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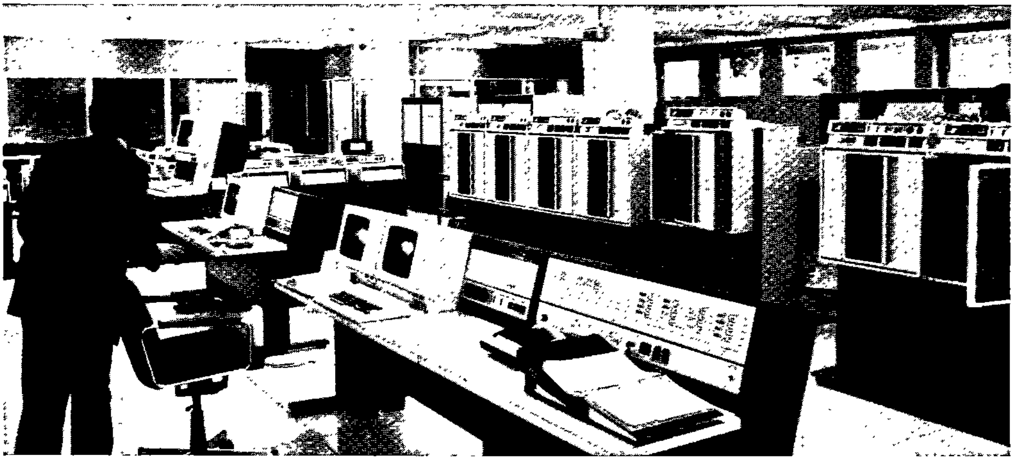
impact of science on society



A variety of computer applications

Front. Above: mother and new-born child leave maternity hospital; paperwork is handled by computer. [*Photo:* CII Honeywell Bull.] Centre, left: Nixdorf 8870/4 system used for inventory control in supermarket; centre, right: executive consulting terminal in an application of management information systems; below: three of nine Nixdorf 620/38 systems used in weekly data capture and preprocessing of national lottery tickets. [*Photos:* Nixdorf Computer AG and Pierre Hauss.]

Back. Above: ICL 2960 equipment manages more than 5 million individual accounts of retired persons, disbursing each quarter 700,000 pension payments. [*Photo:* International Computers (ICL.)] The games computers help to play; centre: CII Honeywell Bull Terminet terminal relays scores in bridge tournament; lower left: chess game and Time-Sharing Network Mark 3; lower right: VIP 7001 terminals communicate quiz results to CII Honeywell Bull 66 computer. [*Photos:* CII Honeywell Bull.]

Reminder to readers

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Computers and social options

An invitation to readers

Reasoned letters which comment, pro or con, on any of the articles printed in **impact** or which present the writer's view on any subject discussed in **impact** are welcomed. They should be addressed to the Editor, **impact of science on society**, Unesco, 7 Place de Fontenoy, 75700 Paris (France).
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The computer and us

. . . there are some human functions for which computers *ought* not to be substituted. It has nothing to do with what computers can or cannot be made to do. Respect, understanding and love are not technical problems.

Joseph Weizenbaum, *Computer Power and Human Reason*, San Francisco, Calif., W. H. Freeman, 1976

Comment

The editorial for this issue is from the input terminal of Charles Salzmann, who holds degrees from the University of Paris, the École Nationale Supérieure d'Aéronautique and Columbia University. The author has fifteen years of business experience in operations research and computer applications. A former president of the International Federation of Operations Research Societies, Mr Salzmann is currently engaged in research at the University of Paris IX and is a special consultant to Unesco on problems of informatics. The author can be reached at 84 Boulevard Malesherbes, 75008 Paris (France).

Computer technology and its impact on informatics policies in developing countries

In the field of informatics, there are two categories of nations today: those possessing a computer industry and those without.

In the latter group, there is a growing awareness of the decisive significance of informatics for the future of nations—an awareness that sometimes takes the form of attempts (or temptations) to develop an industrial computer policy.

My purpose here is to specify the outlook for these countries in the light of anticipated technological progress in the computer field. Indeed, the context in which informatics policy might develop will undergo profound change in the years to come. It will be useful, furthermore, to describe briefly the dominant factors of this evolution.

The informatics of four years hence already exists in the research and development centres of the major computer manufacturers. There is, besides, an active and even prolific trade press on the subject, as well as a fairly abundant literature in the field coming from numerous research centres (which finds outlets in congresses and meetings of all kinds).

In addition, the reader can consider the data cited further along as a sound forecast of what will be achieved, in reality, if we assume that there will be no major economic crisis or serious military engagements by then.

The major impression one obtains from a five-year forecast is that the progress being made in informatics is, far from stagnating, accelerating. In addition, with the performance/cost ratio improving, a great number of new computer applications are becoming economically feasible. Such applications, benefiting from the existence of highly developed micro-informatics and the soaring expansion expected of telecommunications by satellite, will deeply affect the industrial, economic and social organization of nations.

Mini-glossary

Bit	The binary element (0–1) that is the basis of alphabetic and numeric notation by electronic machine.
Byte	A set of binary digits taken as a unit, as in the subdivision of a word.
Gigahertz	10^9 hertz.
K	1 thousand.
Megabyte	1 million bytes.
Transponder	An electronic transmitter-receiver which transfers signals upon receipt of proper interrogation.

A few technical details

The principal components ('main frames') of large computers such as the IBM 303X series, the new Honeywell 66 line, and of the Burroughs, CDC, Amdahl and Univac brands,[1] at

1. I do not mention computer progress in other parts of the world because of its conspicuous lag thus far. The Japanese industry may prove, however, to be an exception.

TABLE 1. Performance of logic circuits, 1978/82 (forecast)

Property	Forecast for 1982	Comparisons with 1978: Current IBM 3033	Amdahl 470/V-6	Honeywell 66/PS
Type of circuit	DCT²L–II[a]	ECL[b]	ECL	CML[c]
Packaging	?	DIP[d]	CHOP[e]	M.P.[f]
Density gate per chip	300	45	70	60
Delay per gate (nanoseconds)	1–2	4	3.5	2.5
Dissipated power (milliwatts)	6–10	40	35	12
Delay × dissipated power (picojoules[g]/gate)	6–20	160	120	30

[a] Direct coupled transistor logic, second generation.
[b] Electric coupled logic.
[c] Coupled mode logic.
[d] Dual in-line packaging.
[e] Custom high-density packaging.
[f] Micro packaging.
[g] Pico- indicates the fractional power of 10^{-12}; 1.055 joule (J) = 1 British thermal unit, or 3.6 J = 1 kilowatt-hour.

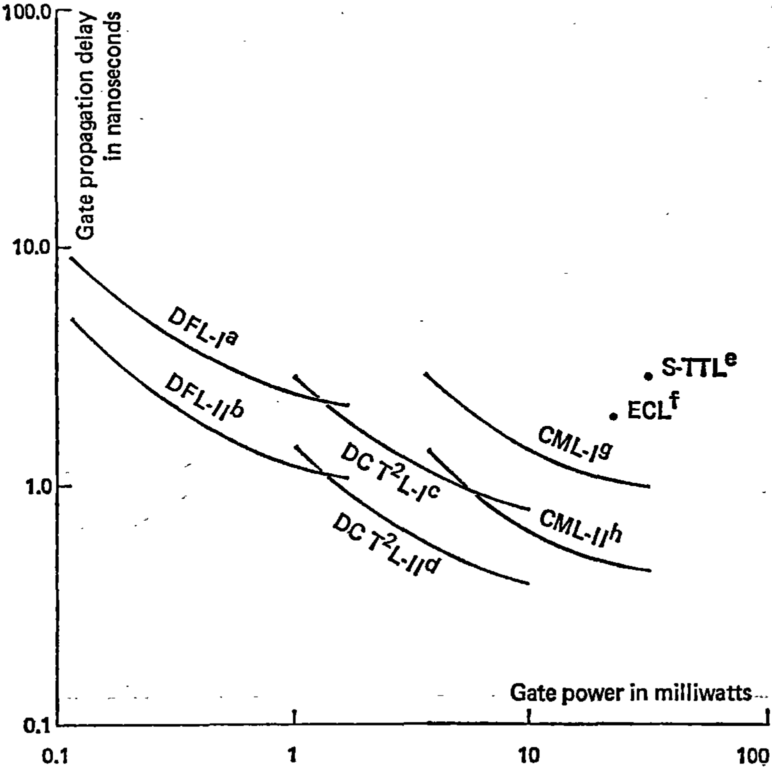

FIG. 1. Speed/power relationships of various types of logic. [a], [b] direct follower logic circuits; [c], [d] direct coupled transistor logic circuits; [e] solid-state transistor logic; [f] electric coupled logic; [g], [h] coupled mode logic.

present offer a performance/cost ratio on the order of $800,000 per MIPS.[1] Between now and 1982, however, this ratio will dip to $200,000 per MIPS, that is to say, a fourfold improvement. This phenomenon, which will upset the economic data of the computer industry, is attributable to certain convergent progress: (a) increasingly efficient (by a factor of 4) and growingly dense (by a factor of 10) logic circuits (Table 1 and Fig. 1); (b) centralized memories whose current chip components capable of storing 4,000–16,000 bits will store 64,000 bits by 1982 (see Fig. 2); (c) the abandonment of 'pipeline' machines in favour of parallel-processor architecture.

It is to be noted that progress will not end in 1982 since we can already foresee, beyond that date, the emergence of lithographic techniques assisted by X-rays. We shall then be able to handle as many as a million bits per chip, an improvement by a factor of about 15.

As far as large-scale discs and memories are concerned, important improvements are expected. Large-capacity (1,000-megabyte) discs are anticipated at a cost of less than

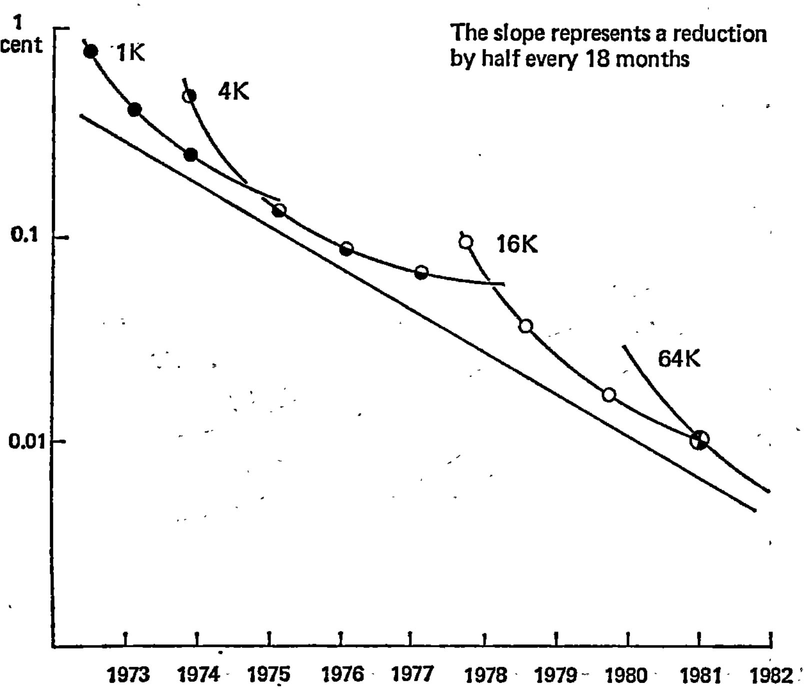

FIG. 2. Diminishing price of memory component (expressed in U.S.$0.01 per bit).

1. MIPS=million instructions per second.

$1 per megabyte per month (an improvement by a factor of 3), with a transfer rate of possibly 10 megabytes per second (a factor of 7). There will also be large-scale memories (handling 10^{12} bits) available at $0.02 per megabyte per month.

As to software, its financial and technical achievements will surpass those of hardware. Noteworthy will be new database software (DB/DC), highly developed and quite independent of both hardware and applications. The operating systems will be 'transparent' (fully automated), throughout the memory hierarchy, to their users.

Microinformatics, 'bureautics', telecommunications

From the time such progress is possible with components, the mass-production of complete computers can be made on the basis of information stored on a single chip: this is microinformatics. Whole new ranges of products will appear, from increasingly 'intelligent' and specialized terminals to new equipment for information processing in offices: 'bureautics'.

Already taking shape is a convergence of technologies for the simultaneous processing of administrative tasks (using computer data), of voice transmission (by telephone), of texts (electronic mail) and pictures (facsimile). These developments will be speeded by the forthcoming installation of powerful and inexpensive transmission systems aboard satellites.

The user will have available a reasonably small antenna (6 metres in diameter) for installation either on a roof or in a courtyard near the processing point. Communication will be in the 12–14 gigahertz range. All the information to be transmitted (whether data, voice, text or pictures) will be converted to digital form by cable (possibly made of optical fibres) towards the antenna's communication control and storage for a few milliseconds. The information will then be sent to the satellite in a single burst, the rate of information transfer being about 6 megabytes per second. The satellite, equipped with a transponder, would then forward the information to the receiving terrestrial stations, also equipped with antenna and control. The process would be cyclically repetitive.

One can also foresee that, thanks to these sure, cheap and virtually instantaneous communications, a significant number of large firms—possessing numerous branches and other sites—could establish new means for the distribution of data processing.

Using comparable means, the official services of various governments having access to communication by satellite will see the efficiency of their 'nervous systems' of command and control increase.

But who are the actors in the play?

Technological progress does not just happen. It is the direct result of the research and development activities of its main cast, the designers and builders of data processing equipment, mainly manufacturers in the United States.

The part of the world's market covered by the United States, currently about 85 per cent, is estimated to be about 80 per cent in 1982—and this in spite of the considerable subsidies that certain governments pay to their computer builders (see Table 2).

An important feature to be noted is that the American manufacturers are fairly concentrated. In 1977, only seven firms had an annual turnover in the information processing industry exceeding \$1,000 million. Of this amount, IBM had a 62.5 per cent share (see Table 3). As to profits, the disparity in favour of IBM is even more vivid. In 1977, IBM earned a net profit of \$2,700 million, whereas Burroughs had \$215 million. The net earnings of each of the other companies were in the neighbourhood of \$100 million.

It is noteworthy that IBM devoted in the same year more than \$1,000 million to research and development; this represents about half of what the entire data processing sector

TABLE 2. Value of conventional, installed computers forecast for 1982 (expressed in \$1,000 million at current rate)

Place	Total	Portion attributable to U.S. manufacturers: In currency	Portion attributable to U.S. manufacturers: In percentage
United States	70–75	68–72	97
Western Europe	37–47	30–38	81
Japan	13–17	5.5–6.5	40
Eastern Europe	5.5–7.5	0.6–0.8	10
Canada	4–5.5	2.8–5	92
Other	4–6	3.2–4.8	80
TOTAL	140–155	115–125	

TABLE 3. Annual turnover of computer manufacturers in the United States for 1977

Corporation	Annual turnover ($000 million)	Growth, 1976–77 (percentage)
IBM	14,700	16
NCR	1,900	20
Burroughs	1,700	12
Univac	1,600	8
CDC	1,500	11
Digital Equipment	1,060	44
Honeywell (HIS)	1,040	13
TOTAL	23,500	

invested in research in 1977. This fabulous sum explains clearly the acceleration of the measurable technological progress and the future flow of innovations. Such investments ensure, by their very nature, the continuation of IBM's supremacy. Indeed, in the United States, the survival of some of IBM's very competitors is at stake.

