Technical Report

INFORMATION TECHNOLOGY FOR DEVELOPING COUNTRIES : PRIORITY SECTORS AND PREFERRED TECHNOLOGY

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Information Technology for Developing Countries: Priority Sectors and Preferred Technology

J G Krishnayya

ABSTRACT

Priority areas for computer-based information systems are located in developing countries, and a preferred technology (midi-computers) is identified. After describing the priority areas where information management and information technology can make positive contributions in developing countries, the bureaucratic (managerial) infrastructure essential for their implementation is examined. Distinctions are made between the skills required for problem analysis, system design, implementation and maintenance. System design is identified as the phase most appropriate for the participation of the professional "expert".

The economics of minicomputer and communication-based systems for the priority areas of developing countries are critically examined. The conclusion is drawn that, for developing countries, microprogrammed mini-computer information processing systems offer significant advantages in cost, redundancy, maintenance, lead-time for implementation, and in the systematic growth of management skills with processing capacity. They can also be combined with microcomputer-based message-switching data-communications facilities. Examples are taken from actual situations in the Airline industry, in logistics networks for commodity distribution, and in a mixed information-retrieval and data-analysis situation.

Information Technology for Developing Countries:

Priority Sectors and Preferred Technology

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1. Priority Areas in Developing Countries for Information Management Systems.

1.0 Current usage and possibilities for change

Before identifying the priority areas for forced development, we must look at the process whereby changes take place in methods of operation in business and in government. In the business world, Information Systems evolve steadily in response to top management's need and desire for more effective control. Greater productivity from capital equipment as well as from personnel are reflected directly in profits and in a stronger competitive position. In easy steps, as "better mousetraps" are invented, the new technology is pressed into service.

In government, on the other hand, there are no simple or quick measures of performance equivalent to profit in a business. It is by no means evident to top decision makers in government which types of productivity should be or could be raised by using information technology, and how the benefits might be measured to balance the costs. A sustained search for new information-technology tools does not take place, although a salesman's initiative may result in some equipment being installed and utilized. In developed countries, however, competitive educational efforts by many manufacturers[K] have resulted in high awareness, and the greater size of governmental agencies has resulted in a considerable specialisation, infor-

Table I. Selected LDC's: Computer Sta tistics by Number & Usage (1971)

Country	Total number	Education & training (5–10%)	Inventory distribution & manufact-	Business administration	Public administration & statistics	Percent of Systems in Public Administration
Bolivia	6	1	3	1	2	38
Brazil	1,219	110	475	445	189	17
Central African Republic	3	–	–	–	3	100
Columbia	82	7	40	20	15	10
Cyprus	5	–	1	3	1	20
Fiji	6	–	–	2	4	66
Greece	175	7	38	75	55	32
Iraq	7	1	1	3	2	29
Jamaica	34	3	8	20	3	9
Kuwait	17	1	8	7	1	6
Lebanon	29	–	4	14	11	38
Madagascar	24	1	3	15	5	21
Malaysia	28	1	7	7	13	47
Morocco	52	3	–	29	20	39
Nicaragua	14	–	–	8	6	43
Singapore	34	3	5	18	8	24
Sudan	4	1	1	–	2	50
Thailand	27	4	6	2	15	55
Turkey	82	8	43	20	11	15
Upper Volta	1	–	–	–	1	100
Zaire	19	4	–	15	–	–

Source (8) Annex.1 Page 8.

Table II. Selected UDC's: Computer Statistics by Number & Size (1971)

Country (value)	Total number	Small (<$150k)	Medium (>$150k)	Large (>$500k)	Very Large (>$ 1M)
Algeria	68	31	22	5	5
Bolivia	6	6	–	–	–
Brazil	1,219	981	193	21	24
Cameroun	10	7	3	3	–
Chile	57?	na	na	na	na
Columbia	82	18	44	16	4
Ethiopia	9	8	1	–	–
India	183	177	5	1	–
Iraq	7	6	1	–	–
Iran	49	42	6	1	–
Kuwait	17	4	4	9	–
Lebanon	29	20	7	2	–
Madagascar	15	11	4	1	–
Malaysia	28	17	10	1	–
Philippines	120	na	na	na	na
Singapore	34	10	12	10	–
Sri Lanka	9	9	–	–	–
Sudan	4	4	–	–	–
Thailand	27	16	11	–	–
Tunisia	25	25	–	–	–
Turkey	82	71	7	4	–
United Arab Republic	27	na	na	na	na
United Republic of Tanzania	7	5	2	–	–
Zaire	19	11	7	1	–
Zambia	5	3	2	–	–
TOTALS for these Countries excluding Brazil and pro-rating Chile, P.I. & U.A.R.	916	644	191	70	11

Source (B) Annex 1 Page 9

mation technology at high professional levels, leading to more and more effective use of these tools.

In developing countries (l.d.c's for short), on the other hand, such competition as there is between manufacturers is exercised in ways less likely to result in greater knowhow in government.(G) To ensure that information technology is used where it can be most effective in improving efficiency and speeding development, therefore, it is necessary to spell out in advance the priority areas and consciously to deploy scarce capital and professional skills into these areas.(F) This alone will ensure that the information systems as they develop - and their associated processing and communications technology - will support, inter se, their fullest utilisation for better decision making. This synergistic gain is foregone in today's pattern of patch-work growth in information systems.

