TRANSFER OF HIGH TECHNOLOGY TO DEVELOPING COUNTRIES

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SUMMARY: This paper reviews, on the basis of objectives and constraints, the characteristic problems encountered when transferring the technology associated with computerised Geographic Information Systems to developing countries.

1.0 INTRODUCTION.

High-technology is an umbrella term for that branch of advanced technology which utilizes electronics. At ITC we are particularly concerned with developing countries, and this is realised through our education, consultancy, and research programmes directed towards the resource problems of such countries. For whatever reason, these countries have chosen to move away from traditional practices; these traditional practices may refer to particular agricultural, settlement, or labour patterns. Having been asked to address the problem of high-technology transfer to developing countries, we can do so only within the context of implementing Geographic Information Systems (GIS's) in those countries which have had, hitherto, little or no experience of computer technology.

There is evidence of large investments having been made, GIS's having been acquired, and at least partially installed in many developing countries, e.g. Brazil, Colombia, Egypt, Indonesia, India, Iran, Malaysia, Mexico, Saudi Arabia, Senegal, Singapore, United Arab Emirates. There is much less evidence that the systems are functioning satisfactorily and almost none that they are contributing to national development; although this is not only a problem in developing countries. We shall try to identify those characteristics of such countries which affect high-technology transfer.

With technology transfer there are supplying organizations and a receiving organization. All parties are guided by different sets of objectives. For the supplier these are: commercial; ideological; or, political; and for the receiver: product related; educational; or, political. Thus, as in any transaction, problems will arise as supplier and receiver attempt to balance their differing objectives.

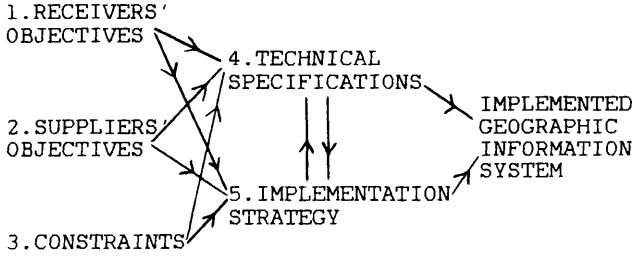
When a receiver of technology attempts to realise the objectives, certain constraints will operate which will make this task more difficult. These constraints relate to: finance; manpower; environment; location; motivation; institutional practices; and, politics.

Some developing countries are extremely poor, but, although the technology transfer may alleviate this poverty, an initial and continuing investment is required. Some other developing countries may not be poor, but their cultures (aspects of which the transferred technology will change) are not those of the

supplying country, nor, more particularly, of the countries in which the technology evolved. Thus even the non-financial constraints listed above may be very difficult to overcome.

A GIS consists of hardware, software, and manpower. Such a system will have particular technical specifications. The system will be implemented in phases over a period, or in one go. The system will be implemented by the supplier for the receiver, or through the mechanism of consultants (acting for either the supplier or the receiver), or both, with the receiver being an existing mapping organisation, government organisation, or a new specially created one with a remit in the field of GIS. The technical specifications for the system, its implementation period, and the mechanism for its implementation are all functions of: the receivers' objectives; the suppliers' objectives; and, the constraints within the receiving country. This is shown diagramatically in Figure 1. It is the purpose of this paper to address the problem of high technology transfer to developing countries, and Figure 1 will be used as a framework. We will consider each of the numbered (1-5) divisions in turn, highlight those items found in each which are, in our opinion, likely to generate problems in developing countries,and present some solutions.

Figure 1. THE FACTORS AFFECTING THE NATURE OF THE IMPLEMENTED SYSTEM



2.0 RECEIVERS' OBJECTIVES.

Lack of up-to-date human and physical environment data is a problem in developing countries. Present capabilities with respect to data collection and their use are inadequate. There is a lack of resources and trained manpower which results in a failure to meet requirements and the advocacy of computer assisted methods, which are thought (and therefore required) to reduce manpower needs.

Explosive population growth and a corresponding increase in food demand force governments to invest in vital development projects, and the tools (including planning and mapping tools) used must therefore be reliable and timely.

Critical assessment by developing countries of the environmental and social impact of technology is now quite customary, and the use of advanced data collection methods may only be advocated if they do not cause environmental and social problems.

Finally advanced information systems are often implemented because it is thought that their existence improves national or political prestige.