Informatics policies among developing countries

Six suppliers by 1985?

If we should disregard, for the sake of argument, certain countries such as Japan and those of Western Europe trying hard to keep pace, economy of scale combined with technical progress should make it a matter of time before countries other than the United States abandon their own manufacture and go shopping for informatics equipment on the world market.

Indeed, start-up costs (experimental research and development, capital investment in specialized plant, establishment of mass production) are extensive—whereas variable expenses such as raw materials and production labour are insignificant. The unit cost price then becomes a function of the quantity of material produced, and then follows control of the market.

It has already been predicted that by the year 1985 there will be, throughout the world, only a half-dozen manufacturers of very large-scale integrated (VSLI) circuits.

Before examining the choices to be made by developing countries, it is useful to emphasize the significance of data processing and the need to have a national policy concerning informatics.

This necessity is related not only to the fact that in each gross national product the fraction representing informatics will grow, but to the increasingly deep inroads that data processing will make in all other national activities—whether economic, technical or social.

The other authors whose articles appear in this issue of **impact** discuss these various applications of informatics. It should suffice, here, to mention briefly what can be anticipated in this field over the next decade, at least in the industrialized countries of the Western world:

More than half of industrial production will be accomplished in automated plants, both for the manufacture of original products as well as for the assembly of parts.

There will be satellite telecommunication networks (already mentioned), combining data handling with electronic mail and telephone.

Enterprises, other organizations and even individuals will have direct access to informatics networks by means of a simple telephone line.

Informatics will be used massively to accomplish administrative chores, i.e. in bureautics.

In social services, such as education, health and leisure opportunities, informatics will play an important role.

What are the choices?

The preceding considerations can lead developing countries to choose among the different strategies possible (note that a choice is inevitable, and that refusing to choose is, in fact, opting for the second category):

An option to pay more—in order to boast possession of a national informatics industry—on every product manufactured locally. The subsidy becomes more onerous as the years go by because (a) the quantity of equipment always increases and (b) there is a disparity in cost prices aggravated by the technological progress made by the major manufacturers of data processing equipment.

Procurement of equipment on the world market, taking full advantage of reduced prices to be found elsewhere and of the competition between major manufacturers. If purchase costs are thus reduced, it will be to the detriment of a secure purchasing policy, of economic autonomy, as well as of balance in foreign trade.

A combination, in order to adopt a mixed strategy, of the two ideas above.

It is conceivable, for example, that a country will choose a nationally subsidized industry, grouping together within one narrow commercial channel[1] its role as exporting nation along with its decision to buy all the rest of the material needed. But if several countries agreed to specialize in different categories of data processing, a kind of international redistribution of effort would be possible.

Given this last alternative, bilateral agreements between a multinational manufacturer and a given country could offer considerable advantages to both parties. Without enumerating them here, one should add that there has been a trend in this direction discernible during the past few years.

Whatever might be the strategy adopted concerning data-processing equipment, it is particularly important that the main thrust of effort in the informatics field concern applications.

Getting informatics on the move

Having arrived this far, we must now be concerned with the applications of information processing—i.e. the capacity to create software adapted to specific situations in each country, as well as to their cultures, their social and administrative mores, to the condition of their communication facilities, and especially to their levels of education.

These factors constitute a fundamental component of any informatics policy, a component which can be enhanced through education: by training operational and maintenance personnel, by the development of pertinent software, by

1. It is useful to note the great importance of specific studies to determine, for each country, the optimal commercial channel, bearing in mind all peripheral products (labour, fixed mechanical plant, innovative electronics and the like).

assuring that users will understand the new potential of data processing.

To conclude, it can be said that making informatics functional should have the advantage of high priority accorded to it, essential element that it is in the elaboration of national strategy. □

Charles SALZMANN

The effects of computerization on the relationship between public administration and the community

Françoise Gallouedec-Genuys

New techniques always have economic and social consequences, and hence political and ideological implications, which pose problems for society. Computerization has been no exception to the rule, particularly since its applications impinge on every field and open up breathtaking prospects in every sector of society.

By way of example, let us consider public administration and the influence of computerization on the relationship between that administration and the community.[1] I shall be considering this problem not in theoretical terms nor in the context of futurology but with reference to actual practice, basing my arguments on the initial findings of a study being carried out under my direction and sponsored by the International Institute of Administrative Sciences. This study, begun in 1976, is being conducted in Algeria, Belgium, Canada, France, Italy and Tunisia and is due to be completed at the end of 1978. Its findings will form the subject of a book.

The role played by computerization in the relationship between administration and community may be perceived in two ways. Computerization may improve or mar that relationship, or it may have no effect upon it. The value of that relationship will therefore either remain the same or will increase or decrease. Nevertheless, computerization may also act upon the relationship by transforming it, or in other words by affecting its nature or its characteristics.

These are the two aspects that I shall be investigating here, with illustrations taken from my own observations.

What does 'computer' mean?

It is something of a shot in the dark to seek to ascertain whether computerization has had any effect on the value of the relationship between public administration and the community. It entails deciphering a situation which has not arisen intentionally and of which people are hardly aware. In other words, one cannot get to the truth of the matter simply by referring to what administrative departments have said or done or even tried to do. Similarly, one cannot go by the impressions formed by members of the community. For the most part they know nothing about the computerization of administration. They know neither where, nor when, nor how, nor why government departments decide to introduce computers, nor do they know what contribution the computer can or might be able to make. In the public's defence, it must be said that central or local government does not in any way publicize its use of computers but, to its discredit, the

1. By community is meant all persons, groups, businesses and institutions in any relationship whatsoever with the public administration; by individual is meant any member of that community.

■ Françoise Gallouedec-Genuys

Ms Gallouedec-Genuys has for some while been concerned with the problems raised by the relationship between the computer and society. Her publications include the following articles and works: 'L'Informatique et les Libertés', Problèmes Politiques et Sociaux, *Paris, La Documentation Française, 1971; 'The Computer and Democracy',* Human Choice and Computers, *Amsterdam, North Holland, 1975; 'Les Aspects Juridiques et Éthiques des Applications de l'Informatique Médicale',* Colloques IRIA, Informatique Médicale, *Paris, 1975; 'Protection of Confidential Data',* Policy Issues in Data Protection and Privacy, *Paris, OECD, 1976; and* Informatics and Administration, *Brussels, International Institute of Administrative Sciences, 1977 (in English). Awarded in 1976 the Prix de l'Association Française des Informaticiens and the Prix Louis Marin de l'Académie des Sciences Morales et Politiques, the author is at present working for the Council of State and at the Centre National de la Recherche Scientifique in Paris.*

public shows scarcely any curiosity so far as the managerial practices of the administration are concerned.

Be that as it may, the individual's impression of computerization and its effect upon his relationship with government departments is doubly distorted. It is distorted in the first place because the individual is ignorant of what computerization and its effects actually are. 'I know what computers mean', he says, 'they mean efficiency, profitability, reliability, speed and the elimination of senseless chores.' At the same time, computers are claimed to lead to 'unbearable working conditions, dehumanized relationships, organized surveillance and an accumulation of errors' (typical and conflicting remarks made by students from every faculty in a French university).

Behind these stereotyped responses there is no precise awareness of the consequences of computerized management, as is shown by the fact that no concrete example is ever cited. The everyday lives of those students are, however, managed by means of a computerized system and they do not seem to have any complaints.

In the second place, the individual's impression of computerization and its implications for the administration-community relationship is distorted and even totally false because of the opinion that he holds of the administration. In particular, he will never be willing to admit that the reason why a government department introduces a computer is to improve relations between itself and the community, and he will not be wrong.

Defining sound administrative management

True enough, at all levels, government departments have turned to computerization purely for their own sakes, and 'in the general interest', of course. Never has the move towards the introduction of computers been made with the community in mind, and never have computerized systems been devised and developed for the sake of the individual. On the one hand, the computerization of administrative tasks is an internal operation, decided on by the public authorities without reference to those concerned, i.e. the community. On the other hand, computerization is regarded as an organizational matter: 'We're snowed under, we're getting behind, things aren't going right, something must be done . . .', and recourse is had to the computer.

As a result, computerization seems generally to have been introduced just to provide assistance and not in the context of comprehensive approach making it necessary for objectives to be redefined and calling for a critical appraisal or even for upheavals. Computers are introduced not so much to reform a department as to improve its management. What, however, is sound administrative management?

Very seldom is the quality of public administration measured by the extent to which it improves its relationship with the community. A survey conducted in Belgium to ascertain the views of senior civil servants seems to indicate that a number of them, on the grounds of efficiency or the necessary discretion of the civil servant, deprecate the taking of that relationship into account. Others, however, acknowledge that improved contacts with the public may, among other things, improve the quality of administrative management.

Yet one would have to be blind or else inclined to see things in an unduly favourable light to claim that computerization does not provide a means, even if only an indirect one, of improving administrative management and also the relationship between administration and the community. This is what has emerged by and large from all our case studies.

How is the relationship between administration and the community improved?

The improvements made relate chiefly to the style and frequency of relations between administration and the community. Computerization provides a means of simplifying procedures. The ex-serviceman, for example, no longer has to come up to Algiers from his oasis in the Sahara in order to claim his pension rights from the ministry. The department now goes to him. In every country, changes have been made in income tax returns with the result that the taxpayer is spared various calculations and no longer has personally to make so many checks.

Computerization and, in particular, teleprocessing, further makes it possible to increase the efficiency of the administration-community relationship. At the University of Western Ontario (Canada), for example, each student can find out immediately, and with certainty, what lectures and courses his previous certificates allow him to choose, having regard also to his current activities, his outside work and his preferences. He is thus able to make a fully informed decision and enrol without delay. In addition, there is no longer a host of administrative and other hurdles to be overcome and no swarming mob. The ill-famed scrummage or rush at enrolment time, with its pushing and shoving, has vanished.

Computerization also helps to humanize relationships between administration and the community. For instance, since the computerization of the national old-age pension scheme in France, pension entitlements are worked out in each individual case well in advance of retirement. Records are prepared and examined sufficiently early for those concerned to be able to provide any further information needed in good time, with the result that pensions can be paid without irritating delays.

Even more far-reaching changes have been made at the pensions office in Nancy (France). Terminals have been installed there with access to pensioners' files and, soon, coaches equipped in the same manner will be serving all parts of Lorraine. This will enable any problems to be quickly settled on the spot and in a cordial atmosphere. It has been found that interviews can start on a better footing and reach a more fruitful conclusion when there is easy access to files and new information can be recorded immediately. All that is required is a properly qualified person in charge.

Litigation, customs formalities and vaccinations

A further indication of improvement in relations between administrative departments and the community is the frequency of contact—greater or lesser according to the individual case. When such contacts are unpleasant because they have to do with an error, a reduction in their number indicates a rise in quality. To give an example, computerization has reduced the percentage of errors in the handling of Algerian giro cheques from 43 per cent to 2 per cent and has thus eradicated a source of tedious litigation. Improvements of the same kind have been made in many fields. Since the introduction of the SOFIA[1] system in France, the need has similarly been obviated for direct and frequent contacts between customs officials and freight agents—contacts marked by high-handedness and suspicion—and both sides find this highly satisfactory.

Conversely, in other cases, what is appreciated is an expansion of relationships between administration and community. In Italy, for instance, the data bank set up at the Appeals Court—now known as the National Legal Data Processing Centre—not only facilitates the work of lawyers and jurists but also provides great assistance to businesses and trade unions. To give another example, parents in Montpellier (France) are sent a computer-produced record of their children's vaccinations every year and are thus able to tell what booster injections are needed.

The public, however, is far too often unaware of this helpful contribution directly or indirectly made by computerization. This is because it knows nothing about the computerization of government offices, but it is also because of a certain attitude which the public holds towards government departments. Whether or not he is informed on this subject, the individual feels that he is only getting what he is entitled to and considers it only natural that a department should organize itself in such a way as to function as smoothly as possible. Viewed in this light, it follows that the reason for the computerization of government departments is simply to enable them to do their job properly.

On their side, government departments adopt nearly the same view. Admittedly, successful computerization results in a more efficient public service and consequently in a more satisfied public, but this end result has not been deliberately sought. The consequence is that while there has been an improvement in relationships between government departments and the community, this has been a mere side-effect of computerization and the improvement has not been as great as it could. Thus, there may sometimes be a complete absence of improvement or things may simply hang fire; and we are familiar with the difficulties encountered in launching certain computer operations, the wrong choices made right from the start and their unfortunate consequences for the community. Part of the reason for this is that the decisions were not taken with the community in mind, but then, of course, the administration has an ideal scapegoat: 'It's the computer's fault.'

When one hears this excuse offered as an explanation, even if it is not correct, is it not possible, despite everything, to see the beginnings of a desire to take the person on the other side of the counter into consideration, and consequently an emerging need for another type of relationship?

The new role of the individual

This conventional and 'counter-clerk' approach to the relationship between administration and community is just one way of appreciating how computerization affects that relationship. There is another way.

This consists in investigating the effects of computerization on the very nature of the relationship between government departments and the community, on its characteristics and substance. Admittedly, this is a less easy and less spectacular operation, par-

1. Système d'Ordinateurs pour le Fret International Aérien (International Air Freight Computer System).

ticularly since, here too, the changes following on computerization have come about solely by chance. They do not occur in all circumstances. They are only embryonic or of small account, and often they are played down because they perhaps contain the seeds of another type of administration—and of something more besides, namely, another type of political structure.

What the computerization of public administration first revealed was a new kind of individual—more active, noisier, more determined. This led to a different kind of relationship between administration and community. It then became clear that it was in the interests of both the administration and the community to get to know each other and sometimes even to co-operate, if those sectors which had been, or were to be, computerized were to be successfully managed. New roles consequently emerged and, as a result, a different kind of contact.

In his new role, the individual is, first and foremost, a presence 'necessary' to the administration. Previously, it had preferred to ignore him; now he is discovered as a justification, a means of legitimizing the measures adopted by the administration, in the event its introduction of computerization. Computers are costly, or at least their cost is better known. Some people are put out by them and it is not always easy to introduce them. Thus in order to obtain the necessary money, time and staff and justify their use when it is no longer enough to cite internal management needs, it is said that they are needed for the sake of the community. But this spells the beginning of a new way of thinking and reflects a first groping towards a different attitude.