Tables I & II illustrate the distribution of computers by application and by size in some developing countries. These data appear to justify the feeling that most of the developing countries are qualitatively in the same situation with respect to computer applications though some have better access to hardware than others. If we exclude Brazil, we find that seventy per cent of the installed systems are categorised as small systems and 21% are medium - i.e. small processors equipped with discs or large processors equipped with tape only. Fewer than 8% are 'large' - i.e. big processors with disc capability. Only Brazil, Colombia and Algeria have systems costing over $1M.

Tables I & II can be looked at in two ways: First, to confirm that computer-power has indeed penetrated into ldcs on a very wide basis geographically and by now presumably has had some effect upon the thinking of potential users in these UDCs. Second, they highlight the gap between the real potential today of computer technology[J] (random-access files for effective information retrieval; on-site, on-line data capture, etc. - and the usage in ldcs.[A] Even the expectations that decision makers have of computer-power are very limited, governed as these are by the capabilities of the relatively simple punched-card and tape-oriented systems they have seen.

1.1 The economic interface with Developed Countries

The first priority area is clearly at the external economic interface[I] with the highly systematic and formatted decision and information systems of the already developed countries, their trade and financial institutions and their statistics-generating agencies.

Let us emphasise that this interface is not visualised as a oneway information transducer which takes facts from an underdeveloped country and transforms them to formats compatible with developed country systems and procedures. (This data-translation is of course necessary, particularly for generating information related to effective utilisation of foreign grants and credits.) We would, on the other hand, draw attention to the need for a mechanism whereby relevant economic data about the developed countries, about international trade and finance, become available in a convenient way to the decision-makers in the ldcs. If the LDC leaders have ready access to this information, for example on commodity prices in world markets, it will be possible for the LDC to develop and to use more effectively its own export and import strategy and to improve its bargaining position in trade and aid discussions. It is impractical to provide such an information service with a content that is uptodate except through a computer-based system designed on informatics principles,(B) one which draws also upon 'published' computer-compatible data from developed countries.

It is precisely such a system property of being on top of the current (trade) situation - rather than struggling with a hundred volumes of printed and mimeographed statistics two or more years old - that can give the ldc officials added weight to counter balance the information/analysis advantage that the advanced country delegation normally - almost inevitably - has in bilateral or multilateral discussions.

The present close coordination of many developing countries with aid giving and term-lending agencies like the U.N.D.P., I.D.A. and I.B.R.D., means that there is need, at the interface between the government of the developing country and the agency, for information formatting and translation from one context to another, conceptually in terms of sources-and-uses of funds, administratively from projects to sectors and departments, and operationally in monitoring the flow of funds and material inputs and the corresponding output measures.

assets - that is, at the management interface with capital-intensive technology. Most ldc's depend for the success of their development strategy upon the installation of infrastructure investments, and manufacturing or processing plants. In the construction phase these are usually turn key contracts for which various expatriate agencies have partial responsibility. Often they are already equipped with information subsystems. A computer-based information system for the ldc government could integrate these project sub-systems and ensure effective performance of the tasks/projects.[B]

During the operational phase, too, infrastructural investments in power, transport, irrigation, etc. must be productive. If their performance is monitored by an information system that incorporates sensitive computer programs,[L] it is possible not merely to detect early changes in efficiency but also to anticipate second-order and tertiary effects. In the case of power plants, manufacturing or processing concerns, a monitoring system is essential because of the multiplier effect of the plant. Not least, greater efficiency in utilizing the flow of raw materials is an important part of the ldc's development strategy.

1.3 The logistics of food, fuel, and major raw material flows

The logistics of food, fuel, agricultural products and other moving inventories are another area where informatics work can offer a high payoff in every ldc. In most cases, the critical problems are not in the collation or analysis of such data, but earlier, in the accurate recording of the actual transaction.[J] It is necessary to send back to the source a transcript of the computer's version of the transaction for error checking. This gets progressively more difficult as the source moves farther away from the computer.[L] It is likely, therefore that centralised facilities, such as 'national' computer centres in ldcs will not be useful for logistics management except in geographically very compact provinces or city-states.

Elsewhere, some form of 'on-line' transaction recording, or batched communication of transactions, will be necessary: it could be simulated by voice contact over the telephone or by telex message, or go in fact directly onto a 'local' computer which is a link in the information chain. The links in this network may be telephone circuits - or messengers carrying tape, diskettes, or cassettes. Through use of microcomputers for multiplexing,[E] and taking advantage of the small "steps" of investment involved in 'growing' minicomputer-system capacity, and in view of the increasing availability of peripherals for the so-called 'mini's, the pattern of the future for ldcs may well be distributed minicomputer networks for logistical applications,[B] despite the generally poor communications facilities.

