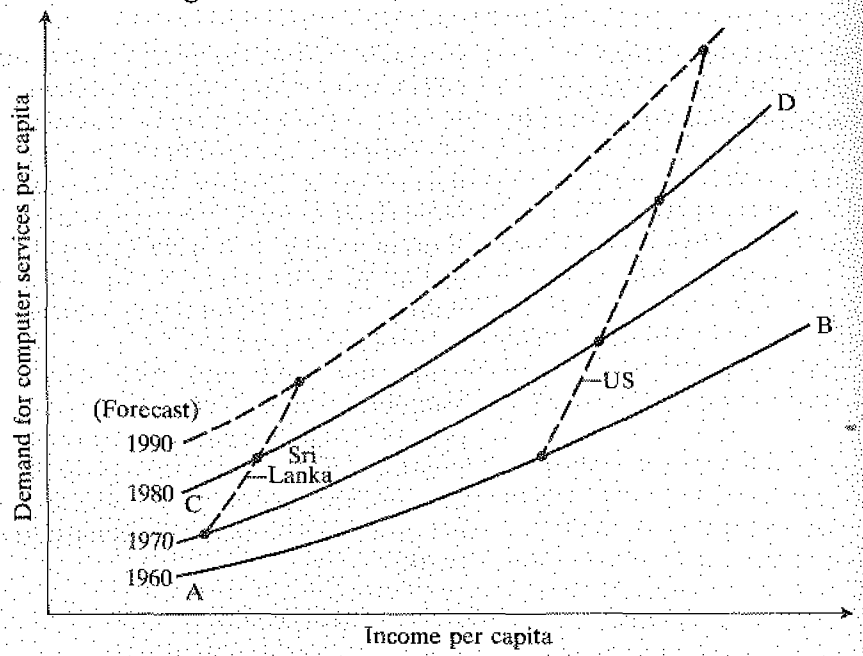

Fig. 1: Demand for computer services and income

As an illustrative example, consider Figure 1. Using an appropriate set of variables (as discussed below), equation (1) might be estimated to yield a demand-income curve such as AB. This line represents the relationship between the demand for computer services (or computer use) and income per capita (e.g., per capita GDP) in a given year—for a fixed technology and costs. Over the years, as costs fall and information technology improves, the curve might be expected to shift to the left and upwards, thus yielding other curves such as CD, parametrized by year. Another variable like the cost of computer services may also be used as the shift parameter (instead of time), but the shifting of the normalized demand-income curves over the years is intuitively easier to comprehend, and the effects of technological change are already accounted for by considering movement through time.

In Figure 1, one of the broken lines might represent the evolutionary path over time of a given country like the US. The essential point here is that a low income country like Sri Lanka, starting its computer development efforts later

in time, could achieve comparable progress much faster—because the demand-income curves have shifted upwards over the years.

Decisionmakers in a particular country might find the demand-income curve for the current year a useful datum, to assess the existing level of computer use in their nation. Furthermore, a forecast curve (e.g., 1990) could be used as a target, based on a projected future income level. Naturally, there average, parametric curves would be helpful mainly to provide a normative guide. At the same time, such a preliminary assessment could be a vital pre-requisite to effective policymaking, provided that it was supplemented by more detailed planning and policy formulation in the computer sector and applications areas. For example, one important follow-up would be to estimate the trained manpower needs, computer imports or financial requirements, to support computer applications in the future, and thereby avoid scarcities in the informatics sector acting as a constraint to socio-economic development and growth in other sectors.

We conclude this section by discussing the variables in equation (1), and problems of measurement. First, the equation might be specified in linear, log-linear, or double-log form, depending on the goodness of estimated fit, and the underlying theoretical considerations. Second, all price, cost and income variables would appear in real terms (e.g., deflated by the implicit price deflator of GDP).

The cost of computer services, C could be measured in terms of hardware or the stock of computers and associated equipment installed. Thus, one possible specification might be:

$$C_t = \sum_{i=0}^{t} dC_{i,t}$$

where $dC_{i,t} = [1 - (t - i)/L_i].dC_{i,i}$

L_i = useful life of equipment purchased in year i.

$$\text{and } dC_{i,i} = \frac{\text{(investment in computer equipment in year i)}}{\text{(price index of computer equipment in year i)}}$$

If C is measured in absolute terms, then Y would be also an aggregate quantity like GDP, while the population (POP) would also be included, on the right hand side, as an explanatory variable (i.e., in Z). If C and Y were measured in per capita terms, then POP could be eliminated. Such a

normalization would help to reduce heteroskedasticity in estimation.

The unit price of computer services, P might be measured by some index such as the cost per byte of RAM or cost per arithmetic operation or rental cost of computer hardware required to carry out a standard task.

The level of economic activity, Y would typically be GDP (or GNP). Alternatively, the shares of GDP (or GNP) from the primary (agriculture + mining), secondary (industry + manufacturing), and tertiary (services) sectors could be differentiated, since they use computer services in increasing intensity, respectively.

