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ABSTRACT

There is a great disparity between the information infrastructure and use of computers in developing and developed countries. With rapid innovations in computer technology, dropping prices and reduced product cycle time, the gulf of disparity will only increase with adverse economic, social, and political repercussions. This gulf can be reduced if the transfer of computer technology to developing countries were formalized and implemented. Strategies for transfer and the content of what to transfer is the subject of this paper. Also discussed and identified are the needs for research in optimum strategies for the diffusion and transfer of computer know-how and technology.

INTRODUCTION

Do developed nations have an obligation to share technology with developing countries? This question is the focus of much debate in international forums today. The "have nots" complain that only inappropriate technologies are shared, that the West is continuing a policy of colonialism by restricting the transfer of technology needed to develop economic autonomy in the third world. Groups such as ASEAN and OPEC argue that the richer nations have a moral responsibility to developing countries that should temper economic self-interest. This issue is central to North-South dialogue (Hansen, 1980).

The transfer of computer technology is one facet of the debate since computers are required by developing nations for economic planning and industrialization. How to transfer computer technology to developing countries must also be resolved. Should special hardware and software be designed or will turnkey systems suffice? What infrastructure is needed before computer technology can be absorbed? Is there an optimal transfer mechanism for countries at different levels of development?

This paper will discuss these and other problems in transferring computer technology to developing nations. Hardware and software considerations are first reviewed, followed by an examination of the human resources, transfer mechanisms, and the environment necessary for effective and efficient absorption of computer technology.

HARDWARE CONSIDERATIONS

The dramatic reduction in performance-cost ratios of computers that has occured in recent years due to advances in microtechnology would seem, at first glance, to serve the interests of developing countries. Computerized information processing is no longer priced beyond the budgets of many businesses and governments with limited resources. However, microtechnology has resulted in a loss of technological independence for many computer centers. Whereas a mainframe computer can be repaired or stripped for change on location, a faulty chip must be returned to the manufacturer. In many countries, this manufacturer is a foreign supplier. The U.S. has attached strings to purchases in the past, refusing to sell computers to Aeroflot or hardware to Charles de Gaulle for a French nuclear plant, for example. What guarantees do third world countries have that microtechnology will be exempt from political interference? To be assured of chips and access to advances in microtechnology, developing countries must either manufacture their own hardware or control foreign-owned computer companies within their frontiers.

India, with passage of the 1977 Foreign Exchange Regulatory Act requiring foreign companies to sell 60% of their equity to Indian investors, attempted the latter approach: access to advanced technology through control of foreign firms. But in response to this legislation, IBM withdrew from India, closing and selling local facilities. In computing, the expected gain proved a technological loss. Today, India relies on many vintage computers. In 1980, one-fourth of India's computers were IBM 1401s (Weiner, 1980). Many experts attribute India's background stance partly to IBM's pullout, though governmental regulations have also hampered the importation of advanced computer systems. For example, Indian firms are required to export goods or services equal in value to imported computers before being given necessary import permits, and the issuance of such permits is snarled in time consuming red tape.

Even if IBM had elected to stay, ,it is questionable whether local manufacture of micro-technology would have succeeded in India. The country lacks integration of well organized small-scale support industries with manufacturing, and has an insufficient pool of skilled technicians, experienced managers, and computer specialists. Cummins, producing engines in both India and Japan, found that it would take fifteen years to develop an 80-90% local work force to make quality engines in India, a standard reached in Japan in two years (Baranson, 1971).

Fifteen years is too long a gestation period in the field of microtechnology. The first four bit microprocessor produced in 1971 has been replaced by a 32 bit micro and more recently with the 64 bit chip; and transistor/chip density has increased by a factor of 100 in the last decade. This speed of technological advance simply outpaces the ability of many developing countries to muster resources necessary to enter this highly competitive field.

There are third world countries with miniaturized industries however. Brazil, which produces electronic digital exchanges, is one example. But to establish this industry, considerable government support and market intervention was needed. The Brazilian government purchased the required technology, then organized a research and development center to adapt the technology to local needs. The technology was later transferred to selected manufacturers[1] and sales guaranteed by segmenting the market and limiting competition.