1.4 Government statistics and accounts

We have identified three operational sectors of governmental decision-making where information systems and information technology will have a direct economic multiplier. Government statistical data handling today has a strong archival flavour and is often not considered to be part of the information stream.[I] This is perhaps inevitable given the primitive information technology in use. However, with better means for recording transactions and for generating information in the operational sectors, it becomes possible to upgrade selectively the treatment of historical and cumulative statistics and accounts at city or district, province and federal levels. Here we would expect that the computer-based system will not only compile statistics but also analyse, and forecast, and assist in short and medium-term planning. (C,F,I)

Statistics collection and the keeping of accounts are the oldest of governmental activities. Their patterns of working were adequate in more leisurely times. Today the environmental rates-of-change are too rapid for them. Yet, with modern information technology & information retrieval techniques, it becomes possible again to use this information tool for the policymaker, providing in an iterative manner uptodate and sufficiently well-indexed information on an ad-hoc basis. The ability to provide a view of 'alternative futures', through simple economic (or complex simulation) models, is of course an essential component here.(B)

1.5 Areas of lower priority

It is our conclusion that some 'easy-to-computerise' fields, especially in independent agencies of government, may not give as good an economic return as the areas identified above. This does raise some administrative problems because it is often easier to introduce change in a small self-contained agency rather than in an economically important one - one that is probably highly interlinked with other operating groups. In the next section we will acknowledge the importance of initial development of a 'show case' example of information technology, and it may be necessary to conduct such a pilot effort in a non priority sector. However, this will have been done with an awareness of the opportunity-cost of the scarce professional skills so used. Since the manufacturers' packages have been developed with an eye towards their major markets, it is not often that they are appropriate to developing countries' priority needs. Sales analyses and pay roll packages, for instance have been implemented first in India "because they are available" but they provided small benefits in relation to the opportunity costs of the time and manpower used to adapt them.[A]

2. **Managerial and political environment in developing countries for using information technology.**

Our approach to information technology is that it must be focussed on better decision making in order to be a catalyst for development. (C,D,F,L)

Until there are enough top government executives who know how to use information for decision making, computer capability is premature. On the other hand, once the top people are alert to the uses of information, it is the absence of an effective and accurate flow of information which handicaps them.

In the continued absence of effective information technology, unfortunately, even keen officials will fall back upon methods of decision-taking that place less reliance on the data they receive, and more on personal judgement. Therefore the building of information systems should rapidly follow the recognition of their need.

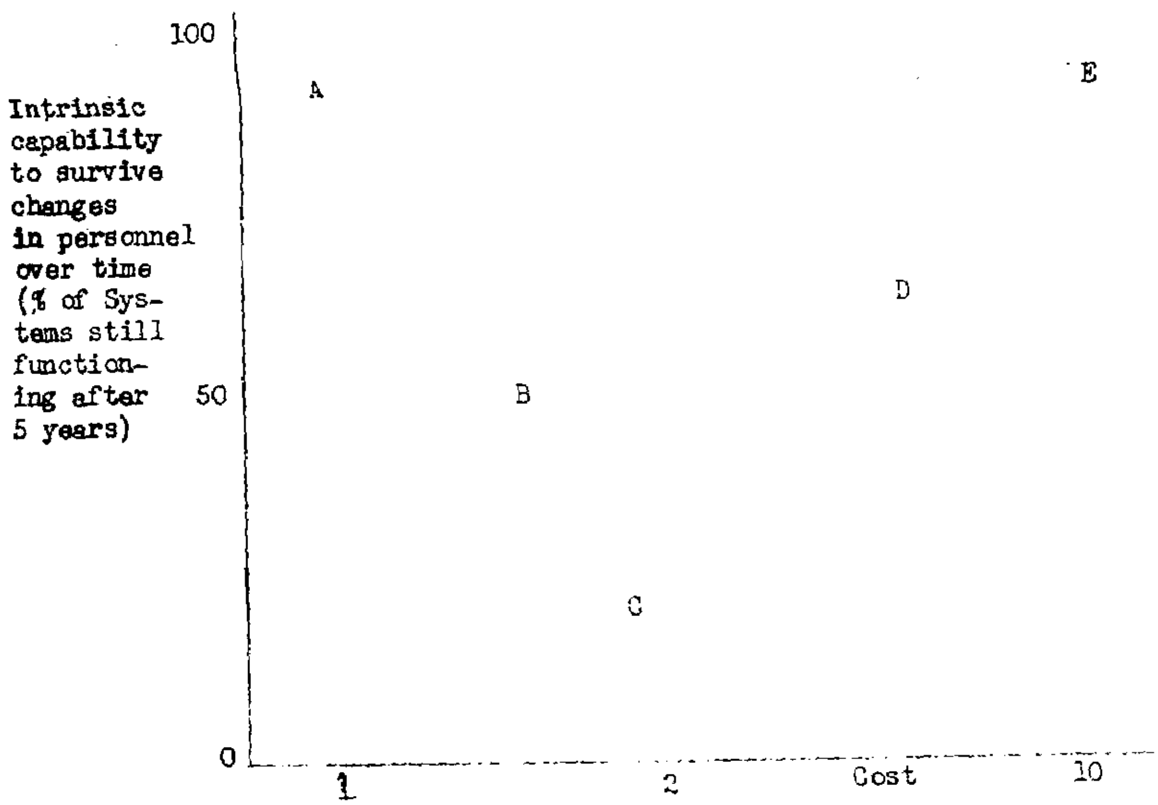

Figure 1: Cost vs Survivability of Information technologies

		Index of Sophistication
A:	Manual ledger system	1
B:	Manual ledger-card system	2 to 10
C:	Edge-punched card system	5 to 100
D:	"Unit record" Punched card system	1 to 50
E:	Computer system	5 to 1000