In his new capacity, the individual is also someone who makes himself heard, who rejects the new system and opposes the administration. An example of this is afforded in France by the attitude of the employers' federations towards the economic data bank of the Ministry of Industry, Commerce and Trades. The individual is also someone who is recognized, someone who is no longer completely on the other side of the fence. Thus SOFIA—the international air freight computer system—has resulted in the emergence of a new type of customs official and a new type of freight agent who is willing to co-operate and who remains even-tempered.

Two forms of participation

This new attitude on the part of the individual is reflected in many other ways and brings about changes in the relationship existing between the public administration and the community. It has other consequences as well. Besides providing grounds for the passive recognition, so to speak, of a new state of affairs, this change makes it possible to point the way to another type of administrative management, a different distribution of roles between the administration and the community.

Two phenomena are emerging—participation in management and participation in planning, or rather, co-operation at these two levels of administrative action. In the first case, this may take the form of information supplied by the individual in the form required by the computer system and possessing all the necessary accuracy.

This new method of collecting information is frequently employed and obviously depends on the goodwill of those concerned, even though the difficulties involved are scarcely any greater than previously. By and large the community willingly accepts the change. The quality of the system depends on it as does the quality of the services it provides. Moreover, this method of collecting information occasionally gives the administration an opportunity to establish a kind of contractual relationship with the community, the administration proposing a sort of 'give-and-take' of information so as to be sure, among other things, of the soundness of the information received.

Participation may take other forms. For instance, in the case of SOFIA, the customs service trains individuals in the use of the system. Thus the freight agents, who have their own computer terminals, themselves provide the data inputs for their declarations which are checked by the customs officials. Periodic meetings are also organized between customs officials and agents in order to discuss problems relating to the use of SOFIA and its improvement, particularly so as to take account of the community's commercial needs.

The second type of participation

The second form of participation resulting from computerization is participation in the planning of systems and, more generally, community participation in the choices made by the administration.

The computerization of administrative services has brought to the fore the idea of the individual's needs and the need to know what they are, perhaps as a result of the influence of the computer specialists who usually come from the private sector and whose training there has been slanted in that direction. According to the computer specialist's 'bible', before proceeding with computerization, the problem to be dealt with must be analysed and both limitations and needs must be identified. Only afterwards can thought be given to a particular system, which will function properly only if it satisfactorily corresponds to the needs previously defined.

However, administrative departments have a habit of conceiving the needs of the community without consulting those concerned. They speak in the community's stead and think on the community's behalf. This is still true in most cases and particularly, in our experience, in the case of local authorities, although an elected administration, so it is claimed, is in closer contact with the community.

This is no longer always true, however, as is demonstrated by the SOFIA system. Even a repressive administration may put out feelers in the direction of the community.

The experience of Canada

The most astonishing case we have encountered, however, is that of Information London in Canada. The Canadians started with the realization that when the political or administrative authorities were guided only by existing statistical information, collected by the administration, social policy was not wisely framed. The authorities therefore sought to give a say to those actually concerned (i.e. the community) and to get them freely and directly to state what objectives and priorities they thought should be laid down in this field. Going one step further, they wanted to enable the community, and hence citizens' action groups, to collect the information required so as to evaluate proposed policies, criticize them and even make counter-proposals.

A programme was thus drawn up and put into effect from 1974 onwards; it consisted of four principal activities: (a) the remote utilization of a computerized data set relating to the social services and intended to provide the community with answers to its questions; (b) summarizing the key points in claims, requests, wishes or complaints expressed by citizens, in a form enabling them to be processed by computer and making it possible to determine the broad outlines of a general or specific policy; (c) the use of computers by citizens' groups to store and process data derived from particular social surveys; and (d) computer training for citizens to enable them to process data themselves, on the understanding that they would be provided with all the necessary facilities.

To what extent has this programme been successfully carried out? First, the data bank relating to the social services has indeed been set up and is operating normally. Second, the computerized processing of citizens' claims has had an impact on many administrative decisions, relating, *inter alia*, to the improvement of the social welfare and unemployment benefit services through the recruitment of staff speaking the most commonly used languages (Greek, Hungarian, Italian, Polish, Portuguese); the organization of baby-sitting services; the adaptation of public transport for use by handicapped persons; and, on a longer-term basis, the implementation of a housing plan. What has been achieved, however, seems to fall far short of the expectations of those who sponsored the project. Third, some assistance has been provided to citizens' action groups, but few people and few groups have taken advantage of the opportunities offered. There has been a similar result with regard to training. Hence the questions to which the Canadians are trying to find answers, while still extending the system to other towns and provinces. What must be done in order to motivate the community further? What must be done to put public administration more in touch with the community and make it more attentive to individual needs? The conclusion is that it is a political problem and that, while computerization may, in the event, help bring about 'participatory democracy', as they say in Canada, it is still necessary for both sides to have the political will to achieve it.

Conclusion

This will be our conclusion as well. Computerization makes things possible but does not determine the course of events.

Computerization is not without influence on political structures, but this influence is not decisive. It may modify the relationship between public administration and the community but it cannot, by itself, change the nature of that relationship. The problem is not a technical one. It can be resolved only if there is the necessary political motivation, and motivation does not spell legislation. □

Intergovernmental meeting on informatics

The Intergovernmental Conference on Strategies and Policies for Informatics (SPIN) is being held in Torremolinos (Spain) from 28 August to 6 September. This meeting, convened by Unesco and the International Bureau for Informatics, has as its objectives the following:

To exchange experiences in strategies and policies in informatics, especially those aimed at ensuring the development of endogenous capacities and the optimal utilization of resources.

To identify ways and means whereby informatics can contribute to economic, social and cultural development, bearing in mind the particular needs of developing countries.

To clarify the prerequisites for the elaboration of strategies and policies at the national level.

To draw up a programme of action for international co-operation and assistance in the field of informatics.

About 500 specialists representing as many as 140 Member States and a variety of non-governmental organizations are registered. The working languages of the conference are Arabic, English, French, Russian and Spanish.

An introduction to informatics

R. E. Kalman

As many national communities transform their socio-economic environment to that of the information society, an examination of the new discipline of informatics is outlined.

A preface of questions

In the course of the evolution of increasingly automated information handling systems, questions regarding the very nature of computer science and large information systems have been raised with persistent regularity.

Principal among these questions are the following: Is informatics a discipline in its own right? Admitting that informatics is a discipline, would it be possible to develop a unique yet comprehensive definition of it? What is the relationship between informatics and some other, new disciplines (cybernetics, information science, computer science) and some more traditional one (physics, biology, mathematics)? Has informatics truly a direct influence on our daily lives, as it is often suggested? All these questions lead to a final one: What is informatics?

The emergence of informatics

Research exposes the structure and behaviour of different natural systems, whether physical, chemical, biological or social. Technology produces constructed systems (bridges, television, artificial organs). Man's imagination creates new, abstract systems (mathematics, philosophy, religion). The observations we make in our universe are quantified in the form of numerical or non-numerical data (as in a population census, descriptions of colours and smells, physical measurements). Once properly structured, data become information [1].[1] Information can modify the state of our knowledge of the universe or help create new concepts in our minds. But the rules and laws governing the features of data flows, even in similar systems, may be rather different from those applying to information flows. Therefore it seems useful to study the two phenomena separately.

The amount of data created by man has been increasing rapidly because of (among other factors) the exponential growth in population, the spread of literacy, and rising expenditures in research and development. Technological advances in electronics—such as magnetic tape recording, other electronic reproduction, microfiches, television and satellite technology—have made it possible to register, store, reproduce and transmit almost unlimited amounts of data to any point on earth. This has led to extreme concentrations of data in certain places.

This high concentration has changed the traditional data 'environment' in some countries, modifying the division of labour

1. Figures in brackets correspond to the notes at the end of the article.

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and creating new social structures. See, for example, the evolution of the labour force in the United States as depicted by sector in Fig. 1. The graph suggests that more than half the economically active population of the United States will be employed in the information subsector by 1980, the majority of whom will be manipulating data [2].

Structuration of data

A similar trend towards data-manipulating societies can be expected elsewhere. Distribution of the economically active population as a function of the gross national product per capita (Fig. 2) shows that, while the percentage of population working in industry begins to diminish after a certain level of GNP per capita has been reached, the sectors requiring more data manipulation (commerce, transport, communication and other services) continue to grow.

Such societies are faced with a problem to be solved. This is that the flood of data created should be structured into meaningful information, understandable by and appropriate to a given society. New technical progress in creating, collecting, processing, storing, retrieving and transmitting data

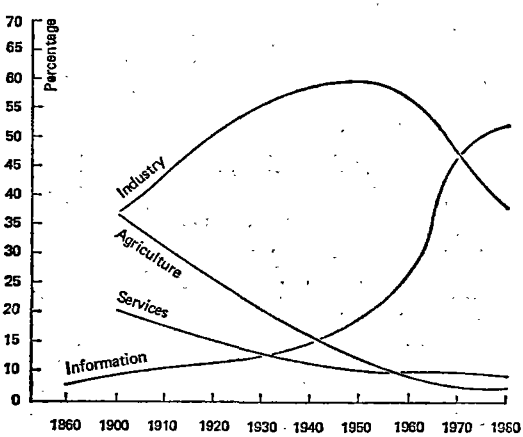

Fig. 1. Four-sector aggregation of the United States' labour force during the present century. *Source:* M. V. Porat.

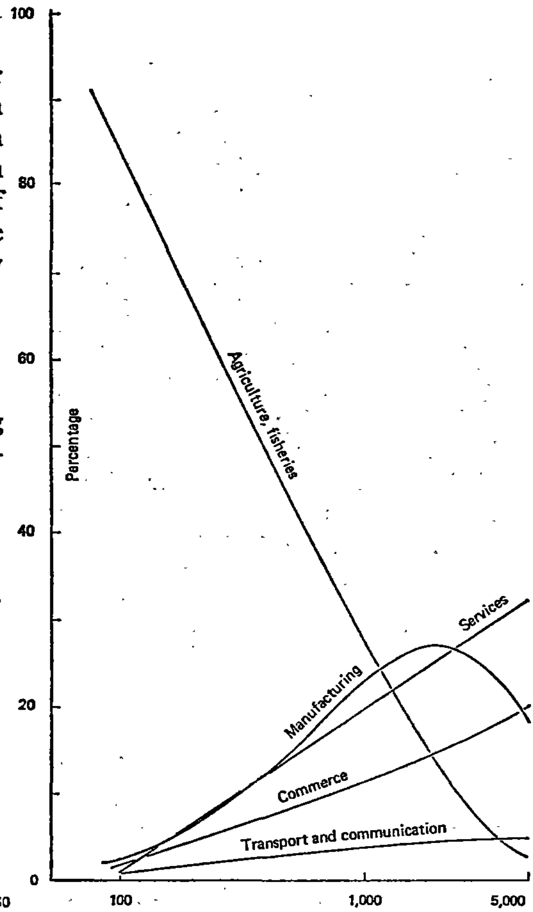

Fig. 2. Distribution of the economically active population, world wide, expressed in terms of gross national product dollars per capita.

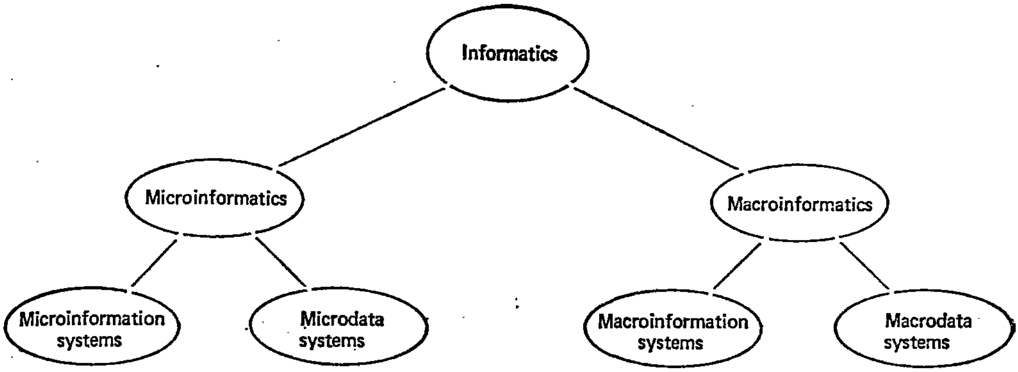

FIG. 3. Structural organization of informatics.

should furnish powerful tools for the purpose—provided it is known how the data flows (a) should or (b) should not be structured from the societal point of view.

Some examples of this structuration include issues related to the successful management of public and private enterprises; analysis and synthesis of scientific and engineering systems; collection and use of personal data for official purposes, including intragovernmental transfer; laws regulating data flows between the public and private sectors, and across national boundaries; competition or monopoly in the shaping of national data infrastructure; and research and development and procurement policies at the national level.

Demands for the structuring or restructuring of data are not new, however, in human evolution. Such requirements have always raised questions that cannot be answered in the traditional scientific or engineering frameworks; they have provoked the application of new complexes of disciplines. We believe that informatics is one of these, dealing as it does with the inherent properties and the systemic features of data and information—whether in living or nonliving systems.

Microinformatics and macroinformatics

Early studies of data and information flow in different systems resulted in plentiful observations concerning flow in computers, telecommunications, information and documentation, mass communication, linguistics and other areas. Some concepts came to have several meanings, the ambiguity becoming misleading. The best example is that of the term informatics itself. While the French *l'informatique* has become universally popular (like optics or electronics) and is translated into Arabic, English, Finnish, German, Hungarian, Italian, Norwegian, Polish, Russian, Serbo-Croatian and Spanish, the term has at least thirty different definitions or interpretations throughout the specialized literature [3]. To preclude ambiguity and in order to provide common ground for discussion, it is often useful to introduce new terms and redefine old ones [4].

Microinformatics

Microinformatics is a set of disciplines within informatics (Fig. 3) dealing with individual data and information flows in various systems. It cuts through the boundaries of traditional scientific and technical disciplines. For practical reasons, microinformatics can be divided in two.

The first chapter is the *theory of microdata systems* (MID), which investigates the features of data flow in individual systems. It is a logical extension of certain activities such as metrology, computer science and telecommunication technology; it deals with interrelated problems such as the extraction of data from nature or society; how to design hardware, software and man-machine interaction to assure the proper flow of data collected (e.g. during a demographic or agricultural census); or how to retrieve data from a data-base and transmit them most efficiently.

The second element is the *theory of microinformation systems* (MII); this deals with information flow in the human environment and is closely related to philosophy, psychology, linguistics, library science, mass communication, artificial intelligence, and the like. It treats such issues as conveying verbal experience through language, or drawings, or other media; how best to express a speaker's or writer's attitudes; the questions of whether machine translation is viable and what are its theoretical and practical limitations; coping with the documentation explosion; and if the complete mechanization of information storage and retrieval is theoretically possible or economically feasible.

Macroinformatics

This is a set of disciplines dealing with aggregated flows of data and information in systems in which individual treatment is either impossible or economically unfeasible. This also divides into two sections.