3.0 SUPPLIERS' OBJECTIVES.

Technology transfer is often the joint venture of several supplying organizations, which may include governments, manufacturers, educational institutions, and mapping organizations. Each of these may be guided by different sets of objectives.

One of the obvious objectives of technology transfer is immediate profit. In addition manufacturers may be interested in creating new markets. Developing countries represent an unexploited market for computer technology. Manufacturers, and other organisations such as those involved in consultancy, are eager to learn about developing countries, and accept early losses to that end. Such entrepreneurial activity may benefit developing countries in the first instance, but if it becomes combined with equipment testing, or later extreme profit taking then it becomes less beneficial.

There may be an ideological element in technology transfer, and one aim is to eliminate inequalities among nations; this may best be achieved by efficiently managing a developing country's resources. Another ideological aim is to provide help to the very poorest in a nation, often within the context of land reform. In both cases GIS may have a part to play. Less ideologically, a supplying government may wish to eliminate that poverty in one country which is seen as a threat to its own security. Technology transfer may be perceived as a means to this end. A further aim of a supplying governement may be to create work for its own under-utilized work force by funding development projects restricted to its own manufactures or requiring its own expertise (or both).

4.0 CONSTRAINTS.

We are considering seven groups of constraints.

4.1 FINANCIAL CONSTRAINTS.

Some developing countries are poor and lack resources, others are richer but dependent on a few commodities. These characteristics create economies which are prone to inflation and where money flow is unpredictable. For a poorer country dependent on aid for technology transfer a single (large or small) grant may be received for acquisition of a GIS, or several (large or small) grants may be received but be unpredictably spaced. For a country producing a valuable

commodity a fall in its price may lenghten the period over which the financial investment (whether large or small) can take place, or result in the complete cessation of further investment. When planning the installation of a GIS system an attempt must be made to predict the type of money flow, and the technical specifications and implementation strategy developed accordingly.

4.2 MANPOWER CONSTRAINTS.

Skills can be described as professional, technological, or operational. In the past skills were acquired through on-the-job training after a general secondary or tertiary education, and this approach may continue to work, even in high-technology industries, as computer awareness becomes part of the general educational package. However this model does not exist in developing countries. Computer awareness is not general. There may be a relatively large pool of academically trained personnel with professional potential, but who have had little opportunity to develop computer skills. Apart from those with an academic training there may be an extremely small pool of educated personnel. There will certainly not be a high-technology industry where on-the-job training can be acquired. Any organisation hoping to implement a computer assisted mapping system in a developing country will have to give far more consideration to manpower training than is expected in developed countries, and of course more finance.

On-the-job training has to be replaced by training courses. If the acquisition of a system has already been planned such courses have to be efficient, and must be directed to the manpower needs of the system. Professional training has always been associated with university-level institutions, and may be undergraduate (3-6 years) or postgraduate (1-4 years). But for this training to be efficient it will have to prepare its students to step immediately into decision making positions, which can only happen if students have had exposure to a very wide range of systems or the specific system they will be using, and exposure to a very wide range of mapping problems or the specific problems they will be facing. The 'very wide range' solution should be searched for, but may not be found. The 'specific' solution is found in well designed student projects carried out at institutions with the right equipment; such projects may be part of a post-graduate course. Post-graduate courses may be the best way to train professionals from developing countries, but very careful attention must be paid to selecting the course. Suitable candidates for these courses can be selected from the pool of young academics in the developing country; such people need technological and decision making capabilities and their university transcripts or references should indicate this. Their diplomas may not.

In developed countries technologist level education is associated with colleges of technology. Developing countries may be poorly supplied with such colleges. In developed countries these colleges are unlikely to provide a technologist

from a developing country with relevant project experience. However the education of these people is extremely important as they will provide, for example, the system managers. They will have to be familiar with many technical aspects of their system.

Manufacturers also provide training courses. To be useful to future technologists from developing countries such courses may have to cope with a low education level on entry. Evaluation and feed-back are extremely important. Such courses are expensive. Identifying suitable staff for technologist posts may be difficult, and may require special testing procedures or very rigourous interviewing. At the moment there is little contact between the conventional education establishments and manufacturers over the training of GIS personnel. Consideration could be given to more cooperation between the education establishments and the manufacturers in the design and supervision of projects for personnel from developing countries.