Most developing countries exhibit a considerable rate of change in roles at the upper echelons of the government, as new functions are recognised, new projects undertaken or new departments and agencies created. In this fluid situation there will always be some who recognise the value of good information services and who will support the design and building of information systems, and others who still need to be shown. It is precisely here that a major impact can be made by the availability, adhoc, on contract terms, of credible informatics and software skills, ready and willing to work in the ldc.(D)

In many situations a mere reformatting of red-tape-bound file bundles into alphabetised, coded and card-indexed data will constitute a dramatic improvement in information services. Especially where ready access to relevant information on a daily basis, rather than complex processing or analysis is the need, an efficiently operated <u>manual</u> "information centre" may be all that is required.(F) Unfortunately the know-how required to perceive, design, implement and maintain such manual systems may be even more scarce than the know-how that comes packaged with a computerised information system. The machine-character of a computer system provides an assurance that the procedures will be continued even if the personalities change (unlike ordinary Kardex systems, so many of which die of neglect as soon as the originator leaves). It should be said also that any successful information system - manual or machine-based-generates from its users ever more demands upon its capabilities. Therefore a <u>good</u> manual system would probably soon grow to computer size and would have had to be designed with that in mind to begin with. We suggest below that computer systems also can be small and flexible and grow by small increments.

2.0 Persons Involved

In considering how scarce skills should be deployed around an informatics project in a ldc, we need to stress perhaps that there are three types of involvement.

(a) The Users - the managers and decision makers who need, define, commission and support the project.

(b) The people who have to run it: statisticians, accountants, bureaucrats, clerks; once the system is handed over to them, they have to operate it and keep it alive and on track.

(c) The designers and implementors. We must recognise that Design talent in reference to Information System is a very scarce resource, and cannot be produced or found in the same quantity as the skills requires to run a system along set principles. Even more demanding of professional skills is designing reliable, fail-soft information systems (i.e. Those which provide some degree of service even under extreme conditions) for the ldc environment.

2.1 Commissioning Information System studies

The decision to commission work on Information Systems for a ldc government - and selecting the problem area - is essentially a political one. It will be taken when government leaders are persuaded that their leverage over economic forces (internal and external) will increase markedly through the use of informatics, and when they perceive they can afford the political costs (however slight) involved not only in generating and formalising information about their country and its economic affairs and relations, (and therefore revealing it domestically as well as abroad to some extent), but more particularly in doing so with the necessary assistance of foreign expertise and equipment. The popular view of computer systems as job-gobbling monsters may also be a hurdle. Ofcourse the priority areas stressed in this paper are frequently totally new activities, involving additional employment directly and also indirectly.

In many ldcs, including some which are otherwise sophisticated, the critical catalytic role of accurate uptodate information is not yet perceived. This perception, unfortunately, cannot be brought about by conventional marketing and educational techniques or by lectures by visiting experts, or even by writings such as the present article.

Collating a number of case studies, we now hold the view that almost the only way in which this is learnt (not taught) is by repeated personal exposure to working examples of good informatics. Often many persons in the upper echelons of a ldc are involved in the decision process leading to the adoption of a new idea. It is consequently necessary for nearly all of them to have had such learning experiences. Initially these exposures could be sponsored by a special unit of the UN office of Science and Technology (see (B)), the IBI-ICC, the OECD etc. At the earliest possible time such viewings should be held in ldcs and preferably in their own country.

Meeting the political objections to informatics based on foreign hardware and software experience is more difficult.

One possibility is for a multilateral government-owned international corporation to undertake hardware supply and support, in effect insulating a given country from the source of its hardware and operating software. This suggestion has not been taken very seriously so far, because the UN has not yet moved in a major way into informatics in ldcs.[8] It may indeed not be necessary as long as there are checks and balances built into the relations between ldcs and the very large computer manufacturers.

In a similar way, human system design skills and informatics expertise can be supplied from a multi-national source. However, such an agency may not have the flexibility and rapid response needed in this field. It is more likely that firms with software and information systems design expertise, who are interested in the ldc market, may instead internationalize their own staff and train local persons when on a job in a ldc.

2.2 System design, implementation and operation

Before taking up the mix of skills required to provide information systems, it may be useful to consider the 'necessary' condition of adequate hardware reliability and support.

Hardware maintenance is a most serious difficulty; in fact guaranteeing and providing maintenance lies on the critical path of any computer project in ldcs. The solutions lie in two directions: either by utilising hardware for which local maintenance is provided by a manufacturer or by a contractor (perhaps the consultant information systems agency itself); or by adopting a systems design and hardware strategy which is not dependent on any one component and which provides for 'fail-soft' (or gradual degradation of performance) in case of equipment failures during the time period required to diagnose the problem and to replace the necessary part. A combination of the two strategies is best; redundancy might, however, be an expensive proposition when an entire system is procured from a major manufacturer such as IBM at normal prices. Fortunately, computer technology especially at the smaller end of the spectrum has been moving in a direction which makes redundancy even in disc and tape units less expensive than it was even three years ago. (E)

Executive software systems and compilers are another 'basic' requirement. Their reliability is harder to detect than that of hardware. Hidden 'bugs' may surface after the system is in use. These can be insured against by a conservative selection among available processor suppliers, perhaps passing up the most novel system in favour of one from a manufacturer with a good track record in his software.

In the final analysis, hardware reliability through redundancy is an economic question. By examining whether the economic value of the application is high enough, we can decide if the cost to guarantee the required level of reliability can be borne.