The first of these is the *theory of macrodata systems* (MAD), dealing with aggregated data flows in large systems. Questions concerning such flow are often studied under headings like large-scale control systems; data network control and routing; data processing and telecommunication policy; structure of the computer and telecommunication industries; and planning of computer utilities or interagency automatic data processing. In the framework of this theory are tackled problems such as the stability of complex control systems; prospects for computerized mail and teleconferencing [5], management information systems in government and personnel management; responsibilities of the public and private sectors in data manipulation; and the elaboration of standards and applications of shared hardware, software and human resources.

The *theory of macroinformation systems* (MAI) concerns aggregated information flows in large human systems; it is closely related to certain aspects of mass communication, the legal, social and documentation sciences, and similar activities. Typical areas of interest in this category include confidentiality of information stored in computers; control of transborder flows of information; regulation of the mass media and motion picture industries; the relationship between public broadcasting and private media; establishment of national library and documentation systems; and the overall problems of what has become known as the knowledge industry.

Obviously there exists a complex pattern of overlaps and interactions between the four theories; but the body of basic observations, the particular methods applied, and the formulas, rules and laws derived may differ considerably. The creation and handling of data, for example, for personal registers, registers of legal entities, land registers or medical records lie in the realm of macrodata theory. Yet when these files are integrated, enabling the public administration to collate information which describes the citizen's personal profile, the data constitute social or legal problems (rather than technical ones). They are therefore discussed in the framework of macroinformation, instead of macrodata, theory.

Different schools of thought

The contours of the four theories and of informatics itself have thus emerged through the specialized literature. But, as far as we know, clear distinctions have not been made. There has been a tendency to refer to all five domains as informatics. To illustrate the point further, we have selected five definitions to characterize the quintuple schools of thought involved.

The informatics school holds that informatics should study information and data flows in all human, non-human, constructed and imaginary systems, seen in both their micro and macro aspects. Probably the first definition was made by A. N. Kolmogorov in the late 1940s when he proposed that a new complex of disciplines should deal with

> the modes of perception, storage, processing and use of information in machines, living organisms and their associations [6].

This wording was first applied to the description of cybernetics. It has since been replaced by another definition [6].

The microinformation school contends that information should concentrate on individual, human flows of information, while according to the macroinformation school a new complex of disciplines is concerned with the cultural, economic and other social effects of aggregated information flows on national and international scales. The first approach (microinformation) is reflected in the following definition,

> informatics is the science and technology concerned with the creation, management and exploitation of recordable knowledge [7]

while the second approach (macroinformation) could be described as follows:

> informatics is the totality of knowledge and totality of extensively rationalized technologies [that aim] at treating information seen as a medium for human intellectual activity [8].

Partisans of the microdata and macrodata schools tend to believe that the subject matter of informatics should be concerned mainly with individual data flows and their aggregation, without reference to their significance:

> informatics is the science of automatic data processing . . . and . . . will be concerned only by manipulation of character strings, without any reference to their meaning [9]

or

> informatics is the complex of scientific and technological fields such as hardware, software, networks and computer-aided design, the complex of their applications in all spheres of human activities; and the complex of their industrial, commercial, economic, social and political impact [10].

Conclusion

In this short article we have tried to show that an important transition is taking place, as certain industrial societies transform themselves into information societies. In order to understand this changing environment and meet the new social, economic and technical requirements imposed by the transition, a new group of disciplines has evolved. This complex is informatics. There are different opinions held, however, as to where the boundaries of informatics lie.

Our analysis should provide, none the less, an adequately general framework within which to place the handling of both data and information flows in all possible systems. The individual flows of data and information can be studied within the appropriate chapters of microinformatics (the microdata and microinformation theories), while their aggregation falls within the realm of macroinformatics (the hypotheses concerning macrodata and macroinformation).

The issues being discussed during the Intergovernmental Conference of Strategies and Policies for Informatics are related to macroinformatics and, particularly, to the theory of macrodata systems. Our approach is not likely to satisfy everyone, but if the dialogue it engenders leads to a better understanding of informatics, our paper at least will have reached its objective. □

Notes

1. The *IFIP-ICC Vocabulary* (Amsterdam, North Holland, 1966) suggests that *data* are a representation of facts or ideas 'in a formalized manner', while *information* is the meaning a human assigns to data by means of the known conventions used in its representation.
2. M. Porat, *Defining an Information Sector in the U.S. Economy*, Stanford, Calif., Institute for Communication Research, Stanford University, 1974 (Information Reports and Bibliographics, Vol. 5, No. 5). The author divides about 150 information occupations into subsectors: A, where 'the final product is information' (writers, librarians, postal clerks, telephone operators); B, 'where the major intermediate product is information' (scientists, engineers, teachers, computer programmers, bill collectors, receptionists); C, information technologists (repairmen, typesetters, bookbinders, telephone linemen). Our more detailed study showed, however, that less than about one-third of these occupations deal with structured sets of data—information—while more than two-thirds create, collect, transform, store, retrieve or transmit numerical and non-numerical data.
3. R. Kalman, 'What Is Informatics?', Algiers, First African Conference on Informatics in Administration, 1976 (paper).
4. It is relevant here, however, to quote Faraday at the time he introduced the words 'electrode', 'anode', 'cathode', 'electrolyse', etc.: 'These terms being once defined will, I hope, in their use enable me to avoid much periphrasis and ambiguity of expression. I do not mean to press them into service more frequently than will be required, for I am fully aware that names are one thing and science another.'
5. For a practical exploration of the advantages of teleconferencing, see B. Lefèvre, 'The Impact of Electronic Communications on Town and Regional Planning', *Impact of Science on Society*, Vol. 28, No. 2, 1977, p. 227.
6. *Bolshaya Sovetskaya Entsiklopediya*, 2nd and 3rd eds., Moscow, 1958, 1972.
7. *SPINES Thesaurus*, Paris, Unesco, 1976.
8. *Encyclopédie Internationale des Sciences et des Techniques*, Vol. 7, Paris, Presses de la Cité, 1972.
9. J. Arsac, 'Informatics and Computer Education' (paper presented at IFIP World Conference on Computer Education, Amsterdam, 1970).
10. Oral communication presented at meeting of experts preparatory to the Intergovernmental Conference on Strategies and Policies for Informatics (MINEXSPIN) at Unesco, Paris, 1976.

An on-line information network for a national and university library

Vladimir Bonačić

The rethinking and remodelling of an established library system to respond to contemporary and future informational needs of an entire culture are described by one of its principal designers.

The Socialist Republic of Croatia in Yugoslavia is lagging in the rebuilding of its national and university library, an institution brought into operation at the beginning of the twentieth century. Other socialist republics of Yugoslavia, who between them share several distinct languages, have reoriented their library services in order better to exploit printed forms to trace books and periodicals, all with an eye towards future integration of microforms within their respective information processing systems.

But the project in Zagreb would hardly be worth mentioning, as a conventional approach, if a great effort had not already been expended as of this early stage in its life. The 40,000 square metres of floor space permitted must now be allotted, finished, furnished and operational by 1982. The project will include, as the main part of the library, a computer-aided service of 'information on demand' as well as an integrally connected library system. The latter, actually an electronic library, will give the user access to a free exchange of information throughout much of the world. The facility will also contribute significantly to the preservation and the promotion of the national cultural heritage.

Planned, of course, is the use of microforms to include COM-fiches,[1] in addition to a lending service for users who might need supplementary reading equipment. The use of Viewdata[1] display facilities will be strongly promoted by creating Viewdata centres coordinated with the activities of the library itself.

Meeting the needs of the future

Perhaps one of the greatest aids to overcome the obstacles imposed on us by the different languages is the practicality of a fully automated information service, in other words, a machine-readable data base. This is why the research institute we are developing, with ties to Unesco, will be deeply concerned with the impact of technology on both the dissemination of information and the associated environment in which we all work.

In the field of education, especially continuing education for workers, in modern industry (13 per cent of Yugoslavia's industry is centred in the Croatian capital of Zagreb), in commerce, and in tourism (80 per cent of all tourism in Yugoslavia occurs in Croatia), it is hard to imagine continuing progress if these sectors do not have access

1. COM-fiche and Viewdata are legally registered trade marks.

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to facilities permitting real-time information retrieval. Truly continuing education and training, for example, cannot be provided simply by wishing strongly. The proper physical means are indispensable. It appears to us that a society appropriately equipped with display material of the Viewdata type (for instance) will be the society best prepared to deal with educational problems.

These are the kinds of informational access our National and University Library will be able to provide. And it should be obvious that such an approach will benefit not only one of Yugoslavia's socialist republics, but the entire federation as well.

The projected information system will not, we stress again, destroy or otherwise impair the traditional, national cultural values—linguistic or other. Realization of the concept should, instead, enhance the free flow of much needed information, between both the various socialist republics of the federation and other nations and Yugoslavia.

It is difficult to see another way for a rather small country to meet the ever new demands stemming from an expanding technological revolution, especially if the country is to avoid full economic or political dependence in the future. □

A participative approach to the design of computer systems

Enid Mumford, Frank Land and John Hawgood

System design can be improved through the participation of the people who will eventually use the system, if they can be provided with the necessary skills. The authors have developed and tested a framework for participative system design which includes a set of analytic and design procedures.

Introduction

It is gradually being recognized that system design, like management in general, is primarily about people. Many past failures of computer-based information systems can be directly attributed to two complementary causes: (a) a lack of knowledge of human needs and motivation on the part of technically oriented system analysts and designers; and (b) a lack of technical confidence on the part of general and departmental managers which makes them reluctant to intervene in design decisions.

The long-term answer must lie in the education of specialists and users, but two present-day trends provide a means for improving the situation. These are, first, the movement towards employee participation in forward planning and work design and, second, the trend away from conventional money-based, cost-benefit analysis and towards multi-attribute utility analysis which takes account of all the different types of advantages and disadvantages associated with any proposed change. We have developed a method which combines these two elements in a formal yet flexible participative framework in such a way that a number of related techniques can be applied as needed. Our approach is based on four important value judgements: (a) that financial, human and technical factors in system design can and should be treated compatibly; (b) that everyone affected by a system change can and should be considered in planning it; (c) that employees at all levels can and should design their own work systems; and (d) that the overall approach to system design and development should be based on the principle of reducing uncertainty.

In our view the process of forward planning, including system design, implementation and evaluation, should be carried out by two types of teams. The first team is responsible for steering the project; it is the direct link between the senior management of the organization and the team responsible for the detailed design. This group sets the basic organizational objectives and constraints under which the new system is to be developed. It makes the 'go', 'no go' or 'postpone' decision. The steering group will usually include the managers of affected departments, official representatives of trade unions and other major interests affected by the new system. The second team is responsible for the detailed system design and consists of representatives of the department where the new computer system is to be

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Enid Mumford

John Hawgood, a theoretical physicist educated at Oxford, has directed the University of Durham Computer Unit since its inception in 1964; his research has concentrated on evaluating the 'intangible' benefits of computer applications. Frank Land, a native of Berlin, is a graduate of the London School of Economics (LSE). After working with computers in industry, he returned to the LSE where, since 1971, he has been senior lecturer in computing and system analysis. Enid Mumford was trained in social science. She has worked in industrial management, researched industrial relations on docks and in coal mines while at Liverpool University, and joined the Manchester Business School (University of Manchester) in 1966. All the authors can be contacted in care of Ms Mumford, Manchester Business School, Booth Street West, Manchester, M15 6PB (United Kingdom).

introduced. This team will define the scope of the local problem, scan the environment for new opportunities or changing constraints, analyse deficiencies in the current system, define development goals in consultation with other groups likely to be affected, and provide decision-makers with assessments of the likely impacts of alternative strategies on these goals; and, finally, design and test the selected system and the work organization and task structures associated with it. Such a team will include members from the traditional electronic data processing (EDP) department, but their function will be to transfer the required skills to other members rather than to carry out the design themselves. Their function is that of technical consultants to the design team.

Background

Economic analysis of information systems

The introduction of computers into an organization's information system generally requires substantial resources. In order to justify the use of such resources, the organization has to set off the cost of implementing the new or changed system (the development costs) against the net benefits the changes bring to the organization. Benefits may accrue to the organization directly through a reduction in costs or an increase in production and profitability, or indirectly in that the changes in the information system enable the users of the system to perform their functions more effectively. Further, some of the benefits of the changed system may affect the organization's customers or even the community at large and have an effect on the organization through the changed behaviour of the customers or the improved image of the organization in the community. Thus the concept of a net benefit to the organization as a measurement of the benefits accruing to the organization over the lifetime of the project, less the cost of operating the changed system over that time, contains a number of practical and theoretical difficulties [1].[1]

In practice there have been a number of different approaches to solving the problem of evaluating the worthwhileness of system changes. At one extreme, organizations will accept information system change projects only if it is possible to demonstrate that the changed system will result in directly measurable savings. In one of the major oil companies, for example, projects are assessed on the basis of a forecast of directly measurable net savings per annum, divided into the estimated development costs. In this company, however, some allowances are made for intangible benefits: under certain

1. Figures in brackets correspond to the references at the end of the article.

circumstances, projects can be approved on the basis of a 'management decision'. The management decision is intended to allow for the subjective evaluation of non-measurable benefits [2].

At the other extreme, cost benefit analysis techniques are suggested which attempt to provide an economic value measured in money terms for all costs and benefits, whether these be measurable through the normal accounting system or not. This approach is often based on sophisticated mathematical methods [3], and has as yet found little application in business organizations, though attempts have been made with limited success to use these techniques in the public sector [4]. The difficulty of attaching economic prices to information treated as a commodity are indicated by a number of authors [5].

A new approach has recently begun to take favour. This recognizes that an organization has many (multi-objective) goals and that these vary in importance to the organization. Further, any goal may be regarded as having a different value by different groups within the organization. Some goals may appear to be conflicting: for example, it may be desirable to have both an efficient system (operating at minimal cost) and a flexible system. It is difficult for a system to be both optimally efficient and very flexible.

Multi-objective, multi-criteria decision methods are being developed all over the world [6, 7, 8] and have found a number of applications in the evaluation of computer-based information systems [9, 10, 11].

The approach to evaluation chosen here is based on this approach. It is guided by the following principles, namely that: (a) all those affected by system change should play a part in identifying goals; (b) all those affected are permitted to declare their own evaluation of the different goals; (c) tangible (directly accountable) and intangible (not directly accountable) values should be treated compatibly by replacing money values as a yardstick for decision-taking by utility values [12, 13]; and (d) use of subjective as well as objective methods of evaluation should be permitted.

This approach has been shown to overcome some of the problems associated with other techniques of analysing the expected value to the organization of making a change in the information system.