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[1]Factors considered in the selection were percentage of Brazilian capital in firms competing for the technology and the firm's rate of "nationalization" of its products.

Some third world countries manufacture peripherals which require less skilled manpower than the production of large-scale integrated circuits, are planning to expand into microtechnology once a sufficiently large cadre exists of engineers and technicians experienced in computer systems. (See Figure 1 listing the relative manpower requirements for electro-mechanical components, integrated circuits, and large-scale circuits.) (Correa de Mattos, 1978). Taiwan, South Korea, the Phillippines, and India's SEEPZ[2] adopted this approach. In SEEPZ, Burroughs is manufacturing 20,000 matrix printers with Tata, an Indian firm, has one of the world's largest such factories.

Singapore has made the design and production of microtechnology a declared goal of economic planning. By giving governmental financial incentives to experts and companies contributing to the transfer of technology, and by endowing a $2 million chair in computer science, it hopes to acquire the technology and assist in creating the manpower base needed. With Singapore's enviable growth rate, its free market with few legislative restrictions on foreign investments, and its traditional access to British technology, the country may well succeed in the manufacture of microtechnology. But Singapore is hardly the typical developing country.

Countries that lack the capacity of producing microtechnology have no option but to buy or lease advanced computer systems from more developed nations. Obtaining hardware, however, is not the only problem third world countries face. There is also the need for software.

Software Considerations

Since software requires less R&D (research and development) and capital investment than hardware design and manufacture, and there is less need for an infrastructure of support industries, many developing countries are concentrating their limited resources on software development. Software is one area where size is not an advantage; empirical evidence shows that small teams of skilled programmers write better software than large teams because of the difficulties inherent in large group management (Brooks, 1975). By concentrating on specialized software, such as graphics, CAD/CAM or process control, developing countries can be competitive with the West while gaining experience in microtechnology (Hoffman, 1980) that might later be applied to hardware manufacture as well.

Of course, writing software necessitates a link with computer manufacturers, keeping in touch with design advances. For example, Intel's 433, a 32 bit micromainframe, must be programmed in Ada, a language being pushed by the U.S. Department of Defense but not widely known abroad at the present time. Singapore is presently posturing to develop systems software for computers manufactured by the Japanese. Indeed, many contend that given Singapore's space limitations (Singapore can only expand upward in multistoried buildings), the country is better suited to software development than hardware. Hong Kong, equally constricted, might well follow suit.

When countries do not have a software capability, they must purchase application and systems software abroad. Programs well written in a standard language typically require extra

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[2]SEEPZ stands for Santa Cruz Electronic Expert Process Zone, a free trade area with no barriers to imports or exports.

	Electro-mechanical components %	Integrated circuits %	Large-Scale circuits %
Engineers & technicians	5	10	30
Qualified workers	80	70	35
Non-qualified workers	15	20	35

Figure 1. Human resources needed for varying technologies of electronic production.

effort to become portable (Brown, 1975) and must be further nurtured through testing, conversion, and documentation. This adds considerable to the cost. Furthermore, software must be maintained while a user community is being developed. Too often transferred software is not nursed through this crucial stage.

An additional consideration is that systems designed for developed countries may be inappropriate (Forsyth, 1980; James, 1980; Stewart, 1977) for developing nations. E. F. Schumacher in Small is Beautiful and A. Toffler in The Third Wave argue for intermediate technology, technology that is designed specifically for developing countries and for the private sector. In the computer environment, an accounting system developed in the West does not necessarily fit the needs of an entrepreneur in village India (Sobczak, 1980). Most of the current third world applications fall on Nolan's first growth and learning curve, (See Figure 2) (Nolan, 1976) whereas applications in developed countries presently focus on database and integrated systems represented by the second and third learning growth curve and are now moving on to the fourth curve.