On the other hand, in creating (or purchasing,) and deploying human design, implementation and operational skills, a number of paths are available. The decision whether these activities ought to be undertaken locally should be taken after ranking them in ascending order simply of the lead

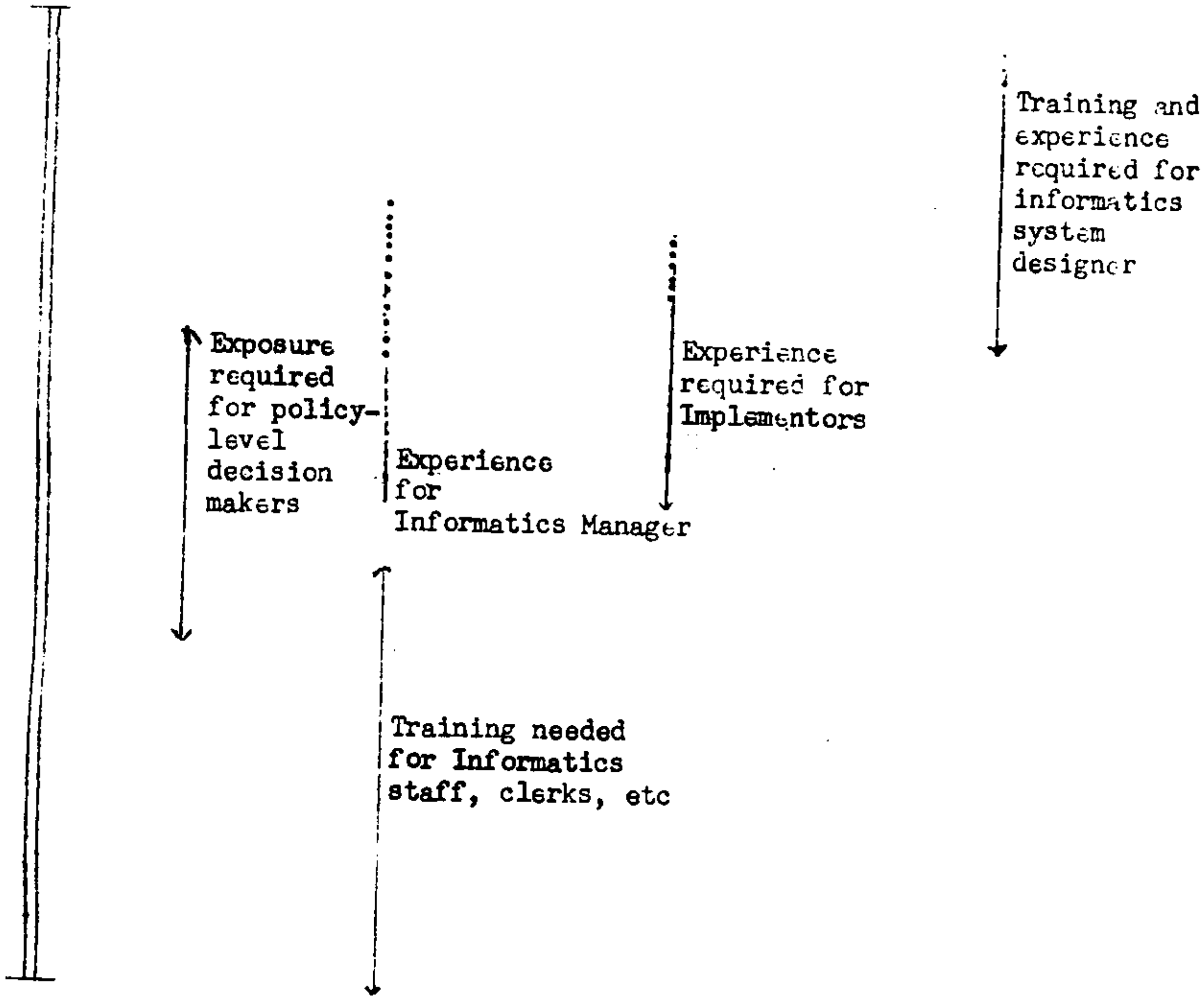

Figure 2: Lead times to acquire Informatics Skills

time required to develop those skills. In this hierarchy we find that 'design' is a more a complex task than 'management' of an information system, with system implementation and software maintenance following in order. We would therefore suggest the purchase of design skills (including the supervision of the implementation). Likewise, initially, management skills should be purchased with an 'understudy' role for the permanent manager, a member of the ldc agency, who need not at first be technically qualified. The management of a well-designed information system is much more dependent on the ability to sense and work with the environment than on technical know-how.

Two other kinds of expertise - that of the operators and users are relatively easy to develop. In fact this can be effectively built up during the time the system is being formulated, built and tested. It is important that the operators and users of the system not only understand its strengths and weaknesses, but also the procedural demands it places on its data sources. Advanced educational technology such as films, VTRs, etc. have genuine value here as having greater communicative power while conveying also element of prestige to the new system being thus introduced.

2.3 Training in Informatics

We have mentioned that 'design' skills require the longest time to develop because they imply a command over the metalanguage of information systems as well as an awareness of the user agency decision needs and priorities.