The vector of other variables, Z could include some of the following:

1. Population (POP), perhaps differentiated by urban/rural, literate/illiterate, or higher income/lower income.
2. Cost index of software services (PS), possibly based on wage rates of programmers and analysts.
3. Index of equipment reliability (REL), based on the probability of component failure per operations or per unit time.
4. Index of computing speed (SP), based on time per arithmetic operation or per I/O operation.
5. Index of size (V), perhaps the volume per component on a microchip or per byte of RAM.
6. Dummy variable (D) to allow for supply constraints on availability of computer equipment.

It is very likely that variables P, REL, SP, and V will be highly correlated, in which case some of them may have to be dropped, to avoid multicollinearity. Certain variables might have to appear in the lagged form.

III. Determinants of computer and informatics policy

While the potentially crucial role of computers and information technology in the development process was described earlier in general terms, it is necessary to explore more specifically the needs of the third world in this area. Given the urgency of taking steps to promote computer applications in developing countries, and the scarcity of economic resources, it is useful to identify the most important parameters, determinants and issues that decisionmakers in these nations should take into account.

A fundamental and general objective of governments is to improve the welfare and quality of life of citizens. In this respect, computers and information technology ought to

be treated like any other instrument of policy, to achieve national goals. Examples of more specific national socioeconomic objectives to be achieved include:

1. Increasing economic efficiency, growth, productivity, and employment;
2. Meeting basic needs and access to minimum levels of essential services (especially of the poor), and ensuring a more equitable income distribution;
3. Maintaining sociopolitical stability, including national security, unity, independence, self-reliance, and integrity of state institutions;
4. Preservation of cultural heritage and traditions;
5. Others (protection of environment, justice, etc.).

Unfortunately, there are many constraints and difficulties that hinder the early development and effective application of computer and informatics policies in developing countries. Some of the issues that policymakers will be called upon to address include:

A. Technical issues

1. Degree of standardization:

Rapid developments in the computer and informatics field have made it virtually impossible to adopt a systematic approach to standardization. Many aspects, including hardware, software, database design, and telecommunications standards vary widely, often making it difficult for users to benefit from each other's experiences, or communicate effectively among themselves. This results in redundancy of equipment, software and skilled manpower, as well as increased costs of rewriting programs and retraining.

Some de facto standards, such as the MS-DOS operating system for personal computers have emerged as a result of market power by a dominant supplier (IBM). However, this process is often slow and not always dependable—thus leaving users to essentially fend for themselves in unsettled conditions. Given the poor information available to most potential computer users in developing countries, the lack of standards and guidelines could quickly lead to chaotic results. On the other hand, excessive controls and inappropriate standardization by uninformed government bureaucrats may stifle initiative and give rise to higher costs due to lack of competition among suppliers.

It would be useful for developing countries to examine several issues. Should some or most standards be developed by international agreements, and if so, in which areas would this be practically possible? Would it be

possible to adopt flexible standards that facilitate software transferability, while still permitting technological innovation?

2. Adequacy of service and maintenance facilities, access to standard software, and availability of trained manpower:
After hardware is purchased, the range of support services that is usually taken for granted in the developed countries is invariably lacking in the developing world. Unavailability of spare parts, trained maintenance technicians, and standard system operating and applications software, could become an insuperable barrier. As reliance on computer and informatics technology increases (especially in the domain of time-sensitive data processing), these shortcomings could increase the vulnerability of many developing country institutions. Therefore, several questions need to be answered, such as how the developing countries might encourage suppliers of computer and informatics technology to make better support systems available, and how these countries could learn from each other's mistakes and successes.

The availability of skilled manpower is a serious problem that has several dimensions (Reiter 1986, Surjadi 1987). In most of the less advanced countries there are shortages at all levels, while in the newly industrialising nations, the difficulties stem from imbalances, where there is often an excess of lower level staff like programmers, while those with graduate degrees in computer science are in short supply (Munasinghe et al. 1985). Comprehensive computer education policies that cover the spectrum from schools to university, and also address the computer literacy needs of the general public are required. Unless there is widespread appreciation and basic understanding of computer capabilities and limitations, people are unlikely to make use of the technology as readily as they should. Countries like Singapore have had the greatest payoffs by not only adopting a systematic approach to training, but also drawing on the support of large international firms like IBM, ICL and NEC (Burstein 1984). Finally, individuals with computer skills are likely to be subject to the same brain drain phenomenon that has affected trained manpower in other sectors. Adequate salaries, good working conditions, challenging tasks, and other incentives are more likely to reduce or even reverse the brain drain, rather than attempting to prevent travel abroad (Munasinghe 1986).

3. Quality of infrastructure services and operating conditions:

Two key items of service infrastructure that could seriously affect the development of computer applications are electric power and telecommunications. Poor power supply will not only limit the reliability of computers, but also increase costs, either due to the adverse effects of uneven supply or the burden of having to purchase additional electrical equipment to protect against voltage fluctuations and blackouts.

The quality of telephone services will determine the ability for computer users to benefit from high speed, reliable data transmission facilities, both locally and long distance. While developing countries could gain significantly from the use of computers in the 'stand alone' mode, the major benefits will not be realized until networking and communications are widely available. Often, even the poorest nations have access to high quality international telecommunications services. Ironically, the weakest links in the communications chain are often the local telephone networks, where the quality of service is poorest, and significant congestion occurs.