In developed countries operator level training is on the equipment staff will use, and is carried out by their eventual supervisors, or training staff working in close collaboration with the supervisors. When a system has still to be installed such training has to be replaced by courses. A course must be at an organisation using similar equipment for similar projects, and with training experience. Such an organisation may be a mapping organisation in a developed country or a suitably equipped educational institute. Such courses are unlikely to exist as standard offerings in any organisation, and will be expensive. Because of the numbers, the training of operators will be the most expensive training element for any organisation in a developing country if it is decided that a pool of trained operators have to be ready as soon as a system is installed.

4.3 ENVIRONMENTAL CONSTRAINTS.

Generally manufacturers indicate some limits related to temperature and humidity beyond which their equipment is not guaranteed to function. The natural environment in many developing countries does not fall within these limits, thus if users are going to adhere to their guarantee conditions, air conditioning will have to be used. This is an expense additional to the actual system. It may be in the manufacturer's interest to ascertain whether the environmental limits are too strict.

Wildlife in the form of ants and rats
may present problems which have implications not found in developed countries.

Many developing countries do not suffer from the extremes of cold found in developed countries, and their building construction is lighter. Without additional investment in construction, workspaces may be prone to roof leakage and vibration.

Dust is a characteristic of developing countries, and uncontrolled can affect the surfaces of storage media.

Finally, variable electrical power supply can be damaging to computer systems, and this is a common problem in developing countries. Extra investment may be required.

4.4 LOCATIONAL CONSTRAINTS.

Developing countries are often located far from equipment manufacturers. Long distances present a risk to manufacturers, and only those with good capital reserves can afford to be interested in such markets. This leads to a lack of competition, and prices higher than those found in developed countries. The prices for computer assisted mapping equipment are also extremely high relative to local prices for other goods. These high equipment prices compared to locally low labour costs create an unfavourable cost-benefit situation for high technology and make such purchases unattractive. So the number of sales remains low, further discouraging competition in the market-place and thus continuing the cycle. In consequence initial investment costs are high, stay high, and cannot easily be met. Elimination of this problem is difficult. Funds are often short and loans (or at least their repayment) may further widen the economic gap between industrialised and developing countries, and this gap created problems in the first place. Grants are only a temporary remedy because they occur infrequently, may not include follow up, and in times of economic depression in donor countries, may cease altogether.

Even when equipment has been successfully installed the location of developing countries causes difficulties in equipment maintenance. Because of distance repairmen's visits are expensive. Cases are known where users have had to wait a whole year for a repair, leaving the equipment idle the whole time. Manufacturers are encouraged to establish local representatives only if they can expect a financial benefit. Most hardware required for GIS is not yet commonplace in developing countries (in any application), so an attractive number of sales is not possible, and local representatives are not established.

However the reliability of computer equipment has been improving and this development is expected to continue. Central processing units, digitizers, plotters, printers, Winchester disks and drives, floppy disks and drives are all expected to give long service with minimal repair. Hard disks and drives, alphanumeric and graphic screens, magnetic tape units, and interfaces fail more often, but the repair may consist mainly of diagnosis and the replacement of the faulty part. Often difficulties occur when various equipment items are not under the responsibility of one manufacturer, or when interfacing between items from different manufacturers is new and insufficiently tested. But there is some hope for improvement. First of all insufficiently tested interfaces should not be incorporated into the acquired equipment. Manufacturers should be encouraged to standardize and improve diagnostic procedures so that users may easily complete them with little (e.g. only telephone) or no help from the manufacturer, and replace any faulty part themselves. An unfavourable aspect of th s procedure is that the user is obliged to keep a rather large stock of spare parts, making investment costs higher. A possible solution is the use of express delivery services from the manufacturers' stocks, but this increases costs too.

Special problems are created by software "bugs", which, although less serious than hardware problems, are much more difficult to repair, because the user is denied access to the source programs. The problem of software "bugs" is world-wide, but the isolated location of developing countries makes it more serious for them. It is difficult to imagine that manufacturers will change their protective attitude towards software, although new techniques have been developed which enable alterations directly to the executable versions of programs. The way to avoid the problem of "bugs" is to use only software which has been extensively tested in practice, but this will exclude the use of the newest programs.

Obviously the best solution for maintenance is to make the staff at the location in a developing country more self-sufficient, so that they can execute repairs on their own. This again stresses the central role of education, and of training in computer related skills.