The third learning curve of integrated systems includes integration not only of the office and word processing (WP) but also of factory applications that includes computer-aided-design (CAD), computer-aided-manufacturing (CAM), process control robots, and other industrial products of micro-technology. Yet another future curve, shown in dashes in Figure 2 will be the result of telematique or technetronics, the synergism of computers and telecommunications (satellite and glass fibres) and represented by the prototype wired cities in Hi-Ovis (Japan), San Malo (France) and Ridgewood (USA). This curve will presumably absorb the fifth generation computer system with intelligence not only in its input devices but also in computing as well as intelligent and smart products for both the home and industry.

Instead of transferring advanced technology, wouldn't a simpler technology be a better utilization of the resources of developing countries? The Thai Airlines recently installed an advanced reservation system. Was this an example of misplaced priorities in a country overburdened by the development needs in other sectors of this economy? Or was it that its effect on the tourism industry and the need to

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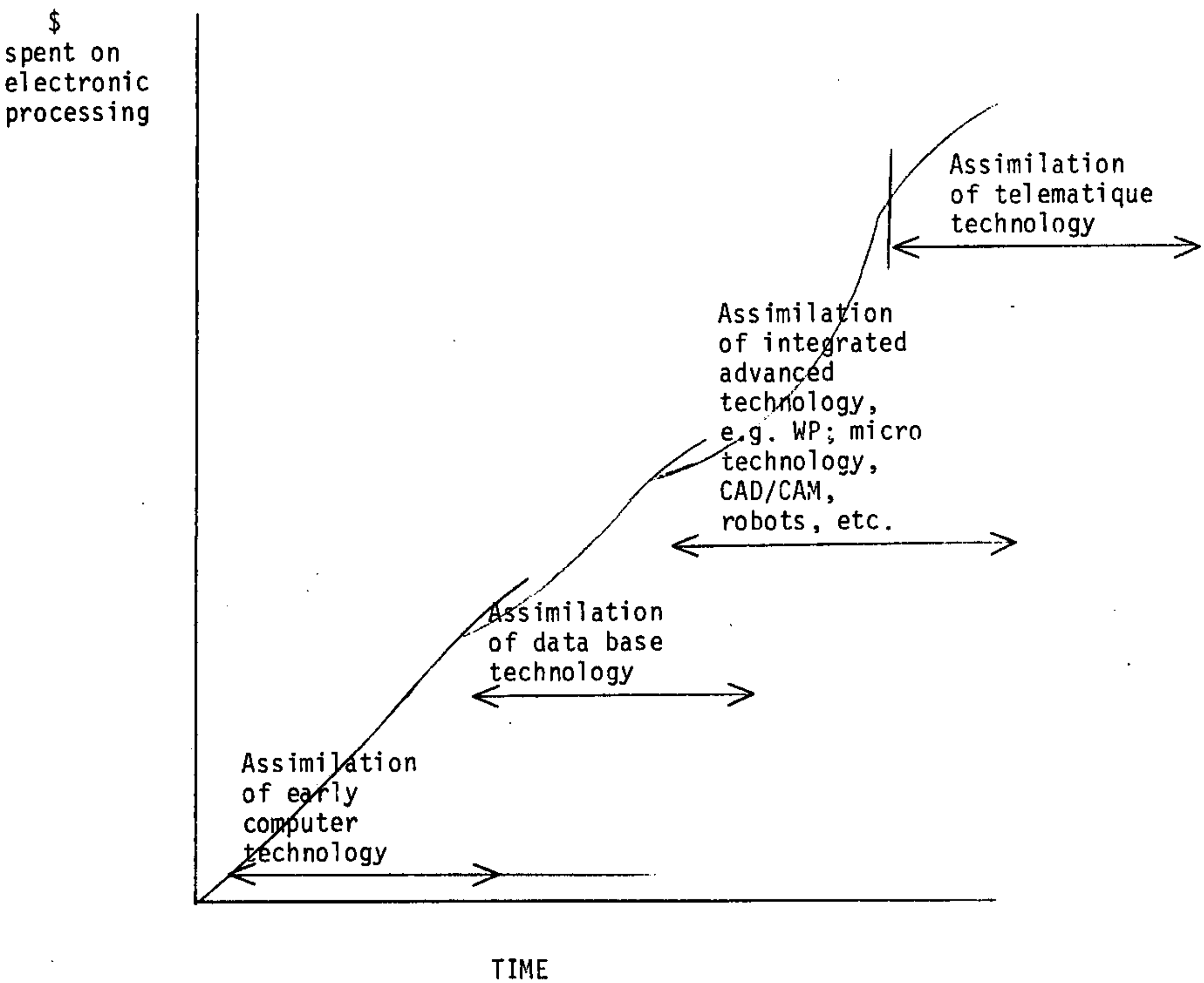