Finally, several related issues arise with regard to the working environment that could adversely affect the performance of information technology devices, including control of temperature, dust, vibration, insect pests, and so on. The key questions are the extent to which the developing countries should invest in various aspects of service infrastructure, to improve operating conditions for computers, and conversely, the degree to which the manufacturers of computer and informatics equipment should design their devices to function normally in more difficult environments.

4. Protection of intellectual property, patents and copyrights:

The development of microcomputers provides an example of a product that has been almost exclusively a private sector venture, responding to market forces. Thus, the spread of microcomputer technology will continue to depend largely on international market forces and the business climate within individual countries. While individual governments may enter into special arrangements with computer firms, it will be the senior managers of the firms that determine their willingness to participate, and profitability will be one of the major factors influencing the decision. Will the entrepreneurial nature of computer firms make the transfer of this

technology different from other kinds of technology transfer?

The widespread and often unauthorized copying of software, as well as the cloning of hardware, have undercut the markets and profits of those who bore the original development costs and first marketed these products. At the same time, the growing competitiveness in the worldwide microcomputer market is already sending computer entrepreneurs overseas in search of new opportunities. While competition that brings down the price of computer products ultimately benefits the consumer, especially those in the developing countries, the flow of new products from risk-taking entrepreneurs will depend on the returns that they expect for their efforts (also, see the section below, on availability of products and access to markets). Developing nations might need to examine their options carefully, in the light of the rapidly evolving legislation and decisions concerning intellectual property, patents and copyrights, in many countries (Davidson 1983, Branscomb 1985).

B. National and economywide issues

1. Broad national policy, ownership and access to technology:

The overall philosophy of the government towards computers and informatics could range from a market oriented completely laissez-faire attitude, to a rigid, highly planned framework with centralized control, often dominated by security and/or bureaucratic considerations (Munasinghe and Blankstein 1985). Most nations would fall between these extremes. Some governments are tempted to place a moratorium on the acquisition of this technology until they can study it more closely. Is this wise, or even practical? Ownership of computers and access to both hardware and software are also related policy concerns, ranging from a bottom-up, user-oriented, and promotional approach to one relying more on top-down planning and controls.

Many countries have foreign exchange shortages and policies regulating what classes of goods can be imported. In these cases, government regulation already determines who can import computer systems and who will have access to them. Will usage be restricted to government agencies or state companies? Even within the government, public organizations might seek to continue maintaining centralized control over data processing, unless computer technology itself favours decentralization. If the government restricts access to computers, will parallel markets emerge selling hardware and software at inflated

prices? This would be likely to restrict access to the wealthy and keep significant local markets from developing.

Government policies on regulation or control of information also have to address a range of additional issues including privacy and abuse of both public and private data, vulnerability to sabotage of data, and the need for backup systems and information redundancy.

2. Institutional framework, sector organization and protection:

The likely impact of information technology on centralized authority is an important issue, since computerization can extend to lower levels of government, business and even individuals who have not had access to computers before. Access to information is power, and this process represents a potential power shift, at least within the government bureaucratic structure. For national governments wishing to decentralize, computers provide very useful and powerful tools. However, for governments trying to maintain central control, the very nature of the technology may serve to undermine tight central control.

It is unclear whether existing institutions could deal competently with the technical and policy issues raised by the computer and informatics revolution. Almost all countries have organizations mandated to deal with issues of science and technology. Are these organizations capable of dealing comprehensively (rather than piecemeal) with such a rapidly developing field, given that the phenomenon does not allow decisionmakers much time for study or reflection, and is virtually unprecedented?

Protection of the local computer sector, import substitution, export promotion, and self-reliance, versus cheaper and more advanced technology from abroad, and avoiding technology lags but perhaps at the cost of more dependence, are also key issues. It is unclear to what extent nations should promote the development of their own computer industries. Certain industries have historically been considered essential to national economic or security interests. Should national governments promote the computer industry in the same manner, and to what extent should they, or could they, protect the industry? Indeed, it is uncertain how a government could protect an industry at such an immature stage of development, where the direction of the technology is not yet firmly set. Protectionism might choke off the inflow of new ideas which seems to be critical to the current development of the technology. Furthermore, there are many individual components of the computer and informatics industry,

with the production of hardware constituting only one part. What aspect of the industry would a national government promote and who would make that decision? Finally, the US experience in particular indicates the vital role that small firms have played in the dynamic growth of the computer sector, whereas many third world countries tend to adopt industrial policies that discriminate against smaller businesses.

The available evidence suggests that smaller but more open economies like Korea and Taiwan are internationally competitive in computer hardware, and could account for as much as five per cent of the world market by 1990, according to some estimates (Crawford 1986). On the other hand large countries like Brazil and India that have sought to protect their fledgling local computer industries have not had much success—local products tend to be much more expensive and many years behind technologically. Unless carefully monitored, protected infant industries are invariably the ones with the best political connections, rather than the most efficient (Gillis et al. 1983). India has recently reversed much of its earlier protectionist policies, and is exploring various options to attract foreign computer companies through joint ventures and other schemes. An extreme example of the autarky is China which followed a policy of complete self-reliance until the mid-1970s, resulting in a technology that was at least one decade out-of-date (Doar and Kelly 1984). The 1980s have witnessed rapid progress in computer technology and applications, following the overall trend towards liberalization in China (Uehara 1985).