Planning and management of change

The approach we describe has two objectives related to the management of change. First, it seeks to legitimate a value position in which the future users of computer systems at all organizational levels play a major part in the design of these systems. The argument here is that people have a moral right to influence the organization of their own work situations and that if this right is conceded then there are likely to be both job satisfaction and efficiency gains. Job satisfaction gains, because the group whose job satisfaction is going to be affected by any change are better able to diagnose their own job satisfaction needs than any outside group of specialists. Efficiency gains, because the people who are in the change situation are likely to have an excellent knowledge of day-to-day work problems and can make useful contributions to the solution of these. Also, it is hypothesized that they will be committed to operating efficiently a work system which they have designed [14, 15].

The second objective of our paper is to persuade groups concerned with the design of computer systems to set specific job satisfaction objectives in addition to the usual technical and operational objectives. Here we argue that, unless job satisfaction objectives are made explicit and the computer system and associated organization of work designed to achieve these, then the human consequences of a new computer system will be unpredictable because these have not been consciously planned for. The result can be that the new system will have undesirable human consequences such as a routinization or deskilling of work, or other features that are not welcomed by the user. Employees in the user department may then respond in a negative way, refusing to operate the system or ensuring that it runs at low efficiency, and, in addition, absenteeism and labour turnover may increase.

Our belief is that greater user involvement together with clear job satisfaction objectives will assist the successful planning, design and implementation of computer systems. Ozbekhan, in discussing theories of planning, suggests that the *raison d'être* of any planning is to change the environment in a manner that is smooth, timely and orderly so that a dynamic evolution that is in line with our ideas of organizational progress can be achieved [16]. He also points out that, because the objective of planning is *change*, it is likely to be a threat to people, unless the different groups associated with the change believe that they are participants in the change process. We would support this view.

Figure 1 sets out the authors' perceptions of the risks associated with the traditional approach to the design of computer systems in which planning and design responsibility rests with a group of EDP specialists. We argue that, when this approach is followed, the sequence of events shown becomes a serious possibility.

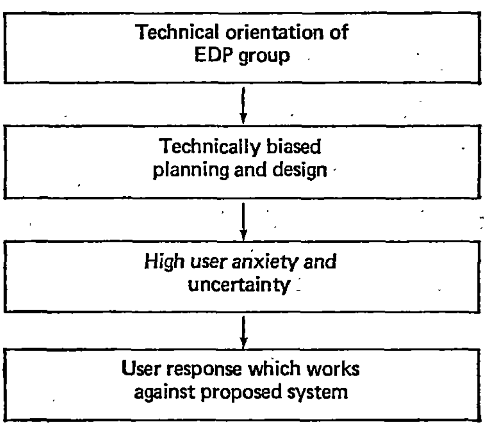

FIG. 1. Succession of types of risks incurred during traditional approach to problem of designing computer system.

We think that if a group believes that it is threatened by another group it is likely to draw together, to show a collective identity and to introduce group norms directed at emphasizing group unity and solidarity. This response enables it to reduce uncertainty by introducing behaviour patterns which are seen as helpful in protecting the interests of the group. If the response of the threatening group is one of increased pressure on the threatened group to conform, conflict will increase. It has been suggested that negative actions feed upon each other [17]. If one group acts with hostility towards another, then this will provoke a counteraction. Also if two groups have an interdependent relationship—that is, they are unable to work in isolation and depend upon one another's services for the successful completion of a task—then hostility is likely to be increased (for they are forced into a constant and irritating association). All of these statements seem applicable to the traditional relationship between EDP specialists and user groups.

Financial and organizational risks

Planning and design approaches that tend to generate rather than reduce conflict place the organization in a risk situation. It may incur financial risks through introducing expensive computer systems which operate at low efficiency, or reduce job satisfaction and increase labour turnover. Many firms underestimate the cost of labour turnover, which can be very high. Gustafson [18] says that the annual replacement of 100,000 employees leaving the Bell telephone system is now seen as involving annual outlays that are 'unquestionably greater than $100,000,000'. Hopwood comments 'when seen in such terms, programmes oriented towards improving the social fabric of the enterprise not only have the right to be considered alongside programmes concerned with technological, market and financial change, but also need to be analysed in a comparable manner' [18]. The firm may also incur organiz-

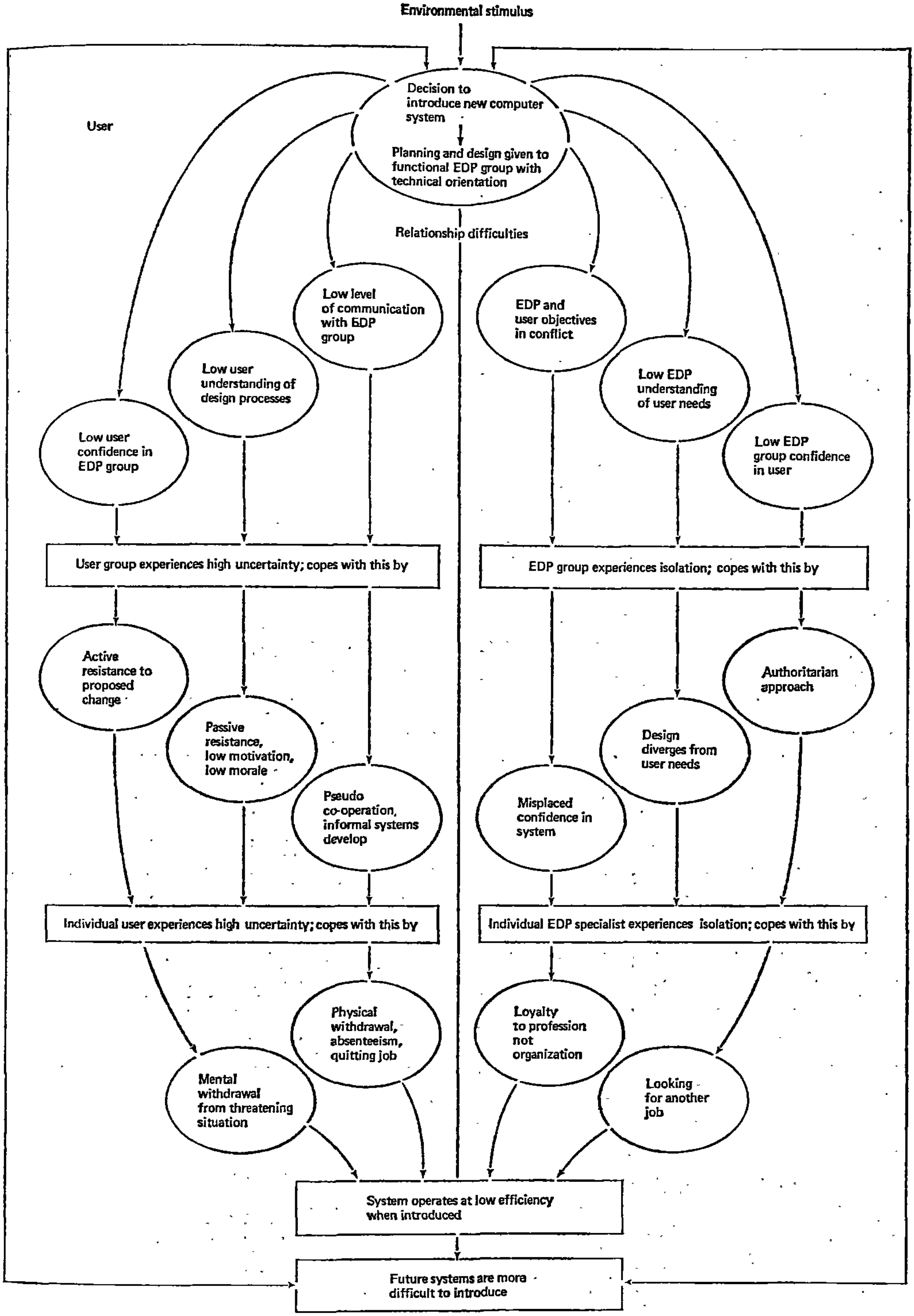

FIG. 2. Detailed development of risks inherent in the traditional approach to system planning and design.

ational risks, for a poorly functioning department may spread dissatisfaction and inefficiency through departments which interact with it. In addition there will be human relations risks. A new computer system that is introduced against the wishes of a user department has the potential to produce serious industrial relations problems [19].

We are therefore suggesting that the technical and user groups associated with the introduction of a new computer system are unlikely to have a complete identity of interest and may have major conflicts of interest. The EDP specialists will be keen to optimize the use of a technology which they know and understand and this can lead them to design systems which have a high technical competence but are poor at catering for human needs, such as a desire for job satisfaction. The user group which has no active role in the design process is unlikely to be able to challenge the technical knowledge of the specialists. This can force the user group into a dependency relationship and the subsequent acceptance of a computer system which does not adequately meet its needs. This produces low commitment to the system together with increased resistance to any future change.

A participative design approach such as we recommend enables the user group to identify its own needs and interests, to turn these into design objectives and to see that these receive equal weight with technical objectives. This is the basis of the socio-technical approach pioneered by the Tavistock Institute in London which has as its objective the design of work systems so as to secure joint optimization of technical and human needs [20]. In Fig. 2 is depicted our view of the advantages of a participative approach as a facilitator of change, that in Ozbekhan's terms is 'smooth, timely and orderly', and, also our value system, which is in line with the socio-technical school of thought.

We suggest that Ozbekhan's 'smooth, timely, orderly change' will be assisted by a simple flow diagram Fig. 3. The process is set out in greater detail in Fig. 4.

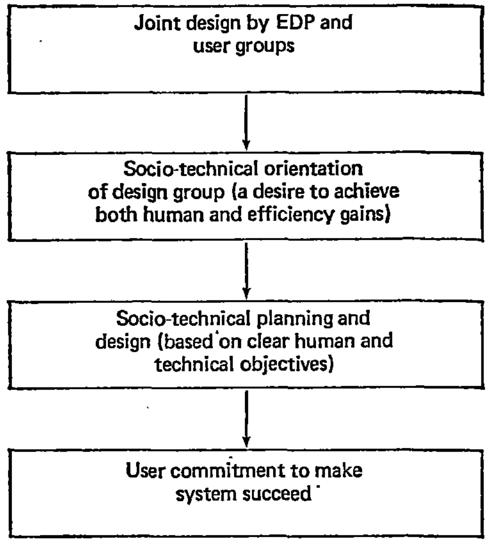

FIG. 3.

Such an approach enables conflicts to be resolved or at least recognized, so that evasive action can be taken or a consensus reached on the objectives that should be attained through the new computer system. Because planning and design responsibilities are shared between technical experts and users, competences are shared and each group can learn from the other. Perhaps most important of all is the fact that user values on participation and on the organization of work can be catered for. Today, many groups of employees are seeking greater involvement in decisions which affect them and a more interesting and challenging work environment. We believe that the use of our method will assist the achievement of both of these objectives.

The participative process

Systems design can occur at three different organizational levels. The top where it is concerned with strategic planning, the middle where it covers system definition for a number of divisions, functions or departments, and the bottom where it relates to the detailed design of an organizational subsystem such

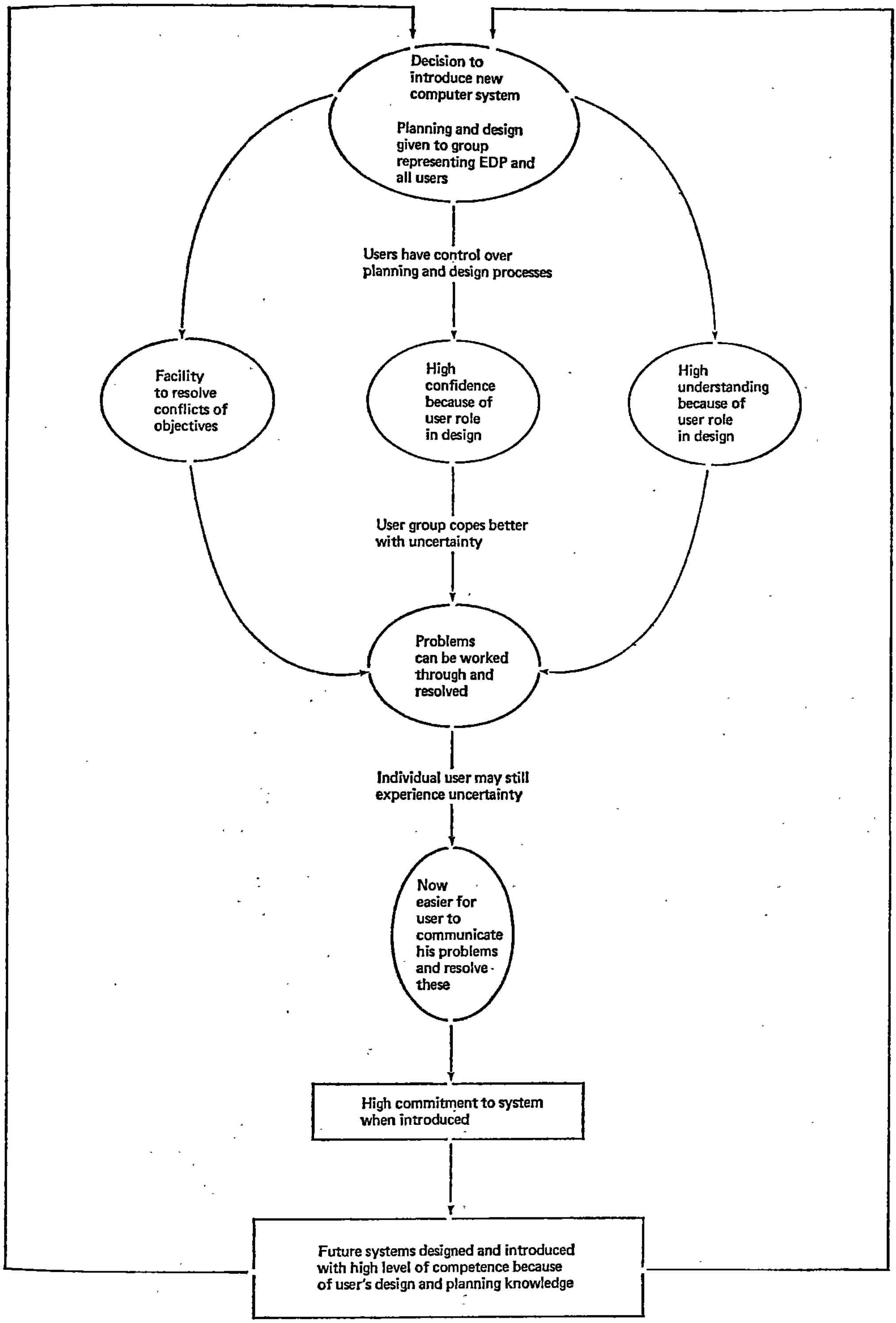

FIG. 4. System planning and design: advantages of approach described in accompanying text.

as single department or function. The participative approach can be used at all of these levels although it may take a different form depending on whether it is concerned with higher or lower level systems. These different forms have been named by the authors as 'consultative participation', 'representative participation' and 'consensus participation'.