For more efficient maintenance in developing countries it could be recommended that all computer using organizations situated close to each other combine their efforts. But it is questionable whether this will be possible in practice, because of the variety of equipment and organizational problems.

4.5 MOTIVATIONAL CONSTRAINTS.

Another obstacle which makes the transfer of technology difficult and which jeopardizes its application once it has been transferred, is the low motivation of employees in developing countries. Low salaries are the most serious reason for lack of motivation. The employees are forced to search for various sources of income and acquire several jobs. They cannot devote sufficient attention to any single one of them, and this has consequences when the application of new technology is involved. Very often even the simplest means of motivating staff are missing, such as promotion and achievement recognition. Finally the failure to meet objectives in any particular project causes cynicism, a feeling of purposelessness, and is thus demotivating.

It seems rather easy to recommend measures that will improve motivation among employees, but their successful execution requires major changes in the economic conditions and the social structure of developing countries. Increasing salaries only for the staff dealing with high technology will create a new technological elite. Motivated consultants are a temporary solution.

4.6 INSTITUTIONAL CONSTRAINTS.

Institutional practices in developing countries generate many constraints for technology transfer. Corrupton is the most serious of these. Although a worldwide problem, the extent of corruption in developing countries must make it a matter for concern. Through corrupt practices unqualified and incompetent, but often influential individuals may be drawn into the ranks of

the civil service. Such executive officers surround themselves with relatives and friends, or other corrupt individuals, instead of surrounding themselves with qualified and efficient staff. Corrupt customs and bribery slow down the acquisition of equipment, make it additionally expensive and prevent normal selection procedures. The result is obviously the late delivery of expensive and often unsuitable equipment. In contrast to the private sector corruption in the public sector is often publicised, and this creates the false impression that it is only active in the public sector.

Another completely different problem is the drain of qualified personnel due to the very early retirement age permitted in many countries. In such a way qualified and experienced staff end their career just when they are in a position to be most useful.

Governments in developing countries often assume an increasing number of responsibilities in order to promote development. If the social structure is reasonably democratic this may create multi-level bureaucracies, which inevitably function slowly. To avoid this independent government groups directly responsible to a minister or even head of state may be created. Such groups (although perhaps suitable for experimental work) are prone to exploitation by empire builders, who will not easily cooperate with other groups in similar fields. Regardless of the structure in the civil service, organisations are established within the public sector which are not required to function as effectively as they might if exposed to all market forces and apart from the excessive bureaucracy and empire building already mentioned autocratic decision making and a lack of power delegation may go unchecked, reduce efficiency, and increase costs - thereby limiting the exploitation of high technology.

A final institutional characteristic is that there may be an excessive number of managerial staff with no technical function, but having a requirement to be involved in technological developments. Their involvement also increases financial and time expenditures.

4.7 POLITICAL CONSTRAINTS.

Some of the political conditions in developing countries constrain technology transfer. Political instability especially undermines long-term development in many countries. High technology transfer represents long-term development. The rejection of western culture in some countries generates resistence to technology. Incompatibility between the political system of a potential supplier and the receiver of technology prevents an otherwise advisable transaction. The abuse of power in dictatorial regimes may lead to the establishment of projects for completely selfish reasons and they are thus almost doomed to fail. High technology may be considered to have military or strategic significance. The transfer of such technology may be restricted to maintain an extant military power balance.

The above mentioned political and institutional constraints may be diminished by some administrative and educational measures,

but their roots lie deep. The elimination of these "social" constraints is a formidable task and we will have to accept the development consequences for some time.

5.0 TECHNICAL SPECIFICATIONS.

The success of an implemented mapping system depends very much on good technical specifications. As shown in Figure 1 specifications are a function of suppliers' and receivers' objectives, and constraints. Careful and precise specifications for all four components of the system - space, hardware, software and manpower - are equally important.

As indicated in section 2.0, reliability is an extremely important technical specification in developing countries. This may take the form of guaranteed minimum downtime and an agreement to correct all software "bugs" found. To be an effective guarantee for hardware this will require fairly local service personnel. Good software can be serviced at a distance. Bad software can only be used by staff with considerable experience of that software and its "bugs". So called portable software may not be as portable as envisaged when non-standard peripherals are used, so portability guarantees are another aspect of reliability. GIS is a fast developing technology. New and more efficient solutions appear almost sooner than one is prepared to accept them. Because it is unlikely that an organisation in a developing country will buy a system in its entirety at one time, or because the vital nature of the problems of a developing country will always result in a demand for the best solutions, systems simply have to be flexible to permit the incorporation of future unpredicted technology.