Figure 2.

be competitive were sufficient reasons to give it high priority?

Many critics warn that the existence of advanced technology is not _ipso facto_ reason for its transfer, that transfer may act against the best interests of the recipient. A software (or hardware) decision should be based on a feasibility study, in which the pros and cons of proposed systems are evaluated. In developing countries many factors taken for granted in the West must be investigated (Champine, 1978) such as a stable electrical supply, a communications infrastructure, and the availability of trained technicians. The ability of the country to absorb new technology must also be considered. For example, it took the Soviet Union thirty years to reach needed standards of quality control and plant efficiency before advanced continuous flow techniques introduced in the 1930s could be fully implemented (Granick, 1967). In addition, feasibility may be a macro decision in countries with planned economies, taking into consideration the multiplier effects as well as effects on employment and potential earnings in foreign exchange. Justification for the Thai airline reservation system might be increased tourism, which brings needed foreign currency into the country, and the creation of service jobs associated with tourism such as porters, hotel clerks, guides, maids, cooks, etc.

When a proposed system entails a distributed processing environment, the feasibility team must also examine telecommunications. Indeed, W.F. Smith and N.W.N. Jayasiri believe a telecommunications infrastructure is a prerequisite to all computer systems.

> "So important is distributed processing to the effective computer use that, in our view, developing countries are unwise to embark on computer use at all until they have first ensured that adequate telecommunication facilities will be available. When they have coped with the technology of the telecommunications, they will be ready for the technology of computers," (Smyth and Jayasari, 1980).

Access to Computer Utilities

Another problem area is the access to computer utilities both for computing power and for its databases. The developed countries with their large economies of scale have been able to offer computing power at low prices and thereby attracted computing work from developing countries. In the case of Brazil, it has been charged that the problem was worse in that the U.S. "dumped" cheap timesharing services thereby discouraging the growth of such services in Brazil. This problem, if that is what it is, will not last long because microtechnology has violated Grosch's Law and robbed large mainframes of their economic advantages of scale. But the problem of access to databases is a serious problem. The preparation and maintenance of some databases are very labor intensive such as the case of bibliographical databases where many of the keywords must be specified manually. Such informational databases are now largely in developed countries. In one recent sample, 75% of two million computer searches came from the U.S. Lockheed in 1979, had over 100 out of the 500 publicly owned databases. Such information is power and if it is economic information, it is economic power which with a little transformation can become social and political power. Even if the developed countries did not overtly and consciously exercise this power, the databases are viewed as being biased with ideological and social values that developing countries do not necessarily want. This may lead to a confrontation like one that occurred recently in UNESCO when developing countries wanted to restrict the news reporting allegedly monopolized by developed countries and the developed countries objected vehemenently against a violation of the freedom of information. If there is no resolution of this problem in the North-South dialogue, it may well be resolved by developing countries adding restrictions to the transborder flow of data into their countries. This may result in the restriction of legitimate data flow necessary for international trade to the detriment of both developed and developing countries.

The Need for Human Resources

Developing information systems is labor intensive, requiring experienced systems analysts, a scarcity in most developing countries. This leads to a fourth area of concern in discussing the transfer of computer technology: the need for computer specialists and data processing managers in countries receiving the technology. Are the human resources available for effective implementation of advanced systems?