Software development in developing countries, especially for export, is an interesting prospect (Schware 1987). The demand for software (especially customised products), the relatively high development and maintenance costs in the market economies, the low wages and availability of programmers in developing countries, the emergence of international software markets and software subcontracting abroad, and specialized software needs for domestic markets, are favourable factors. However, absence of entrepreneurs as well as manpower with the requisite computer skills, inadequate capital markets and government incentives for small software firms, small local software markets, poor marketing skills, the emergence of semi-automated programming, language barriers, and competition from more advanced developing countries, could be severe drawbacks. At least in the short run, relative wage levels should offer significant comparative advantages to many developing countries.

For example, a UK or US programmer who commands a monthly salary of about US$2,500, is at a definite disadvantage with respect to his or her counterpart who commands only US$150, 450 and 800 in Sri Lanka, Philippines and Malaysia, respectively.

3. Impacts on growth, productivity and employment: The dominant trend for at least two more decades will be the increasing productivity in information technology intensive sectors, driven by decreasing costs and improved performance at the device level based on: (a) semiconductor, magnetic bubble and optical memories; (b) processing elements based on post-VLSI technology; (c) optical fibre, microwave and satellite telecommunications links; and (d) input-output devices (optical character readers, advanced keyboards, voice input devices, printers, optical displays). Further, system and application level advances (software, computer architecture, networking, and telecommunications facilities such as integrated services digital networks), as well as higher computer literacy and reduced social and cultural resistance to the use of information technology, will also increase overall economic productivity and growth.

These positive impacts on national output (i.e., the income effect) will create more jobs in the country. At the same time, the growth of the computer sector will also give rise to some employment (a direct effect); but this effect will be small unless it goes beyond the public sector to private industry and manufacturing. Finally, computer technology will have a price effect, as the reducing costs of computer services will tend to displace labour (especially production sector workers). The net impact on employment will depend on the relative weights of the three effects—income, direct, and price (Carnoy 1985).

The issue of potential labour displacement in local economies also has both long and short run implications. In the short run, the introduction of microcomputer technology is likely to increase job opportunities as new types of information processing activities are made possible. On the other hand, over the long term, microcomputer technology, particularly robotics, may have a profound impact on the structure of work and the labour force. Bound up with this is the issue of labour productivity and wage competitiveness of developing countries in the world economy, as the field of robotics develops.

Government policy should seek to maximize the benefits

of higher economic growth, while avoiding or mitigating the harsher effect of employment (Munasinghe 1986). For example, in an economy with surplus unskilled labour, but a shortage of good managers, the emphasis should be placed on improving managerial productivity by providing them with computer-based tools such as management information systems. This type of policy targetting could actually increase employment at the lower levels, to the extent that a hard pressed manager who had previously managed 20 subordinates would now be able to supervise the work of 100.

While it is not certain that all the economic impacts of computerization can be foreseen with enough clarity to allow policy makers to evaluate them, perhaps something might be learned from the changing labour structures of the more developed countries as they enter the information age (Leontieff and Duchin 1986). A particular country that had no intention whatsoever of introducing robots into its own labour surplus economy, would still be well advised to monitor world trends and developments in industrial automation. This would serve at least as a defensive measure, to help avoid investments in activities where the advantageous of indigeneous low cost labour might be quickly eroded by cheaper robot based production abroad.

4. Social and cultural effects and constraints:

If computer and information technology are viewed as cultural artifacts, they could cause unforseen long term social and cultural transformations, as for example, the automobile and television have already done (Textor 1985). It is unclear whether information technology would strengthen or disrupt cultural and social structures within developing countries. Also, since computers and software are by and large designed and manufactured in developed countries, could they reflect and reinforce socio-cultural biases that are alien to developing countries, and is it possible to gauge the impact of such biases within those countries?

Command of information technology will shift power among individuals and groups, and create new elites, modes of behaviour, and traditions. A prudent policy might seek to use the technology to decrease the income disparities and dualism that characterize most developing societies, thereby reducing social tensions and fears (some of them caused by information technology itself). Finally, allowance will have to be made for sociocultural

constraints, including religious preferences, gender based roles and differentiation, language, and attitude to change.

C. International issues

1. Transborder data flows:
The transfer of information across national boundaries is already causing considerable concern among developing countries, as individuals, companies and multinational enterprises increasingly use global communications links. The tradeoff between security concerns (covering all kinds of sensitive information ranging from military to economic data), and the increased efficiency inherent in freer information flows, needs to be defined and analysed.

Some priority issues that need to be addressed include the question of who owns the data, and whether developing countries have the right (or the capability) to control information vital to their interests, even if corporations, individuals or institutions claim a similar interest or a prior right to the information? These questions are made more immediate by the ease with which computers, including microcomputers, can manipulate, store and transmit information. It is possible, but by no means certain, that the proliferation of computer technology will reduce the ability of countries to control the flow of information across their borders.

Another related question is who will control the flow of data within a country, and across national borders? This issue is closely related to the problem of access noted earlier. Information technology makes the exchange of data very easy and cheap. In the US, microcomputer users form extensive networks for the exchange of information and software, typically violating all manner of copyright laws. At the same time, this free flow of information has been central to the development of new software and new applications, greatly enhancing the benefits and usefulness of the technology. Some researchers have warned that the rapidity of both data and financial transfers is inherently destabilising, as multinational banks shift large sums in lockstep, leading to major unpredictable international capital movements, currency instability, and other strains on the world economy (Wachtel 1986). Such flows are essentially beyond the control of even the most powerful governments.