The consultative approach is seen as most appropriate for securing agreement on strategic planning objectives. Here the major planning decisions are taken by senior management, probably at board of directors' level, whose hierarchical position enables them to take a broad view of the enterprise's future needs. Senior management will take these decisions, however, only after consultation with interested groups lower down the organizational hierarchy. A consultative structure must exist or be created so that this sounding of opinion can be thorough and accurate.

Representative participation is seen as appropriate at the system definition stage, when powerful interest groups at middle management level will wish to express an opinion on where system boundaries are to be drawn and on the broad form any future system should take. Representative design teams will include selected or elected representatives of all grades of staff and all trade union interests in the departments which a new system will affect.

Consensus participation attempts to enable all the staff in a department to play a part in the design of a new work system. They are involved when efficiency and job satisfaction needs are being diagnosed through feedback and discussion in small groups. As the design team formulates alternative design strategies, these will be discussed at staff meetings and the choice of work organization and task structure to be associated with the technical part of the system will be greatly influenced by the views of the staff. Experience has shown that consensus on system solution does not always emerge easily and conflicts which result from different interests within a department may have to be resolved first.

The procedures we have developed for use by design teams are described in the following sections. These are: (a) variance analysis for identifying operational deficiencies; (b) job satisfaction analysis for measuring the lack of fit between employees' actual and preferred work situations; (c) future analysis to identify significant opportunities and development goals; (d) benefit assessment for system change to compare the desirability of alternative courses of action; and (e) socio-technical system design to bring human and technical factors to bear simultaneously on system improvements.

Procedures to assist participation

Diagnostic procedures

Variance analysis

An important prerequisite to designing an improved system of work is a detailed knowledge of those weak parts of the existing system which produce operational problems. The method used to obtain this is known as variance analysis and was developed by Louis Davis of the University of California, Los Angeles [20]. A design group which uses this approach will examine in detail all the different operations which a department or section undertakes and note those areas where variances are prone to occur. By variance is meant a tendency for the work system to deviate from a desired standard or specification. This tendency arises as a result of some problem associated with the work process itself in its normal operation. Variance analysis is not concerned with temporary problems, such as machine breakdown, or with human errors which are a result of inadequate training. It concentrates on system weaknesses associated with the organization of work operations. An important objective of the method is to identify clearly those key variances that significantly affect the ability of a work system to pursue its major objectives. These variances are often found at the boundaries of a system, for example, where the work of one department interacts with that of another and these are problems of co-ordination.

Once variances have been identified they must be examined in detail in order to determine the following: (a) where the variance originates; (b) where it is observed; (c) where it is controlled (corrected); (d) who has responsibility for this control; (e) what he does to control it; (f) what information he requires to restore control and where he obtains it; and (g) possible alternative control mechanisms (of which a computer may be one).

Variances are frequently not controlled where they originate but, later, by supervision. A good design principle is to ensure that corrections are made as close to the source of the variance as possible.

Many variances interact with others, thus causing a set of problems that affect the efficiency of the work process from the input to the output stages. A variance matrix is a useful method for showing this interlinking. An example of a simple variance matrix for a department dealing with customer orders is set out in Fig. 5. It shows how variance 1, 'orders which incorrectly identify goods required', and variance 3, 'too many orders for staff to handle', have the greatest impact on the total work system. Particular care must therefore be taken when redesigning the technical and human parts of the work system—to get these two variances under better control. The computer can be of assistance here.

This example shows some of the variances associated with a line department with one functional activity. The same approach can be used at different levels in the organization, for example, identifying the variances of a research and development department or a planning activity. Or a single manager

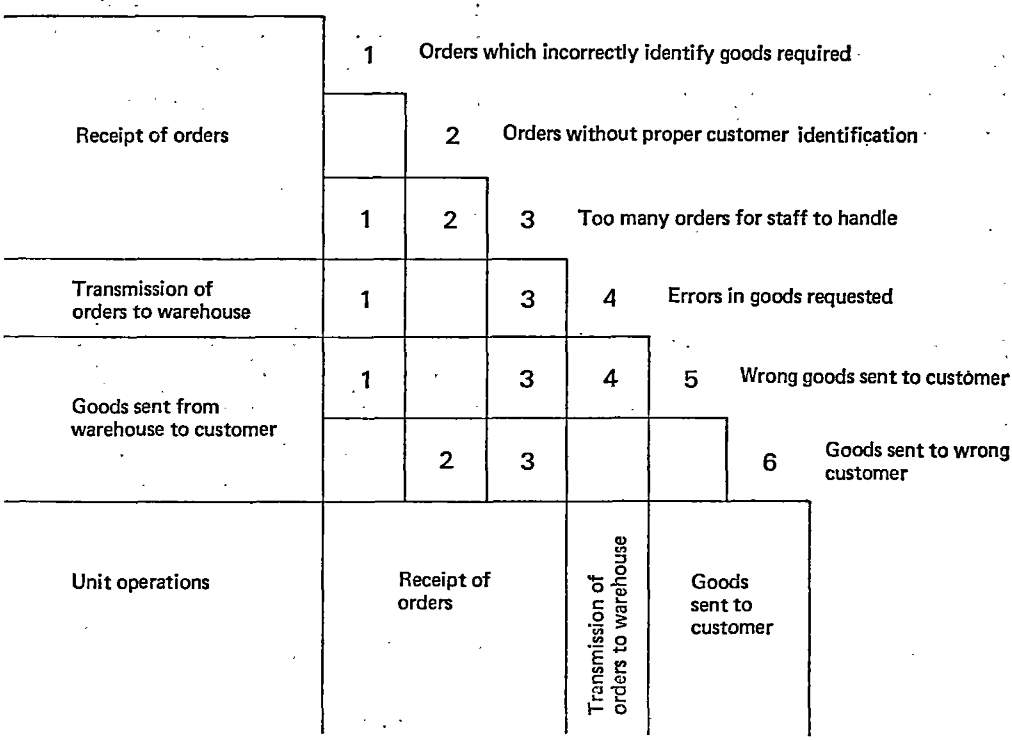

FIG. 5. Simple variance matrix of department handling customers' orders.

Needs to be met in the work environment

Needs associated with personality

Knowledge needs

To what extent does the existing organization of work meet the needs of the group of employees that the design group represents for work that fully uses their knowledge and skills, and to what extent does it provide them with the opportunity to develop their knowledge and skills further?

Psychological needs

To what extent does the existing organization of work meet the needs of employees for recognition, responsibility, status, advancement, esteem and security? Does it also give them a sense of achievement? [23]

Needs associated with competence and efficiency in the work role and the successful performance of work activities

Support/control needs

To what extent does the work situation provide employees with the kind of support services which enable them to carry out their job efficiently? These support services include the information and materials necessary to work at a high level of competence, as well as supervisory encouragement and good working conditions. (We assume that an efficient and supportive work environment increases job satisfaction.)

To what extent also does the way work is controlled, through checks and audits, fit with employee ideas and wishes on how their work should be controlled? The level and structure of wages and salaries will be an important part of the control system.

Task needs

To what extent does the way in which work is organized and jobs are designed meet employee needs for the following? (a) the opportunity to use a variety of different skills and different levels of skill; (b) the opportunity to attain targets, particularly quality targets, and to obtain feedback on how well these targets have been achieved; (c) autonomy—the opportunity to take decisions, exercise choice, and exert a degree of control over what is done and how it is done; and (d) task identity: the opportunity to undertake work which is viewed as important, which is organized in such a way that the work of one group is clearly separated from the work of other groups and which has a reasonably long task cycle, so that an employee can look back with pride on the way in which he has solved a particular work problem or carried out a challenging set of tasks [24].

Needs associated with employee values

Ethical needs

To what extent does departmental management, and senior management also, treat employees in the way they think they should be treated? This applies particularly to issues such as communication, consultation, and opportunities for participation in decisions which affect employee interests.

This job satisfaction information can usefully be collected by questionnaire, provided that three important criteria are met: (a) the information is collected by an external consultant, as only in this way will employees be convinced of its confidentiality; (b) aggregate data derived from analysis of the questionnaires are given to everyone who completed a questionnaire; and (c) questionnaire data are discussed with all employees who completed a questionnaire in small groups. This will check accuracy of the data, provide an understanding of the reasons for high and low satisfaction, and get employees involved in improving the design of their own work organization.

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can be used as the unit of analysis and his personal variances identified. This last approach would prove useful when designing information systems.

A major part of the socio-technical design task is to eliminate system variances or enable these to be more effectively controlled. If a computer system is being introduced, then its ability to assist the elimination or control of variances is one measure of its efficiency.

Job satisfaction analysis

Job satisfaction is defined by Mumford as the fit between what an individual or group is seeking from the work situation and what they are receiving from it, in other words, the fit between job needs and positive expectations and the requirements of the job [22]. Job satisfaction is seen as being achieved when three kinds of needs are met in the work situation. These are personality needs, competence and efficiency needs, and needs associated with personal values. It can be argued that an improvement in job satisfaction should always be made a design objective and a design group concerned with job satisfaction should be able to answer the questions raised in the accompanying box.

Variance analysis and job satisfaction analysis will provide essential diagnostic data for gaining an understanding of existing efficiency and job satisfaction problems. In addition, there is a need to identify future needs and so a 'future analysis' is also required.

Future analysis

The time taken to design, construct and implement a computer-based information system will depend on the scale of the planned change and the resources available to make the change. Even quite small system changes take substantial time and resources, whilst the implementation of major systems may require a period of several years. Time cycles of three to five years are not uncommon for the period between the start of an information system project and its implementation. To recover the cost of development and to cover the operating costs and provide an adequate return on the capital employed, the system might be expected to be operated for a number of years before it is to be replaced by a new system.

Suppose it takes three years from project start to project implementation and a further five years of system operation before the advent of a new technology makes it advantageous to design a new system (which itself takes two years to design and implement). Then the system which is being planned at A in Fig. 6 will have to meet the requirements of the organization not only three years later when it is implemented, but also through its lifetime of seven years. In other words, those who design the system must be capable of foreseeing the needs of the organization ten years later.

Many types of changes have had an impact on the information system. For example:

The development of new technologies may decisively alter the best way of carrying out certain tasks—witness the new possibilities offered by the coming generation of micro-processors.

Revisions in an organization's structure, changes in functional boundaries and responsibilities.

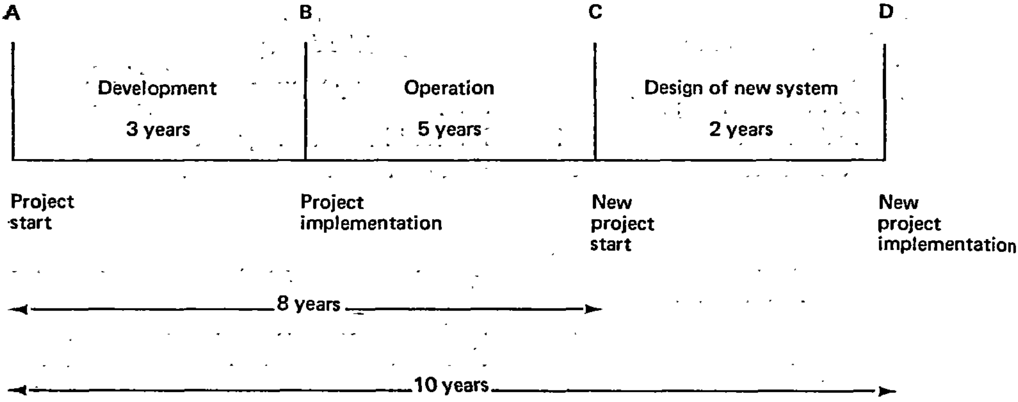

FIG. 6. Lead times required to develop and install a new information system.

Alterations in the organization's senior management, leading to changes in the style of management and hence in the way the information system is used.

Changes in the attitude of employees to work, as witnessed by the revulsion against certain aspects of assembly-line functions.

New laws, such as revised company legislation, tax laws, laws concerning privacy, laws relating to industrial democracy, can have important effects on systems.

Changes in the economic climate such as new or altered competition, the general level of activity and inflation, rates of interest, may have important impacts on the goals of information systems.

Alteration in the organization's scope or function by mergers, take-overs or activities such as nationalization by government action.

In order to design a system which meets the future as well as the present requirements of an organization, system designers have to: (a) predict the kind of changes which could occur over the expected lifetime of the system; and (b) predict the extent to which the kind of changes outlined above will have an impact on the jobs the system has been designed to carry out. In other words, how sensitive is the system to changes?

Forecasting, planning horizons

Because it is inherently impossible to build a completely flexible, completely portable system capable of coping with any change, we have to define in some way the extent of change it is possible to accommodate.

The further the designers look into the future, the more they are faced with uncertainty regarding the changes that may occur and the potential impact on the system they design. At some point in the future, the uncertainty is so great that the system designers cannot conceive of any design which can cope with a possible range of circumstances. That point of time is called the forecasting horizon.

In practice, the forecasting horizon will vary from organization to organization and will vary in different epochs. At times of high technological change, such as now, with the coming availability of new micro-computer technology, the forecasting horizon is closer to the present than at other times. A similar effect is noted at times of economic instability. Some organizations have a very stable environment and thus can forecast with reasonable certainty over quite long periods; others live in a much more dynamic or uncertain world and forecast for a short period ahead.

System designers cannot plan to build systems on the assumption of a system life which could go beyond the forecasting horizon. The planning horizon for a new system must lie within the forecasting horizon. The expected lifetime of the system, then, is related to the planning horizon of the system.

The traditional method of designing computer-based systems has not dealt with future uncertainty adequately, and the actual (as opposed to the expected) lifetime of systems has been disappointing. The situation stems from the division of function between user and specialist EDP departments. The user: (a) is not aware of the inherent lack of flexibility of the computer-based system; (b) does not realize the sensitivity of the system to different kinds of changes; and (c) regards many aspects of future policy to be outside the scope of discussion and, in many cases, regards questions of future policy as confidential. Hence, he makes no special effort to predict the kind of changes which might occur.

A specialist designer, in concentrating his efforts on finding a technical answer to meet the immediate problem, is unaware of the dynamic nature of his environment and the extent of uncertainty about the future. The level of communication between user and specialist regarding the future tends to be low and unstructured.

This implies a structured approach to future analysis. The two groups involved in the design process (the steering group and the design team) join together in the first instance to attempt to define the forecasting and planning horizon for the system. At this stage the scope of the new system has already been defined and the groups have a rough idea of the expected lifetime. Changes can affect the system in two ways: (a) by a change in the system logic: new tax laws make it necessary to change the rules for calculating tax deductions; (b) by a change in activity levels. The acquisition of a new company may make it necessary to change the product coding system and to cope with greater volumes in the same time.

The structured process involves a sequence of steps:

Step 1. Draw up a list of factors relevant to the system which are subject to change.

Step 2. Assess the likelihood of the factors changing significantly over the expected lifetime of the system.