According to a survey reported by J.A. Jordan,

> "for the moment Asian needs for hardware design, architecture, innovative systems development, and theoretical language experimentation are well met by graduates from programs in the developed countries or from the region's nascent computer science programmers," (Jordan, 1980).

But there are far too few qualified programmers and analysts, too few higher-level managers with an appreciation of the costs and benefits of computing, and a dearth of self-trained computer people that form the backbone of the user community in developing countries.

Universities in many developing countries are offering computer science courses in an effort to fill these needs. Both Hong Kong and Singapore, for example, have certification courses in system analysis. Training programs are also offered by governmental agencies such as the Philippine National Computer Center; by intergovernmental institutes such as the Asian Institute of Technology (AIT) in Bangkok; by consulting organizations such as the Hong Kong Productivity Center (Mead); and by vendors.[3] In addition, many students are sent to developed countries for degrees in computer science.

Educational programs within developing countries are often hampered by a shortage of instructors. At the University of Penang in Malaysaia for example, the Department of Computer Science had fourteen positions filled out of 26 in 1981 sending the remaining twelve to developed countries for a Masters degree. On returning, these would most likely serve their two year contract and then move into better paid jobs in industry. There is also a short supply of instructional materials in computer science written in local languages. As a result, professors are burdened with translating textbooks as handouts for students, as is the case in Chang Mai in Thailand.

Training abroad is becoming an increasingly expensive proposition. Tuition worldwide is on the rise, and subsidies are being terminated, such as Great Britain's former grant of one year free tuition to students from developing countries. In the past, New Zealand and Australia attracted many students from developing nations in the Commonwealth (36 countries fall into this group); today the tuition structure in both countries is increasing for the foreign student.

Another disadvantage is that computer science courses in the West are not geared to the special needs of students from developing countries. They face scholastic, linguistic, and social problems while abroad and on their return home often find they are unable to integrate their acquired knowledge with operations and management of local firms. A revised computer science curriculum is proposed by Ellis Horowitz of the University of Southern California for such students, integrating courses in computer science, electrial engineering and business administration, and emphasis on

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[3] IBM in 1975 offered 372 student days of customer education in Latin America.

the social and economic aspects of computing (Horowitz, 1977).

If vendors were to develop compilers in local languages, the training of computer technicians would be facilitated. But surprisingly, programmers in developing nations oppose such compilers. They feel their job security and high pay scale is based, in part, on their knowledge of English (Sterling, 1977).

Having discussed problems in the transfer of computer technology relating to hardware, software, utilities, and human resources, the process of transfer will now be described.

The Process of Transfer

The main stages in the transfer of technology are shown in Figure 3. These stages are common to all transfers and are well documented elsewhere (Anderson, 1970; Manning, 1974; Bhattasali). In surveys in the U.S., user specification (Box 2) has been identified as the most difficult state in computer projects (Goulet, 1977). Since technology of transfer typically involves the government of a developing country, both micro and macro objectives and constraints must be specified at this stage in operational terms. Case studies show that disappointment with completed projects can more often be traced to incomplete user specifications than to changed needs of the user. So, the assistance of skilled and experienced analysts in formulating user specifications cannot be overstressed.

To obtain foreign currency to pay for the transferred technology and needed import licenses, government approval of the transfer is required in most developing countries. This is often a time-consuming task, involving bureaucratic snarls, because a number of agencies such as planning departments and the Central Bank may be involved.

Generally, Western donors of computer technology are not restricted by their governments though business transactions are monitored for violations of antitrust legislation and special permits may be required if the technology has a military application. For example, cryptological devices and teleprocessing equipment require export permits in the U.S.

In pricing technology, the computer industry has been criticized as overcharging developing countries. Former President of Mexico, Luis Encheverria, voices a familiar complaint.

> "The purchase of patents and the payment of royalties is too expensive for underdeveloped countries. Scientific colonialism deepens the differences between countries and keeps the systems of international domination in existence," (Gillette, 1973).