2. Availability of products and access to markets:
The availability of the latest technology is an important issue, that depends on the relationship between, and attitudes of, developing countries who constitute the market, and the multinationals who control and sell the

products worldwide. The type of technology made available to developing countries is also a major area of concern, determined by both the design of the technology, and the ease with which it can flow across national borders.

The design question centres on the target group of users. For example, currently available microcomputer hardware and software have been designed primarily for US businesses and individual consumers. The flexibility required to serve these two groups has produced systems that are also useful in developing country applications, but the latter has not been the primary consideration. Do current design criteria adequately meet the needs of developing country applications (see the earlier section on technical issues), and if not, how uniform are those needs across the third world and how should they be met?

Control of the flow of technology across national borders is the second aspect of the availability issue. Many countries already control the importation of foreign technology. Technology exporting countries may also move to restrict the outflow of information technology, as the US Government is now doing, on the grounds of protecting national security. It is difficult to determine whether these controls are legitimate or effective, and the extent to which they are harmful to the interests of developing countries.

Agreements on licencing, joint ventures, patents, copyrights, dumping of products, and protection of the local computer industry through restrictions and tariffs constitute a few of the related problems to be addressed. For example, do international copyright and patent agreements, or the absence thereof, encourage or discourage computer manufacturers and software developers from distributing and supporting their products in developing countries? Software publishers in particular might be leery of circulating their product in a region where unauthorized copies might be made and distributed, without hope of legal retaliation. Stronger agreements might encourage not only the distribution of equipment and software in LDCs, but also the development of systems and programs targeted more precisely to the needs of these countries.

3. Potential for greater south–north dependency:
A longer term issue concerns the establishment of new forms of south–north dependency caused by the introduction of, and over-reliance on, computers. The developing countries' attitudes towards self-reliance and self-respect versus learning from abroad are likely to vary,

and will have to be clarified on a case by case basis. In the absence of a local computer industry, it is not clear whether the introduction of computer technology will increase or decrease south–north dependency, i.e. the reliance of third world countries on the physical and informational resources of the developed world. For example, the use of computers within a developing country might suggest dependence on software and peripherals manufactured in developed nations, but conversely, the use of this technology in the third world could decrease the reliance of the latter on the industrialized nations, for information and data-processing services.

4. Role of the aid donors:
The role of aid donors and the way in which they could be most useful to the developing countries in the informatics area during the coming decades is still unclear. At present, much of the importation of microcomputer systems is done with donor agency funding. At the same time, these agencies are also trying to develop internal policies dealing with the acquisition of computer systems. Do these agencies have a useful and legitimate role beyond funding the acquisition of hardware and software?

Donor agencies currently treat computers and information technology as a tool that supports projects in other traditional aid receiving sectors such as agriculture, energy, health and transport. It would be an important step forward if they were able to recognize informatics as a new and important sector in itself, and therefore subject it to integrated rather than piecemeal or ad hoc analysis.

IV. Sri Lanka – A case study of computer policy development

After having discussed the main policy issues in broad terms, it is helpful to illustrate how some of these general considerations might be applied in practice, by examining the specifics of computer and informatics policy development in one developing country. In the case of Sri Lanka, the information revolution was viewed more with optimism and hope, rather than dismay. Since the early 1980s, the President of Sri Lanka had pointed out in clear and convincing terms that science and technology must play a key role in national development. Consequently, those entrusted with the task of policy development approached their task with confidence, believing that the systematic and careful analysis of issues and formulation of enlightened policies would permit Sri Lanka to take maximum advantage of modern technology.

In 1982, President Jayewardene set up the Computer

Policy Committee (COMPOL), to prepare a national policy framework (Munasinghe 1983). Following the recommendations of COMPOL, the Computer and Information Technology Council (CINTEC) was created (in early 1984) by an Act of Parliament, as the apex body, to formulate, coordinate and implement policy in the computer and informatics area (Parliament of Sri Lanka 1984). In developing and executing policy, CINTEC works in close collaboration with many institutions including the Ministries of Higher Education, Education, Posts and Telecommunications, and Industries and Scientific Affairs, the Natural Resources Energy and Science Authority, several designated Centres of Excellence, the Computer Society of Sri Lanka, and other governmental and non-governmental bodies.

CINTEC which functions directly under the President, has followed the COMPOL policy recommendations, and successfully provided a guiding framework within which Sri Lanka public and private sector institutions in the computer field can develop and interact fruitfully, without unnecessary duplication, wastage of scarce resources, and policy conflicts. The emphasis has been on promotion, encouragement and coordination, rather than controls and regulations that can stifle initiative. For example, one of the first successes achieved, shortly after the creation of CINTEC, was the reduction of import duties on computer products, to a nominal five per cent.