Step 3. Identify those components of the proposed system which, if subjected to change, would cause damage to the workability of the system.

This completes the diagnostic stage of our approach. The next step is to set objectives and evaluate alternative strategies for meeting the needs identified in the variance, job satisfaction and future analyses. We call this stage of the design process 'benefit assessment'.

Benefit assessment

Our approach to multi-attribute utility analysis, which we call BASYC (benefit assessment for system change), expresses the benefits of alternative policies to different groups of people in terms of relative progress towards the goals important to them. The BASYC approach is intertwined with the other procedures described in this article, but its key concepts can be displayed simply (Fig. 7).

The sequence is shown without an exit to emphasize that a decision 'emerges' after a number of cycles of discussions held by members of the design team with their constituents, with other interest groups and with their steering committee. The discussions are guided and disciplined by the formal structure of utility calculation, but as the figure shows, the sensitivities are central to the pattern.

The word 'sensitivity' is used in two senses here: in its mathematical sense—in which it means the extent to which a value would change if one or more of the input variables changed, and in its conversational sense—drawing attention to the effect of proposed policies on the feelings of the people involved.

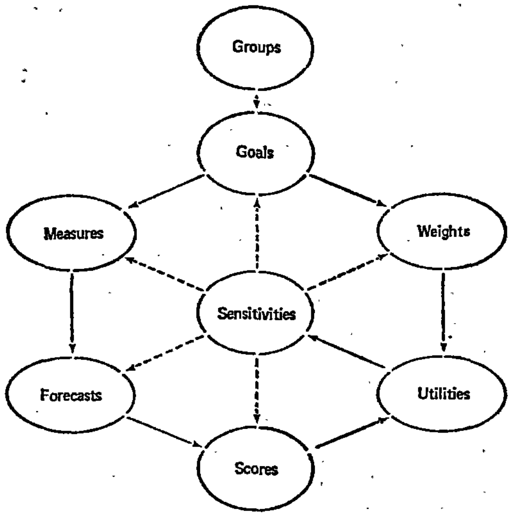

FIG. 7. Closed-circuit nature of the BASYC analysis.

The detailed, sequential steps to be taken by the design team are as follows.

Identify interest groups which are not already represented in the team (customers, owners, managers, taxpayers), paying particular attention to any subgroups that might suffer from proposed changes. Each member of the team, in addition to acting for his own constituents, will also assume responsibility for one of these unrepresented groups.

'*Short-list' the measurable goals*, relevant to the situation being studied, which are most important to all the interest groups; including here groups which have direct representation on the design team and those which have indirect representation. The techniques of variance analysis, job satisfaction analysis and future analysis will provide a great deal of the information required to do this.

Assign a weight to each goal for each group, to represent its importance to that group in relation to the other goals; this should be done in consultation with members of the group. Job satisfaction must always be included as a goal for internal groups. (For calculation of utilities, these weights are converted to percentages so that the total weight of all goals for any one group is 100.)

Estimate current measures (often several are required for each goal) and set target measures for the planning horizon date; again, all three of the analytical techniques will provide information for these measures. Guesswork (by people who know the current system) is good enough for the first cycle. Later, sensitivity analysis will determine where better values are needed.

Define alternative system strategies for comparison with the current system (including changes already decided); this is the beginning of the socio-technical design phase, and at the preliminary stage a few wild ideas are quite advantageous as they often suggest practical strategies not generated otherwise.

Forecast the effects of the alternative strategies on the measures at the planning horizon, doing this both optimistically and pessimistically as outlined in the future analysis section above. Again, the sensitivity of recommendations to assumptions will determine how much effort to put into refining forecasts.

Score each strategy for its success in meeting each goal as seen by each group using a scale running from —10 (change very much worse than existing system) through 0 (same as existing) to +10 (change very much better than existing system). Note that the comparison is between the changed system at the planning horizon and the existing system also at the planning horizon. Different optimistic and pessimistic scores corresponding to different trends are often needed. Often the scores will be the same for all or most of the groups, but this needs checking as groups' ideas on what constitutes 'success' may differ. This scoring operation needs human judgement; it is not mechanical.

Calculate utilities by multiplying each percentage weight (for each goal for each group) by the corresponding score (for each goal for each group, for each strategy) and adding over all short-listed goals. This is a purely mechanical operation, conveniently done by computer. The result will be (optimistic and pessimistic) utilities for each strategy as seen by each group. The numbers obtained are not important in themselves. What we are seeking is the ranking order of the alternative systems as seen by each group and, more important, the sensitivity of the ranking order to changes in goals, weights, measures, scores or assumptions.

Consider the sensitivities carefully to decide what further investigations are required. Often it can be seen that some strategies can be discarded, and occasionally all can agree that the right decision has emerged. More often, a new or compromise strategy will require examination in a further cycle before an acceptable solution is found. The actual decision when 'enough is enough' must always remain with management—or with the steering committee if this power has been delegated to it.

It must be emphasized that a number of the stages of benefit assessment are likely to be negotiating processes as the representatives of different interests on the design team press for priority to be given to those goals and strategies most likely to further the needs and expectations of their constituents. One advantage of the method is that these issues are brought into the open.

When a decision to proceed emerges, the team will usually go on to the full socio-technical design process, described below. This may be iterative, with initial cycles corresponding to design of prototype systems or part-systems, followed by BASYC cycles to check on likely benefits (as compared to those estimated in the assessment stage).

The BASYC approach has been applied in two major projects: comparison of alternative computerization schemes in saving banks [25], and benefit assessment in public libraries [26], the latter being an application not involving computer system design at all.

Socio-technical system design

A participative approach to work design means that the employees of a department or their representatives construct a new form of work organization which is based on a diagnosis by them of their own needs. There are a number of philosophical approaches to work design which such design groups may want to consider. The two most frequently used are 'job enrichment' and the 'socio-technical' approach. Job enrichment focuses on the job of the individual worker and tries to build up this job in such a way that it increases in interest, responsibility and challenge. The job may be extended by adding to it preliminary activities such as setting it up and acquiring the necessary materials, or completion activities such as final quality inspection and the rectification of errors, tasks which previously have been carried out by other individuals. The aim of job enrichment is to improve the relationship between the individual and his work.

The socio-technical method was originally developed by the Tavistock Institute in the United Kingdom, and this takes a very different approach. The concept of a socio-technical system is derived from the premise that any production system requires both a technology or process of transforming raw materials into output, and a social structure linking the human operators both with the technology and with each other. A socio-technical system is any unit in the organization composed of a technological and a social subsystem having a common task or goal to accomplish [27]. If we are concerned with clerical systems based on the use of a computer, the technical system will consist of the tools, techniques and procedures used for processing the raw material of information. The social structure is the network of roles, relationships and tasks which interact with the technical system. The purpose of the socio-technical system approach is to produce technical and social structures which have a high capacity to achieve technical and social goals and which reinforce each other in the achievement of these goals.

Socio-technical analysis incorporates a logical analysis of the technical components of the work system (machines, procedures, information) and the grouping of these into 'unit operations' [21]. Unit operations are logically integrated sets of tasks, one set being separated from the next by a change of state in the input or product. For example, in a purchasing department, the tasks of preparing accounting data for a computer, putting the data into the computer, and correcting errors is a logically different set of activities from matching accounts with goods-received notes and investigating discrepancies. Work design which uses a socio-technical approach identifies unit operations and allocates one or more unit operations to each work group. The work group then has the responsibility for allocating tasks amongst its members and for training its members so that eventually each individual is competent to carry out all tasks.

The analysis of the social part of the work system consists of analysing the role relationships within the system, in other words, who needs to work with whom for the system to function efficiently. In addition an analysis is made of the job satisfaction needs of individuals in the department, using the theoretical framework described earlier.

An important aspect of the socio-technical approach is the notion of 'control'. A further analysis of the technical part of the system is carried out, using the variance analysis technique already described. Operating efficiency is then improved by giving each work group the responsibility for eliminating and correcting variances which occur within the set of unit operations for which it is responsible. Job satisfaction is also improved by handing over this control function to the group. The group requires a set of problem-solving skills to enable them to handle variances successfully and the acquisition of these involves an enhancement of the knowledge of individual group members. It is believed that responsibility for, and ability to solve problems increase the interest of work and provides a sense of achievement.

Final steps, conclusions

Once our new system has been designed, it then has to be implemented and its success evaluated. Both of these stages are complex and demanding, and there is not the space to discuss them in this article. We would suggest, however, that the creation of a small prototype system is a wise safeguard as it enables the selected system design to be tried out and modified before it has widescale implementation [28]. When the time for evaluation of the new system arrives, we find that an excellent check of its technical efficiency is the extent to which it has eliminated or gained better control over those variances identified at the diagnostic stage without introducing new ones. A second measure is the extent to which job satisfaction has improved through the creation of a better fit between employee job needs and expectations and the requirements of their jobs on our five satisfaction variables.

'Participation' should be associated with system planning and design. This belief is based, first, on the value position that people affected by new technical systems should have a right to influence the design of these systems and, second, on the practical proposition that the future users of systems will possess a detailed knowledge of both the efficiency requirements of the situations in which they work and their own job satisfaction needs. They will, at the same time, have a knowledge gap in that they are unlikely to have much experience of the analytical and synthesizing skills that are required in system design. We have attempted to fill this gap by developing a set of simple, structured procedures that will take a newly formed design team from an initial diagnosis (which covers efficiency, job satisfaction and future contingency needs), through the setting and weighting of objectives and the development of alternative strategies, to a choice of system and its socio-technical design. Table 1 shows these different procedural steps used at different organizational levels and with different forms of participation.

In conclusion we would argue that the traditional approach to system design has been technically competent but socially incompetent. We believe our method provides an opportunity for an approach that is both democratic and humanistic. □

TABLE 1. Participative approach at different organizational levels

	Strategic planning	System definition	Subsystem and work design
Scope	Whole organization	Division or function	Department or subfunction
Time scale	Five years or more	One to five years	One year or less
Form of *participation*	Consultative[1]	Representative[1]	Consensus[1]
Task	To identify systems likely to be needed under different circumstances, and make outline contingency plans for system development.	To specify overall system architecture, interfaces, hardware and software compatibility requirements, etc., within agreed strategy.	To design system modules and work procedures within overall concept defined at higher levels.
Team	Three or four senior managers or Board members plus two or three internal or external consultants.	Five or six operational staff selected by senior manager responsible for division or function, plus technical experts as advisers.	Five or six elected or selected departmental staff, plus department manager if he/she wishes, technical expert and trainer/consultant.
Diagnosis	Check performance or current system against original design objectives and forecasts. Identify relevant economic, social and technological trends.	Analyse operational and job satisfaction deficiencies of current system (variance analysis, job satisfaction analysis).	Identify and measure local variances between system performance and agreed social and technical targets.
Goal setting	Identify new opportunities and adjust priorities of different elements in broad aims of organization.	Define system development objectives relevant to different interest groups within broad priorities laid down at strategic level.	Interpret system goal as detailed local social and operational targets.
Assessing alternatives	Define main alternative strategies and forecast their impact on broad aims under different conditions.	List all feasible system options and forecast their effects on system goals important to interest groups.	Consider possibilities for local variations within overall system parameters and compare likely measures.

1. In each case the form of participation in the adjoining column may also be appropriate. For example, a consensus approach might not be feasible in a department with more than fifty staff. A representative approach might be preferable. Similarly, if for any reason a representative design group cannot be created a consultative approach can still be used.

	Strategic planning	System definition	Subsystem and work design
Consultation	Discuss goals and options with representatives of major interest groups and with other study teams; present to board for decision.	Discuss goals and options with 'constituents' and with other study teams; present to decision-maker for choice of system.	Discuss goals and options with all departmental staff and with other study teams; obtain staff agreement to prototype trials.
Planning and design	Work out details of chosen strategy or contingency plans and check forecasts under different conditions.	Outline recommended system and work out details of modular structure and interfaces; recheck forecasts.	Design and implement prototype modules and/or work procedures, observe effects and redesign accordingly.
Evaluation	Present to board and, if accepted, to unions, other study teams and relevant external agencies; report reactions to board.	Collate results of local trials, check their compatibility with overall design and important goals and present to decision-maker.	Check redesigned procedures and subsystems against the full list of operational and social targets and present to staff for agreement.

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Management information systems and the transnational enterprise

Max Lopes Cardozo

An analysis is made of the relationships between computers, management and transnational corporations, followed by an examination of the influence of information systems on organizations and how they function.

I

Computers

A computer can be programmed only to solve well-defined problems. There are many instances when the computer, properly programmed and fed with the correct data, out-performs man by many orders of magnitude—in terms of both speed of execution and low rate of error. A computer can be put to work twenty-four hours a day, seven days a week, without even a coffee-break. In other cases (pattern recognition or combinatory problems such as playing chess), however, man performs better. At the moment a problem becomes less defined or vague, the computer becomes unwieldy and rapidly worthless. Yet man feels at ease in these circumstances, dealing adequately with such problems as driving a car through traffic. We may therefore conclude that for real-life problems, whether simple or complex, man is essential; aided by the computer, he often becomes much more powerful.

In modern practice, the cost of the set of programs that must be made to enable a computer to perform the required jobs—the programs being known as the software—comes to 70 per cent of the total; the actual equipment, or hardware, makes up the remaining 30 per cent. The trend is for the software to take an even larger share.

In the field of business management (directing and controlling, i.e. steering an activity), the use of computers—data processing—is restricted to a number of areas having common features: on the one hand, the data must be precise and, on the other, the application must be highly structured. The main application is in managing the flow of goods [1],[1] often called logistics, or in managing well-defined services (such as payroll or purchasing).

Let us elaborate this a bit to show how simple-looking things can rapidly become complex. The flow of goods, for example, can be described simply, as in Fig. 1.

We refer to the 'flow of goods', although in the processes depicted hardly anything moves; there are many stations in the sequence where goods await further handling. The information (hereinafter, INFO) stream flows in the other direction: for a customer to obtain a product, it must first be ordered by someone at the sales point. And for the system to distribute it, a factory must make

1. Numbers in brackets correspond to the references at the end of the article.

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the product. The product's basic materials and components must be purchased, made and assembled.

Many products consist of major subassemblies; these, again, are composed of other subassemblies, these of their component parts, and these last of basic materials. A very simple product may have four levels of this kind, while a complex one may have ten. Their control systems must be so designed that all materials, parts and subassemblies are ordered and made at the right time and in the correct sequence—so that the end-product can be assembled, tested, packed and shipped to its destination. Many 'safety' stocks are kept on hand to guarantee the system's smooth operation although, for reasons of economy, each level of inventory is regularly scrutinized.

The planning of order in industry

We draw attention to the fact that every single item, be it product or part, can be described exactly, uniquely identified, and therefore addressed by a code number. The same is true for processing and manufacturing operations: they are described in manufacturing instructions. In the older industries, there is still much empirical craft (art) in making things. But in industries based on scientific technology, specific processes are completely understood and described.