The industry counters that high research and development costs must be recouped and that implementation of advanced systems is labor intensive, requiring the expertise of highly-paid specialists and consultants; costs which must be shared by the beneficiaries of the advanced technology. Computer manufacturers and software houses in the West are largely privately owned, responsible to stockholders, operating in a highly competitive market. Their concern is in expanding markets and improving the earning capacity of their firms. Responsiveness to requests for transfer of technology by developing countries is more often based on an awareness that economic growth and improved living will result in increased foreign trade, than on moral exhortations about the inequality in the distribution of the world's wealth.

Too often the cost of donors/developers of transferred technology is not recognized. In airline reservations,

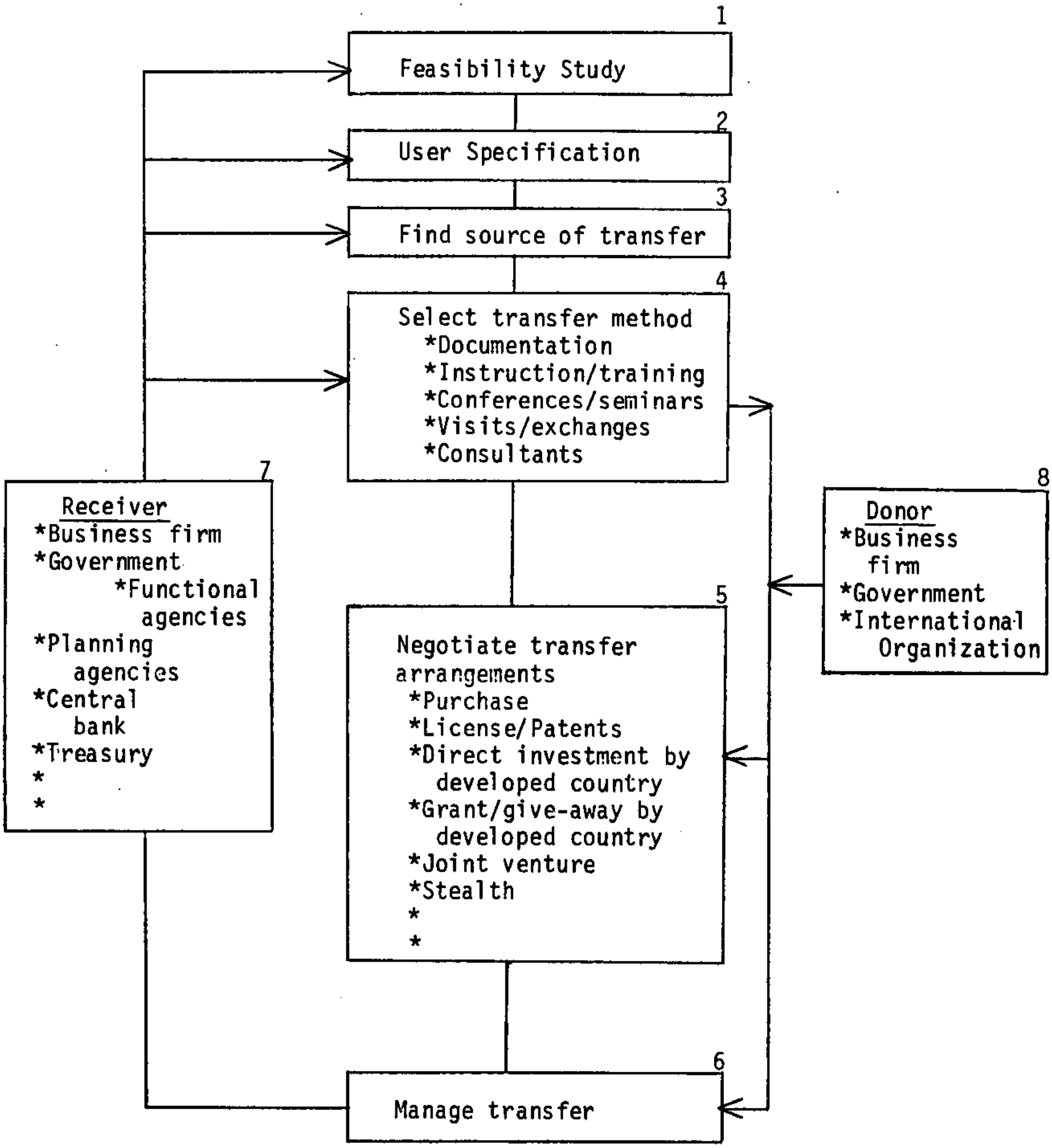

Figure 3. Process of Transfer

for example, American Airlines invested thirty million dollars in the early 1960s, TWA invested 26.5 million dollars and five years of effort before abandoning it to be involved in two years of litigation to recover some of the costs from suppliers; and United Airlines invested 99 million dollars in two separate attempts to implement their system. When the third world implements such a system, much time and effort in implementation is spared and indirectly a substantial contribution has been made by the developed countries.

Certainly patents do tend to support oligopolistic structures but patents are recognized in the West as "intellectual property," an intrinsic part of the system of property ownership (Lall, 1976). Western dominance of patents (99%) would be mitigated if more effort on research and development were expended by developing countries.

During negotiations for the transfer of technology, computer companies should not promise more than they can deliver, nor should expectations of recipients exceed a reasonable level. Both parties should recognize that computers are interactive human-machine systems, that a society's ability to absorb computer technology depends on social and cultural factors as well as technical competence. In fact, we still can't identify what conditions are essential for the successful transfer of technology "in the special environments of individual countries. This is an area where history can provide some guidance and valuable insights but certainly no authoritative answers" (Rosenberg, 1970).