Sri Lanka had less than one hundred computers at the end of the 1970s and no formal computer training courses—a disappointingly poor performance, even for a small low income country (1985 population about 16 million, and GDP per capita about US$400 per year). However, today there are thousands of microcomputers, hundreds of larger systems, three university computer science departments, microprocessor laboratories in eight of nine universities, and microcomputers in more than 300 secondary schools. Government departments, banks and private businesses are being steadily computerized, and the national telecommunications system is being modernized. This progress has been achieved because of the successful introduction of national policy guidelines which encourage application of information technology through systematic analysis and planning in the different parts of the public sector, and by allowing considerable initiative on the part of the businesses and private individuals.

In spite of this rapid growth, the use of computers in Sri Lanka is still in its infancy, both in terms of the number of systems installed and their level of sophistication.

However, the success of CINTEC has reinforced the conviction that, given the support and guidance of the Government and a commitment of resources that are very modest in terms of an overall national investment programme, the resulting developments in computers and information technology would bring about significant improvements in other sectors of the economy.

A. National objectives and computer policy guidelines

The following broad national policy objectives were identified in the National Computer Policy Committee's report of April 1983 and subsequently approved by the Government of Sri Lanka.

(a) Harness computer technology in all its aspects for the benefit of the people of Sri Lanka and to further the socio-economic development of the nation.
(b) Promote and guide the development of computer-related resources and their application in order to anticipate and meet the future needs of the national economy.
(c) Enhance and supplement manpower resources and increase the efficiency and productivity of management and workers at all possible levels.
(d) Improve the quality of life of the people of Sri Lanka, including the job satisfaction and working conditions of employees.
(e) Increase the flexibility and dynamism of Sri Lankan society to enable it to successfully meet the challenges of the future arising from the ever increasing pace of world-wide scientific and technological advances.

In order to meet these objectives, the following initial set of national policy guidelines were drafted. They are subejct to appropriate revision and updating in the future, on a regular basis.

(a) Acquisition:
Potential users should be encouraged to treat the acquisition of a computer and/or related items as any other investment, including clear-cut identification of computer needs and technical, economic and financial evaluation of the project. Government imposed regulations, rules or financial disincentives that would restrict or delay purchasing of computers and related items should be minimized wherever possible.

(b) Utilization and access:
Sharing of computer hardware, software and data

resources should be promoted. Computer installations should be fully utilized by permitting access to users during as many hours of the day as possible. However, it would be undesirable and impracticable for the Government to attempt to compel owners of computer facilities to share their resources. Interchange of information among different users should be promoted, regarding available computer hardware and software resources.

(c) Promotion of computer education, literacy, appreciation, and applications:
The Government should improve computer-related skills and promote their application as widely as possible, especially in the following areas: scientific analysis, higher education, industry, business and financial management, and schools. Particular attention should be paid to identifying and encouraging the application of computers in the public sector. Efforts should be made to ensure adequate financial incentives and job satisfaction, in order to attract and retain the services of computer personnel in Sri Lanka. The establishment of norms and standards for computer education and training should also have high priority. Computer literacy and appreciation of the potential of computers among the general public should be increased.

(d) Self-reliance and export of computer services:
Efforts should be made to make the country as self-reliant as possible in computer skills, to establish a sound indigenous capability to evaluate and acquire foreign computer technology when necessary, and also to export computer services (both software and hardware, especially assembled products).

(e) Computer-related infrastructure and legal environment:
The Government should give high priority to improving infrastructural facilities that are essential for developing computer use in Sri Lanka, including local and overseas telecommunications services and electricity supply. An adequate legal environment should also be created which recognizes the role of computers, as well as their impact on society.

(f) Other areas related to computers:
Developments in areas related to computers such as satellite communications, other telecommunications and robotics, should be closely monitored and adapted for

application in Sri Lanka whenever appropriate, by both the Government and other interested groups.

B. Computer development scenario

A desirable and practicably achievable scenario for computer development in Sri Lanka can be examined. In the short run (up to three years), Sri Lanka expects progressive gains in productive efficiency of private and especially public sector organizations, through the use of computers in those areas where management skills are scarce. They will enable the intellectual community to enhance their contribution to national development. The initiation of a major effort in computer education which will encompass schools, universities, industry and commerce, and the general public, is already under way.

It is hoped that the medium-term (five to ten years) might lead to the development of Sri Lanka as an Asian service centre for computerized international banking and trade. Sri Lanka's assets include the attractive economic policies of the Government, a stable climate for investment, convenient geographic location, highly educated manpower base and acceptability among all countries in the region. During this period, the development of more decentralized domestic institutions to meet the needs of administration, finance, production, and exchange of goods and services will be pursued. This would provide an additional impetus for entrepreneurial activities more in keeping with national character and temperament. By this time, the carefully nurtured centres of excellence would be making significant contributions.

In the long run, towards the turn of the century, Sri Lanka is aiming for a systematic transformation of the economy. It is possible for the country to move rapidly from the agricultural to the services-oriented stage of economic development while avoiding some of the worst aspects of the intermediate heavy-industry stage with its accompanying environmental pollution and urban slums. Concentration on industries that are knowledge-intensive and efficient in the use of scarce resources will contribute to the achievement of these goals.

C. Organization of the computer sector and policy implementation

The means by which the scenario outlined above might be achieved is described next. The overall organization of the computer sector is shown in Figure 2. The policy formulation and implementation has been guided and led by CINTEC, but the degree of success achieved so far would not have been possible without the coordinated response of many public and private organizations and individuals.