In order to build into the information system design a strong awareness of local conditions (and, equally important, of their dynamics), an expert local collaborator is necessary. Training for expertise in Informatics is not yet available in English-speaking ldcs but some efforts (F) are being made in this direction. The French program in Libreville, Gabon, is a good examples of a combined Computer Science and Informatics programme at University (undergraduate) level in sandwich form for civil servants and others. Training that takes place in developed countries is less satisfactory because of the differing priorities in curriculum and pedagogy imposed by their stage of development. An alternate method for developing expertise is for middle level professional workers - Accountants, Engineers, Army Officers or Civil Servants - from ldcs to be attached to established consulting firms for periods of 6 months to a year. They have already a good acquaintance with the administrative, economic, technical and educational environment in their country and need to absorb the facts about computers and computerised systems and to fit them into the metrix of their own working environment.

3. The Economics of Minicomputer-based systems

Computers were first used as statistical tools, and later for assisting accounting operations in large corporations, where the serial nature of their data storage was no disadvantage. Meanwhile larger computers were being developed for scientific research partly with military funding. Random access disk and drum storage attached to large fast computers provided many more economical computing than smaller stand-alone machines. There appeared to be a consensus over this through the late 1960s. (J)

Table III. Comparative Task Suitability of Midi-computer and Conventional D-P Systems

	Type of Task	Midicomputer	Conventional D-P System
(a)	On-line logging of transactions	Yes, well suited	Yes, but high overhead cos due to multiprogramming
(b)	On-line information retrieval	Yes. Usually single-purpose.	Yes; in general uses high-level language & memory larger than 512k bytes
(c)	On-line file updating	Yes	Yes, see (a)
(d)	Batched card-source file updating	Yes, for smaller volumes (upto 30,000 cards a day)	Yes. Efficient when high speed I/O balanced to processor speed
(e)	Very large scale mathematical models	No	Yes, when memory larger than 256k bytes
(f)	Medium-large mathematical models in Fortran	Yes	Yes, runs faster
(g)	Special purpose mathematical analysis	Yes, at high speed (microprogrammed using Writeable Store)	Yes, but microprogramming not possible.
Basic Nature of the techno-economics		Can be specialised to handle unbalanced job mix	Requires a balanced mix of jobs to justify large core, and multiprogramming operating system

However, for the types of 'catalytic' information processing we have identified as priority areas for developing countries, it appears that mini-computers may in fact be a more suitable system basis from economical as well as practical considerations.

3.1 Minicomputers vs Conventional Architecture

The relatively small core memories of minicomputers make them unsuitable for running large-scale mathematical models which require that large matrices be operated upon, or that differential equations be solved. These operations do not appear, however, in the priority areas chosen by us. Instead, the emphasis in our applications is on indexed information retrieval & on-line analysis, on-line capture of logistics transactions, and data processing.

The mix of compute-bound and input-output-bound jobs, which is essential to the economics of larger computers, is not available. Moreover, in developing countries, reliability through redundancy of both input-output devices and processors is a positive advantage. Two mini-based systems, each with a 300 lpm printer may be preferable to one larger, 'general purpose' computer with a 600 lpm printer. More often than not there is no cost-penalty attached to such redundancy because of the different pricing conventions and market conditions surrounding conventional computers and minicomputers.

For example, IBM's vast volume is based not just on a few mainstream data processing applications but on all kinds of application environments.

Its software and hardware features, especially the Operating Systems, are therefore built to function in a very large variety of situations. Because they are so general-purpose, they are de-tuned or less efficient for any specific situation. They are also bulkier, to allow for options that may not always be used, both in hardware and software. Typically an IBM system will require more core memory for a given set of tasks. This reflects in the capital as well as the running costs of the system. Developing countries' applications are the least likely to take advantage of all the peripheral options offered; they would nevertheless have to pay for the features built-into the processor to provide this flexibility. This is a factor in some other manufacturers' pricing policy as well as IBM's. The overhead costs -- documentation, sales promotion, sales support and training -- which form a large part of the customer price of any computer equipment benefit disproportionately the customers in the developed countries. Typically, a customer in a developing country needs only very specific equipment and supporting aids. These he - or his system designer - will go out and buy. They benefit from none of the huge expenditure on 'marketing' which is loaded onto the manufacturing cost of the machinery. Because business-machine or general-purpose computer companies spend much more money on marketing and on a very broad spectrum of applications programs, their products carry a large price burden. Minicomputer manufacturers, on the other hand, generally concentrate on providing reliable systems software alone, thus making possible a selling price which is much closer to the manufacturing cost.[H]

The technical advantage of minicomputers in developing countries include the ability to utilise a wide variety of peripheral devices of

Table IV: Elements in the Cost-to-the-owner of 'Midicomputers' and Conventional D-P Systems

Cost Factors	Midicomputers	D-P Systems
(a) Mass Production	Yes	Yes
(b) Hardware Options	Yes, available modularly	Usually built-in at hidden extra cost.
(c) Variety of Peripherals	Wide Compatibility	Closed market
(d) Hardware Maintenance	Yes, lower cost because less complex.	Yes, a major revenue item.
(e) Operating System and System Software	Yes, representing smaller investment of upto 200 man years.	Yes, representing huge investment of c.1000-5000 man years.
(f) Documentation	Yes, usually complete.	Experience mixed; systems are too general for documentation to keep up.
(g) Applications Software	Not usually.	Yes, to suit major class of customers; a big sales point & cost element.
(h) Applications Literature	Not much	Aimed at broad spectrum of developed country markets.
(i) Sales force	Minimal	A very large part of cost & mostly benefiting developed countries.
(j.) "Free" educational services	Yes, on hardware & basic software.	Yes, but mainly aimed at management, & promotional in nature.

large as well as small capacity. The possibility also of modular hardware growth in easy steps is really a managerial advantage[G] because of the opportunity to develop effective management capability in stages before making further increase in hardware capability and the consequent fixed investment. With large conventional systems there is invariably a long time between installation and full utilization because of the difficulties of learning to manage the new technology. During this time the unused capability causes psychological as well as financial burdens.