Even in developed countries, advanced technology is resisted (Dalal, 1980; Canning, 1976; Kotter and Schleisinger, 1977). Familiar arguments against automation are rehashed, but in addition resistance is stiffened by the public's awe of computers. In developing nations where unemployment is a problem (both real and disguised) and a low level of computer literacy exists, the transfer of advanced technology encounters social, cultural and psychological barriers (Foster, 1973; Pool, 1971; Gruber and Marquis, 1969; Arnell, 1980) even greater than in the West. The management of the process of transfer therefore requires sensitivity and skill in human engineering. For example, technicians may need training before they are able to translate computer terms and concepts into the local vernacular. A common language might even be of greater importance than a potential donor's technical proficiency in selecting software. This might exclude the U.S. from sales in non-English speaking countries for example.

A smooth transfer of technology also requires skilled management of donor personnel. Cultural shock is common when Westerners are assigned abroad to assist with system conversion. Erratic communications, an unfamiliar labor structure, frustration over bureaucratic delays, and inner fears that a prolonged absence might mean professional obsolescence at home add to the tension inherent in all conversions. Finding technically qualified specialists who can adapt to foreign environments (Canning, 1980) and prove good teachers as well, is a major problem for donors of technology.

Macro Considerations & Policy Implications

The developing countries have a comparative advantage in low cost labor, but this is being eroded. The dislocation between artisan, agricultural, and industrial sectors is increasing. A polarization of skills is taking place. Competent technology is resulting in unemployment though the magnitude and impact is difficult to isolate because of the many side-effects.

For example, many studies and the collective judgment agree that computer technology will produce unemployment. Yet when the impact on related industries like manufacturing components and peripherals are considered, the net effect is one of positive employment, not unemployment. This is borne out by a study done in India which is summarized in Figure 4.