Even a successfully implemented mapping systems may cause demotivation if it does not deliver results as stated in development policies. Individual systems may form a part of a much larger integrated GIS and therefore an individual system should be able to export and import information to and from other systems both physically and conceptually.

Specifications should also identify manpower requirements. Because sufficient qualified manpower is usually not found locally, the mechanism for training the available manpower has to be specified.

Once specifications have been established procedures for finding a suitable system commence. Compared to similar exercises in industrialised countries, an extremelly limited choice of hardware may be available for testing. The systems with good support inside the country are always preferable to otherwise superior systems with little support. This makes the selection procedure easier, but at the same time one may have to adapt the technical specifications to the available systems and make a number of compromises.

6.0 IMPLEMENTATION STRATEGY.

System implementation strategy provides guidelines for the

distribution in time of components acquisition and implementation. The components are either physical or manpower.

Considering manpower resources, an organisation may import skilled staff, or train its own people. Training may be carried out externally, or in-house. Different training approaches were discussed in 4.2, but it is our experience that training at the operator level must be given immediately before skills are implemented, or they will be lost.

Considering physical resources, an organisation may choose to implement a system in its entirety, or in modules. Modularity can be achieved in several ways. For instance it may be achieved by purchasing a "starter-system" consisting of a single graphics/alphanumeric screen; digitizing, interactive editing, and plotting software; a digitizer; a plotter (at least A3 format); some magnetic storage; and a "super-micro" central processing unit (cpu). As more funds become available this system can be upgraded in several ways. For example one can purchase an additional cpu; more graphics screens, more digitizing capability, data manipulation software; more plotting capability. If there is an element of self-funding, products will have to be sold before additional modules can be purchased. Modularity will be achieved by initially concentrating on those aspects of a system which produce saleable products.

Only countries with a large supply of assured funds at the outset of the development will be able to adopt a non-modular approach and at the same time buy an advanced (operational with high quality output) system. However such countries may opt for a modular approach for educational or managerial reasons.

Whether or not an organisation adopts a modular implementation strategy, a decison will have to be made on whether to buy the system hardware and software from one supplier, essentially a "turn-key" system, or from several suppliers. With the purchase of a "turn-key" system one is dependent on one supplier and the responsibility for servicing is therefore completely clear. However if the market in a country turns out to be particularly small for that supplier he may renege on his responsibilities, with no other supplier willing to step in, thus rendering the whole system useless. A "turn-key" system is not tailored to actual needs and may also present the operator with redundant software, and encourage a "black-box" attitude towards the system, but a timely product is guaranteed. To build a system from a variety of hardware and software (including in-house software) will be a good educational experience, take an unpredictable number of (salaried?) manhours, and definitely create hardware and software servicing problems. If a development is highly product driven, then a "turn-key" system in conjunction with a good servicing contract is advisable. An organisation may not be entirely free to choose between these various options because of financial constraints, so, very few organisations in developing countries will be able to opt freely.

Components have to be implemented in the following order (Figure 2), although looping may occur with a modular implementation strategy.

Figure 2

SYSTEM IMPLEMENTATION

	PHYSICAL COMPONENTS	MANPOWER COMPONENTS
1		planning manpower
2	space preparation	
3		systems manpower
4	hardware acquisition	
5		software manpower
6	software acquisition	
7		operations manpower
8	materials acquisition	
9		distribution manpower

7.0 CONCLUSIONS.

Technology transfer is an important issue. Attempts to realise it must be continued despite difficulties, but one must proceed selectively and cautiously. The successful implementation of technology depends not only on good technical specifications, but also on the right social, political, and institutional environment. The existing type and capacity of educational institutions in developing countries are not adequate. Education abroad is therefore unavoidable, but usually special courses are required. At the same time local educational support has to be strengthened. Educational institutions in developing countries should be provided with computer facilities to enable hands-on practical training. Special attention should also be paid to on-the-job training. The training of technologists and operators which forms the basis for the implementation of a new technology has to be given a high priority. For the long-term planning required of a GIS reliable funding must be assured.