Minicomputers do provide a very wide choice of sources for the peripherals with which they can be conveniently linked. The simpler structure of their operating systems is a major advantage, also, in enabling maintenance programmers in a developing country to comprehend them sooner.

3.2 Microprogramming and on-line working

Although many conventional computer processors are microprogrammed, there is a very high cost threshold for the customer to use this facility to specialise his machine for some task. On the other hand, the facility of a Writeable Control Store is commonplace in minicomputers, and it can be taken advantage of, typically, with an investment of a few weeks of effort to facilitate some application. This facility can be important in relation to input-output operations for on-line data entry, on-line information retrieval and data communications.[J]

The ease and lower cost of attaching on-line devices to minicomputers is significant. This makes it possible to downgrade the punched-card input medium with all its associated mechanical problems, delays due to checking, and complex manual batching controls.(E) Although on-line key board terminals are by no means error-free or 100% reliable, (relative to high speed card readers) they do generate fewer mechanical failures and their low cost makes possible reliability through redundancy.

3.3 Data Communications

Because of the relatively high coverage and quality of public telecommunications services in USA and Europe, data communications systems have developed in a number of fields including on-line inventory systems (as with airline seats or railway wagons), message systems, e.g. for banks or civil aviation, and for public and private "time sharing" systems. Networks, permitting the sharing both of computing capacity and of data over long distances are now in operation.(J)

Not all of this technology is relevant, leave alone feasible in developing countries where communications are generally poor. Besides, without having previously created large machine-readable data bases, the question of sharing them does not arise. On the other hand, in the context of a specific information-communications system developed to support logistics management of critical commodities over a transportation network, it is possible to see how some of these (computer-network) concepts can be scaled to suit the application. With Minicomputers as terminal nodes and microcomputers as message switching and encoding elements, such a system can be made operationally reliable without requiring massive investments from the

PTT in new data communications facilities. Similarly, our priority fields do not reflect a demand for a US-type general-purpose time sharing system. Yet, an on-line information retrieval service within an agency/Ministry, or secretariat might prove to be a major catalyst. Similarly, a remote-batch services - in the most simple form having only a low speed card reader terminal, with printer output being hand-delivered - may effectively connect dispersed users to the processor.

In respect of data communications as with other applications, an easy-to-manage, step by step growth pattern is established by an architectural decision favouring minicomputers. In developing countries, the means thus to limit the growth of computing capacity to the actual priority needs and thereby to conserve both funds and personnel can be significant in ensuring that information technology has strongly positive marginal as well as average effects on economic growth.[B]

4. Examples and Conclusions

This paper has had the dual purposes of focussing attention on the priority sectors for applying information technology in developing countries and on highlighting minicomputers as a more effective vehicle with which to implement these information systems. Though minicomputers have been extensively used in the developed countries, they are still largely thought of as being laboratory tools or front-end processors or otherwise as subordinate to 'real' computers. In only a few instances, such as CDC's Ticketron multi-station on-line service in New York and London, has a minicomputer system been proved in face-to-face competition with a conventional system (in this case the IBM 360/50).

However in the developing countries the issues are not just financial viability and the elapsed-time-to-cutover. Reliability and maintainability loom much larger. The simplification of hardware maintenance, and of software updating and modification which come with the smaller CPU, modular I/O structure and streamlined, simpler operating systems are of immense benefit in a developing country. The likelihood of a finite amount of technical literature actually containing the information that is required in a software or hardware emergency is much higher with a minicomputer system. Likewise the confidence and assurance that comes with having several similar small systems which back each other up is not to be denied.

Systems analyses have been initiated in India in res[illegible] of the seat reservation and data communications system required for the national airline (74 domestic stations) to see whether it could be designed as a message switching system with a set of identical redundant multiple minicomputer modules. Preliminary studies (G) indicate that very considerable savings may result. Other studies of the logistics problems associated with nationwide commodity distribution systems for food or steel suggest that the greater availability of existing inventories created by better current location and quantity information provided by a distributed computer system might have significant economic value in a shortage economy, leading also to foreign exchange savings. Still another analysis, of the data archives of the Meteorological Department of India, revealed that an indexed filing system implemented on a real-time disc-and-minicomputer system (which was