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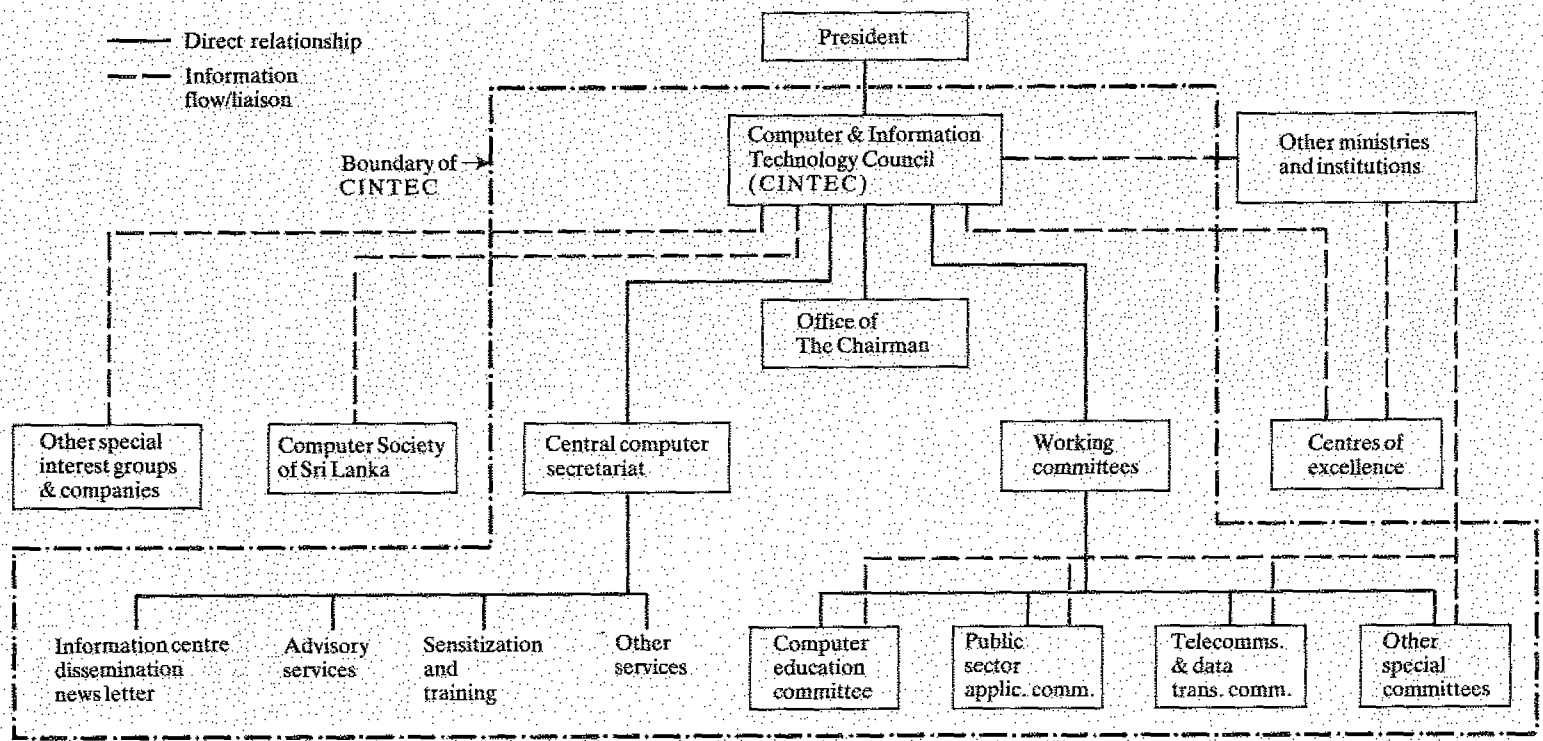

Fig. 2: Role of CINTEC in the computer sector in Sri Lanka

There are several CINTEC standing committees in key areas like computer education, public sector applications, and telecommunications, that work closely with all types of potential users, to establish priorities and policies that will promote and simplify the application of computers and information technology. There are also over 15 user groups and committees, sponsored by and loosely affiliated to CINTEC, in sectors such as accounting, agriculture, energy, engineering, health, language, and law. These groups are helping to bring together, businessmen, professionals, academics and private users, to solve common problems and share experiences. CINTEC has organized and supported a large number of international, national and local conferences and training seminars. It also provides advisory services to potential computer and information technology users, and disseminates useful information through various publications and the mass media.

CINTEC is supporting the growth and development of several Centres of Excellence, and has also established channels of communication with the Computer Society of Sri Lanka, computer vendors, and other private special interest groups and companies. Such non-governmental bodies are playing a key role in assisting CINTEC, especially in areas such as:

(a) Establishing and maintaining a code of conduct for computer professionals;
(b) Maintaining the standards of computer education among private organizations;
(c) Providing a regular forum for exchanging ideas and information dissemination in Sri Lanka;
(d) Helping to ensure the integrity and security of data in computer installations and to prevent abuse of privacy.