The positive side effects on employment are important also from the viewpoint of broadening the industrial base of the country. But then computer technology changes and so does the need for raw materials. For example, copper used in hard wire communications is being replaced by glass fibers using commonly available sand. Such substitution will alter the pattern of demand and supply and require long range forecasting as well as both long range and short range conscious planning by developing countries. They must adopt policies to counter these disclocations and economic distortions despite the painful domestic and international consequences. These policies include:

1. Assure diversified supply of computing resources. This may include buying old but still workable computing resources from developed countries at scrap value.
2. Monitoring the integration of the production of electronic parts in the national industrial policies.
3. Overcome bottlenecks in resources and labor.
4. Initiate computer literacy to increase absorption capacity of computers not only among adults for the short term but also in schools for the long term.
5. Require that imports come in technological packages that can be broken up so that its components, i.e., software, may be replaced locally.
6. Ensure that imported computing

Computer installations	9000
Manufacturing	1519
Sales	1151
Ancillary units	1000
Total employment created	12670
Employment displaced	-8000
Net increase	4670
Net increase per computer	18.4

Source: Kamta Prasad and Promod Verna: Impact of computers on employment (Delhi, India: Macmillan, 1976), p. 125.

Figure 4. Net increase in the number of jobs as a result of the use of computers.

technology and products do not include the importation of cultural patterns and values in conflict with the local cultural environment.
7. Explore regional and collective planning, forecasting and commercial policies with other developing countries.
8. Negotiate favorable agreements with developed countries.

For a successful negotiation, the other party must be willing to cooperate. The developed countries may agree to give developing countries preferential treatment in access to resources including databases. In the U.S. the technology export licenses are being toughened as part of the revised EAA (Export Administration Act) of 1979 in response to the danger of high technology leaking to the Russians. In protecting against its enemies, the Americans must not let the developing countries suffer. They should discourage and at least not encourage the electronic brain-drain from developing countries through visa and immigration control. Instead, the flow of brains to developing countries should be encouraged through financial incentives or through programs like Fullbright and even the Peace Corps. This author met an American couple (a system analyst married to a programmer) working for the Peace Corps in Fiji. But they were initially attracted to the coral and scuba diving in the pacific and were eager to return to the U.S. because they felt that they were becoming technologically obsolescent. We need more incentives for skilled personnel to want to go to developing countries.

Summary and Conclusions

In 1977, only 818 of the 188,900 general purpose computer systems in the world were within developing countries (Statistics, 1977). Most of these were functional applications corresponding to the first learning growth curve of Figure 2. The developed countries, on the other hand, are assimilating database technology and advanced computer applications as represented by the second and third growth curve with the fourth curve of technical society on the horizon. Can this gap between the "haves" and "have-nots" ever be bridged? Yes, perhaps in some cases. A developing country can leap frog, skipping growth stages to implement advanced systems when the application is stable in design, portable, and relevant to the environment, such as the airline reservation system. But most applications follow the curve, progressing slowly through all stages of growth on each curve. Even developed countries experience user resistance, technical problems and delays: the average time and cost overruns of computer projects in the West are 54% and 59% respectively (Lehman, 1969). Information system development is a labor intensive activity with progress dependent on the availability of adequate hardware, appropriate software, trained technicians, computer knowledgeable users, and an environment conducive to new high technology.

The manufacture of advanced computer systems in developing countries is not a solution to bridging the technological gap for third world countries that lack large capital (Bylinsky, 1981), assimulation of specialized labor (Rawski, 1975), the industrial infrastructure and the R&D base (Ewing, 1976; Gerstenfield, 1979) for such manufacture. Software development, however, can be written in developing countries because it is less dependent on capital or infrastructure, or even economies of scales and has a shorter gestation period. But even given software and imported hardware, information systems must be designed and implemented and there is a shortage of the needed analysts, programmers, database specialists and EDP managers. They cannot be easily bought from developed countries (Solo, 1975). They need to be trained and educated in an appropriate curricula not necessarily available in the developed countries.

More case studies (Meursinge, 1977; Teece, 1977; Hsia, 1973; Tilton, 1971; Bradbury, 1978) research is required into what effect market structure, channels of diffusion, economies of scale, government intervention, market entry condition, employment, technological assessment, financial resource levels, public policy and licensing policies have on the effective transfer and absorption of computer technology. Only then can we progress rapidly on a course that will bridge the gap in computer technology between developed and developing countries.

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