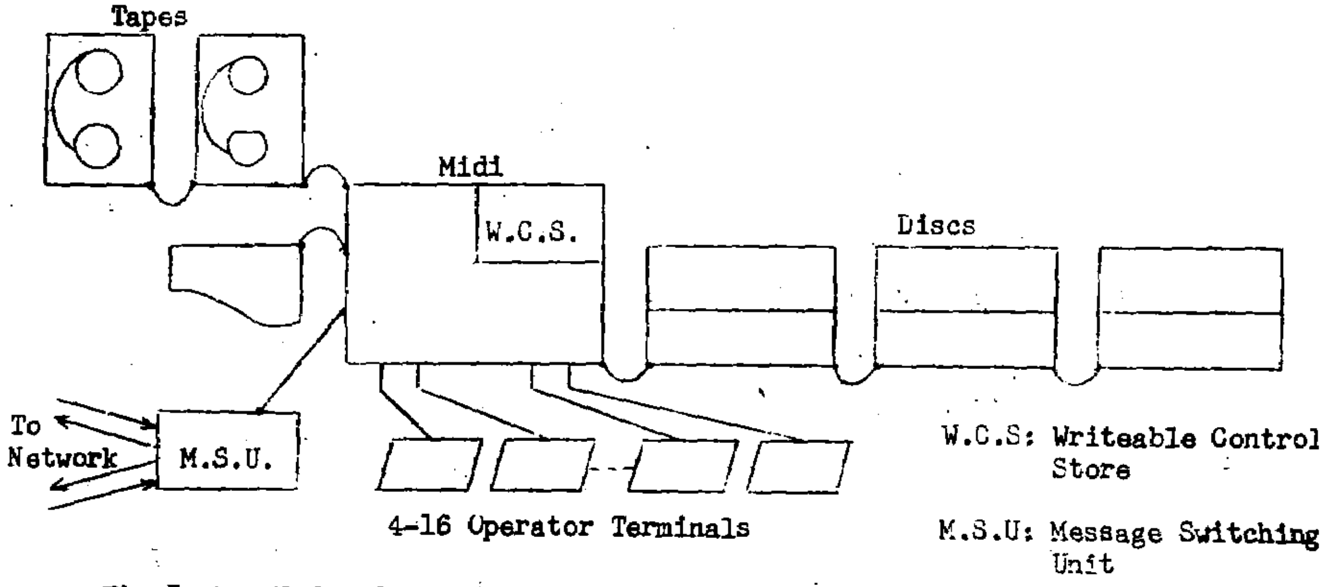

Fig.3: One Node of a Modular Distributed-computing System Supporting Logistical Operations.

During normal working hours local transactions are logged and analysed. After hours the stations on the network exchange messages. The "head-quarter" node can poll the other stations to update central inventory records.

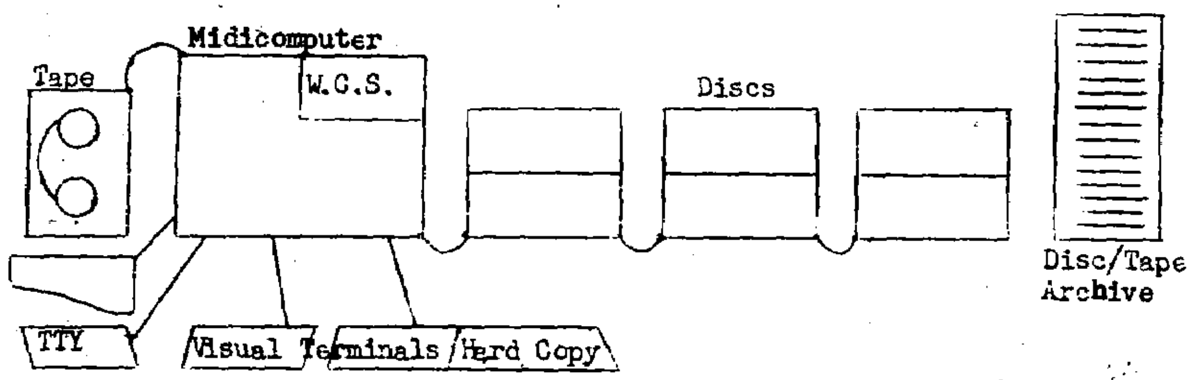

Fig.4: Information retrieval and analysis System for a Data Archive.

In the case considered, the archive holds historical weather records. A Multi-level indexing system enables the user at a terminal to retrieve the data set needed. The Writeable Control Store (microprogramming) speeds up certain data analysis methods such as Fourier Analysis. Output can be on the screen, hard copy device or line printer. Total list price: c. $105,000.

also micro-programmed to do fourier analyses) would make this valuable data archive accessible at a fraction of the cost of the medium sized computer previously proposed. The medium sized general-purpose machine was intended to be used for mathematical analysis of atmospheric differential equation models, but it required only a little study to show that these analyses in fact placed very great demands on sheer computing power that could not be met by a medium sized computer. A remote batch link to a nearby large computer was suggested instead.

The conclusion we draw from these examples is that minicomputer systems can be designed to perform economically most of the priority information processing tasks in developing countries. When the sheer computing requirements are beyond their capability, it seems to be the case that the prescription swings to the other end of the size spectrum. This results in bypassing completely the mid-range products of the major manufacturers of data processing systems. This conclusion is likely to prove controversial because these are the systems on which they have placed most emphasis in their marketing. I shall therefore close by suggesting that in evaluating alternative technologies for computer projects in l.d.c.'s, we should be aware of (1) the high opportunity costs of managerial and systems-design manpower, and of overcapacity in capital investments, as well as of (2) the need for reliability through modularity and duplication of facilities, and of (3) the ability of minicomputer-based systems to combine specific solutions to data processing problems with step by step growth capability, and ease in achieving on-line, real-time data-capture and information analysis.

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