V. Framework for international collaboration in computers and informatics

While the earlier sections focussed on how individual developing countries might formulate their own computer policies, we discuss below how international cooperation could help in bringing information technology to bear on development problems. At the international conference of the Third World Academy of Sciences (TWAS), in Trieste, in July 1985, the discussions led to the conclusion that developing countries should move quickly to formulate and apply computer development policies. In the same vein, a proposal to pursue the setting up of a new International Centre for Computers and Informatics (ICCI), as soon as possible, was unanimously approved

(Munsasinghe 1985). Recent dialogue in the international informatics and development community has further reinforced the consensus on the need for such a centre, based on the network principle (Dow 1987, Munasinghe 1987, Wesley-Tanaskovic 1987). World telecommunications have also recognized the important role an international centre could play, in promoting development through the application of information technology (ITU 1984).

A. Role and functions of ICCI

There are several important reasons why an International Centre for Computers and Informatics (ICCI) could play a crucial role in the development process. First, there are many aspects of informatics policy that are common to most third world countries, and ICCI could mediate and catalyse fruitful exchanges of ideas and information among these nations, thereby minimizing duplication and costly mistakes of policy. Second, there are several initiatives and projects that individual developing countries may not be able to undertake on their own, which could be done collectively through ICCI. The Centre would not only facilitate south–south collaboration, but also could actually help to identify some of the issues and problems to be examined. ICCI would provide a critical mass of analysts, researchers and implementers, essential for success in a relatively uncharted and difficult area of study. Finally, ICCI could play a vital role in acting as an intermediary between the south and north, and facilitating the mutually beneficial transfer of information technology and knowledge.

The proposed Centre's primary focus would be practical research, pilot studies and applications on the role of computers and information technology in third world development. On a preliminary basis, ICCI might provide the framework and driving force for third world computer development and application efforts in the following broad priority areas:

1. Policy analysis, formulation and implementation—comparative studies among countries, country level studies in selected developing nations, and detailed studies of applications in specific sectors.
2. Education and training—a broad range of activities focussed on skilled manpower development and promotion of computer literacy. Institution building efforts would be made especially effective by directly involving developing country collaborators, in the field.
3. Software development—both for domestic use and

export of services, with particular emphasis on rural applications. Some specific sectors with promising scope for applications include: agriculture, education, energy, health, industry, nutrition, population, transport, and urban planning.

4. Hardware and microelectronics development—although competition from the developed countries would be severe, joint efforts based on the pooling of scarce skilled manpower and financial resources of the developing countries could be very useful. Emphasis would be in areas like use of existing components, computer architecture, basic communications devices, and chip design, rather than advanced chip manufacture.
5. Dissemination of information—act as a clearing house for all types of written and electronic data in this area, produce its own publications and reports, organize and participate in meetings (face-to-face and teleconferencing). One major objective would be to facilitate and encourage the work of relatively isolated researchers in the developing countries.

While there are a number of other international and regional organizations in the computer and informatics area, they do not appear to adequately cater to all the needs of the developing countries. This is because the range of issues is so enormous, while constraints and political problems often prevent existing bodies from functioning effectively. Therefore, there would be ample room for ICCI to play a valuable role—complementing rather than duplicating the work of existing institutions.

B. An organizational framework for ICCI

ICCI could begin to function effectively, as a small core group of experts located in a developing country, acting as a coordinating point and central node of a network linking many existing or new regional and national centres in other countries. The advantages of this approach would include:

1. avoiding the high startup costs (both capital and recurrent), associated with a major new centre;
2. avoiding the need to launch yet another large international organization, given that there may be little enthusiasm for this concept at present in the international community;
3. serving the critical needs of the developing countries in this area, in a way that requires only modest initial resources, and permits the centre to build up its

programme and obtain additional resources, through proven results; and
4. using information technology itself to pioneer and prove the value of the network approach for application of science and technology in the third world. ICCI will be able to benefit from the synergistic inputs provided by many institutions and individuals, with relatively low cost and advanced telecommunications itself facilitating this relatively novel form of collaboration.

Pursuing this line of thought, the following broad outlines suggest themselves for the functioning and organization of ICCI:

1. The Centre should be an independent, international (but not necessarily an inter-governmental) body. Furthermore, it is vital to protect the autonomy of ICCI, by having an international charter and an independent Board of Governors drawn from the highest levels of the scientific and development communities, and those with practical experience in the decisionmaking process, in developing countries.
2. The Centre should respond mainly to the needs of developing countries, but ideas for study could be suggested not only by third world governments, but also non-governmental agencies, universities, bilateral and multilateral aid organizations, and other groups active in the development area. Mutually beneficial collaboration with the private sector may also be pursued, provided the interests of all parties are well specified and understood.
3. ICCI might begin with a relatively small core staff focussing on project and program development, coordination of network research and applications, providing intellectual leadership and guidance, articulation of third world needs, information dissemination, and mobilizing resources (funding and manpower). While some key activities would be the direct responsibility of ICCI, much of the work ought to be defined and carried out by associated organizations in the ICCI network. Projects and studies could be international in scope, at the national and governmental level, or involve specific institutions and individuals.
4. Three types of funding would be sought from a variety of sources:
   — seed money and longer term core support for the Centre

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Computer and Informatics Issues, and Policy for Third World Development

Article *in* Information Technology for Development · December 1987

DOI: 10.1080/02681102.1987.9627109

1 author:

Mohan Munasinghe
Munasinghe Institute for Development
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