So in order to make and deliver a product, everything must be in readiness: factories, warehouses, means of transport, a functioning organization with well-trained personnel and established channels of distribution. As in a play, the dramatist has created his brainchild, the actors through hard work have identified themselves with the *dramatis per-*

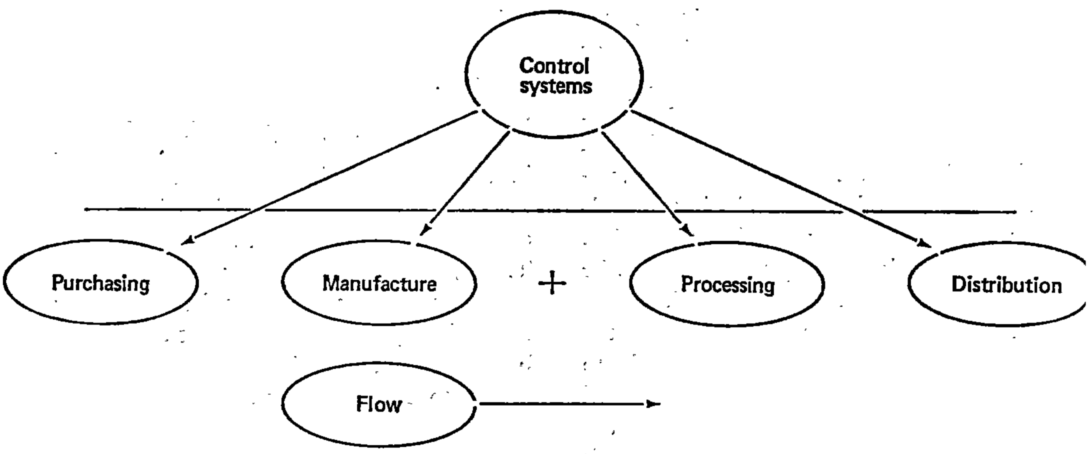

FIG. 1.

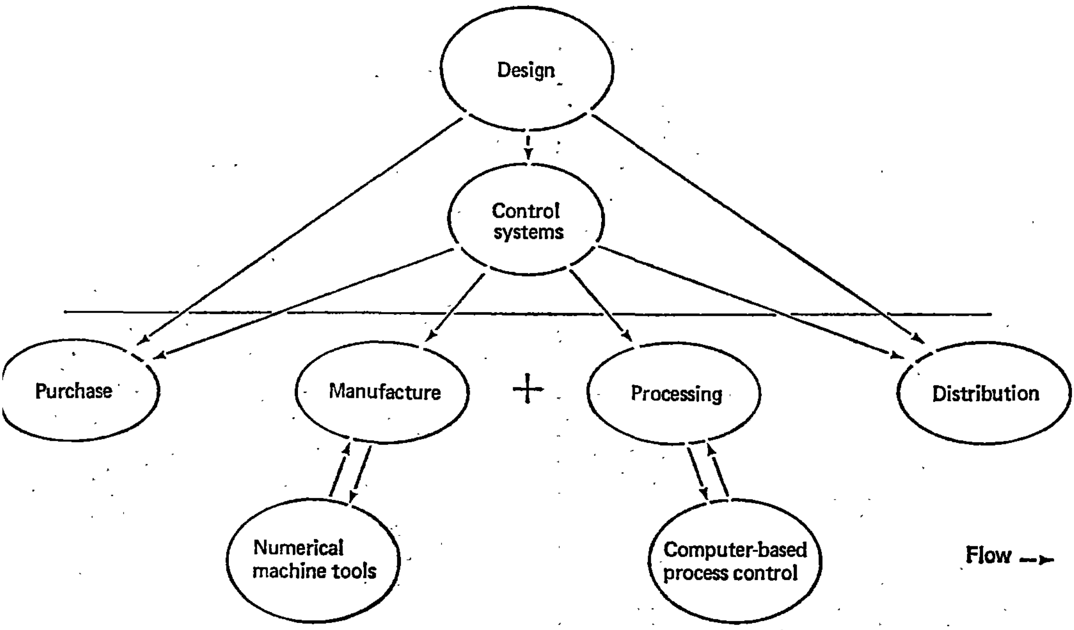

FIG. 2.

sonae, the theatre is properly staffed, the audience is waiting, and the play can begin.

Prior, then, to the logistic process is a design activity which results in detailed description of the products and processes we have been considering. It is with a view to this requirement of detailed, machine-readable data that computer-aided design (CAD) can be very useful. This is even truer for numerically controlled machine-tools and computer-controlled processes. In these cases, the test of whether the part or subassembly in question has been correctly designed is accomplished automatically—although this will depend on the product one is considering. For large-scale integrated circuits and specifically, for example, computers and other digital electronic products or those for the aerospace industry, CAD and computer-aided manufacture are mandatory; for others, these processes are, for the time being, a matter of choice.

Now our original diagram becomes a little more complicated (see Fig. 2). Yet the story does not end here. Because manufacture requires infrastructures of supplies, storage and distribution, as well as human resources, today's rapid technological and political change means that everything is in constant movement. One cannot react to customers' demands unless previous steps have been taken, well in advance, to anticipate needs. All this means that most of the activities indicated are not reactions to real data; they are controlled by forecasts. There is thus a planning environment, implying that the flows of information are reversed.

Do old bottles suffice for new wine?

In managing any kind of organization, there is a hierarchy of operational planning systems [2]. Ranging from the very detailed plan, controlling or influencing an individual action, one finishes with long-term planning used to create new classes of product, new production facilities, new markets and their distribution channels. The first has a time-horizon of a day or a week; the second looks ahead for a period of four to seven years (depending on the type of industry being considered). The notion of making new products in existing manufacturing facilities is not realistic in technology-based industries; especially for long planning periods of seven years and even more, a new product line is usually accompanied by new production facilities. Beyond the horizon of the life-cycle of a product, we enter the domain of strategic planning. Here, there is little use for computers.

The advent of the computer and computer-based INFO systems has brought one great advantage: the tremendous amount of paperwork characterizing current business activity can be (a) generated automatically or (b) skipped entirely because data are stored in every management information system (MIS). Many modern systems provide direct access to MIS memories so that, if one needs to know something specific, one seeks it via print-out or a terminal with visual display. Complete, periodic surveys thus become superfluous, implying great savings in time and money.

These real-time systems have considerable impact, therefore, on an organization. Once a real-time system is operational, everyone in the hierarchy has access to the same data. (How often, where the older 'batch-processing' mode still prevails, will top management in large enterprises be presented with data already months old, then make decisions concerning situations that have since been corrected by middle or lower management!) In control systems incorporating a number of decision levels, where delays occur in transmitting information from one level to another, it is well known that instabilities are to be expected.

The term MIS, incidentally, is used for those computer-based systems that not only process information but have built-in decision rules. Normal operations are thus automatically controlled, and only exceptional cases are presented for managerial (human) intervention [3].

Retrieval systems

Apart from these control systems, we should mention retrieval systems. Those that use a common data base can aid in simplifying and speeding the making of decisions. Let us take, for example, the personnel file used in an organization; it serves as a common data base for quite a number of programs: some twenty to thirty INFO systems can be associated with this data base. The personnel department can, apart from using the file in a straightforward way, also use it in career planning. A medical INFO system can, with much advantage, be connected to the personnel file. By updating this data base, all dependent INFO systems can be brought to the same level of correctness.

Such systems, quite elaborate, are highly useful in modern management. They can be designed, too, so that the privacy of the individual employee is safeguarded. Each subsystem is accessible only to authorized persons, each of whom has a 'need to know'.

Let us take another example, that of a customer service providing direct access (on a real-time basis) to the inventory file of a sales organization. This is done either by a terminal with visual display or by telephone to a sales assistant using the same display terminal. Thus both customers' requests and orders are dealt with instantaneously, with a minimal chance of mistake, and the system lends itself, without difficulty, to providing an input to the MIS control systems mentioned earlier.

It is worth mentioning, in this category, airline reservation systems, in which decision rules are built into the system in order to allow for priority reservations. Sophisticated telecommunication and message-switching facilities on national or world-wide scales, combined with large computer facilities, provide very good service [4].

In all cases of man-machine interaction, we obviously exploit the speed of the machine and the fact that a human being can scan rapidly a text or a picture. By a technique called list processing, a machine operator is presented with a 'menu' from which he can choose. He then makes his choice known, by using a light pen or pushing one of a set of buttons numbered, say, from 1 to 9. The list processing program has been designed so that questions and answers are handled in correct sequence.

When computer-based models are used in decision-making, operational research and simulation techniques can be applied in a few cases. An example is that of the large, linear programs in matching to desired output the crude oil offered to petroleum refineries. Most of these techniques are optimizations, and their main use is of a qualitative rather than a quantitative nature. In contradistinction to engineering or other physical design problems, it is only in rare cases that the model used approaches the real situation closely enough to give valid answers. Relations between variables are often vague, and uncertainty plays a dominant role. (Uncertainty is treated with the aid of probability calculus—the answers to many questions derived from probability theory being counter-intuitive. This is very apparent in problems dealing with the queuing of people or jobs, or in traffic congestions.) So computer-based models give indications, by their answers or through their simulations, of how to tackle problems in the real world.

Management

Whether top, middle or lower, management comprises all those persons engaged in directing and controlling an organization's activities. The definition implies that a manager must know, first, what he wants done, and then by whom. Every organization strives for continuity, implying that on-the-job training is essential. So a manager must always, when assigning tasks to people, weigh the benefits from (a) taking the best qualified individual for a specific job against (b) the longer term gain to be derived from personnel development.

This weighing of the pros and cons of short-range *v.* long-term advantages involved in decision-making suggests that management is more of an art than a science. Most of us know that the art of *What to do?* is often called decision-making, yet the label is somewhat sterile [5], as it does little credit to the great talent of arriving at correct, relevant decisions. In real life, one deals with a great number of variables, all interconnected [6]. For each variable, there is a zone of indifference in which the manager's attention is dormant. Crossing the zone's boundaries triggers off danger signals. Attention to action is aroused and, when the signals are strong, immediate reaction follows. Crossing the other side of the zonal boundary, to continue the simile, alerts management to action of a long-term nature—often to safeguard the very continuity I have mentioned.

Please note that one of the many variables, profit, comes actively to our attention only when it is too low (thus requiring action to protect the continuity of the enterprise) or when it is too high for a given set of circumstances. In the latter case, management decides to plough back profits through new investments which, although costing money now, have good prospects for the future. In most cases, the alerting signals are subjective (within the manager's mind) and cannot easily be quantified. Great managers have an unfailing sense for these indicators; others, while they may be great leaders, make wrong judgements. While business is slipping badly, they perceive that they and their organization are doing well.

The decision process has a close bearing on our subject, and the reader will understand by now that, in decision-making, computer-based systems can be used only in low-level yet often very complex problem areas in which discretion is severely limited or where—expressed somewhat differently—the degrees of freedom are very few, preferably one or two.

Our remarks on management would be

incomplete if we omitted the important aspect of supervision. Everyone is familiar with the difficulty of making oneself understood when giving an order. Besides keeping the progress made under observation, supervision is especially needed to correct deviations from a set course. Planning systems, with the progressive planning periods mentioned earlier, are used as the formal supervisory instruments. It goes without saying that informal checks and briefings are also essential elements of management.

The transnational enterprise

National boundaries are not necessarily natural limits for many types of enterprise, whether private or public. Indeed, many national States are of more recent formation than well-established transnational firms. Obviously there are classes of entrepreneurial activity that are transnational by their very activities, like shipping or air transport, communication or banking. Many transport and communication activities, for example, are basically international, although they are often organized as networks of co-operating national institutions or companies. There are also the examples of mining and agricultural operations, where the minerals or crops processed are not indigenous to the firm's home country. Then there are technology- or science-based industries and some service industries (e.g. tourism and insurance) that are not, by definition, bound geographically.

For all these, the general law of economies of scale holds. To be a little more precise, this 'law' is valid for homogeneous product groups but not necessarily for an entire firm. Many large corporations are involved in multi-product activity, and one cannot apply the law of economies of scale to these firms without further investigation. There is a further restriction: economies of scale are to be realized in production but not necessarily in distribution. There is a widespread belief that economies of scale are limited by size of operation or equipment. This is not true, and it can be refuted by reasoning [7].

Given these restrictions, the decrease in unit cost with increased scale of production is the economic force driving many an enterprise to look for new markets for its products. The market is often found abroad. To obtain easy access to a foreign market, a method often applied has been (and remains) to acquire an existing firm (often with production facilities) in the same, or roughly the same, industrial branch in the country concerned. By pooling knowledge as well as facilities to mutual advantage, economies of scale are arrived at (perhaps after considerable time). This pattern, applied to the automotive and electronic industries, is well known.

There is a final remark to be made on the transnational company. The management of the enterprise deems itself to be in a weak position when dealing with the authorities of a foreign nation or, for that matter, with such vested interests as trade unions. Management is extremely anxious to avoid giving the impression that it has not the interests of the local country at heart, or of the local enterprise in particular. The local authorities and vested interests sense, on the other hand, that powers beyond their control—and of a menacing nature—are conspiring against them [8].

In reality, however, the transnational wields no power other than the offer of a product or service (or design or process) for sale or lease. Prior to the offer, the transnational has invested heavily in capital goods and, more significantly, human capital [9], investments that maintain their value only in a continuing business. It is to be deplored that this mutual distrust, for which there is seldom good grounds, tends to hamper the free flow of goods, services and technological knowledge. Mankind needs these badly, and transnational enterprises are the chosen vehicle.

Effects of INFO systems on organizations

Information is essential to the functioning of every human being, reaching him through his various senses.[1] From the data and other signals he receives, the individual extracts certain information and then acts or reacts in order to adapt himself to the environment—changing the environment to his advantage whenever this is feasible. An organization, that is, a group of individuals sharing common goals, does much the same. Every organization has patterns of relationship (a) between its own members and (b) with the external environment. These relationships determine, or *are*, the structure of the organization, normally a stable entity.

Whether a member of the organization functions properly depends on the knowledge of the structural patterns that he gains with the experience of working within the structure. The information that the manager needs to analyse and decide on problems flows mainly through the structure. To perform his task correctly, the manager therefore must be intimately familiar with the social structure since every organizational change (however subtle) of which he is unaware can lead to wrong conclusions. This being so for all managerial levels, it applies especially to top management. Yet the operational experience of top managers has taken long to accumulate, a human factor explaining why organizational structures change but slowly.

From these observations we can conclude that structure depends, to a large extent, on the informational environment prevailing at the time of the organization's formation. This, then, becomes of particular significance to the internal structure (and mode of operation) of the transnational firm—which, by its very nature, has complex lines of communication.

Flow of streams of information

Biological metaphors have serious limitations, but they help illustrate a point when we realize that living organisms are well adapted to their environment. A bird of prey, for instance, has remarkably developed eyesight; there are numerous other examples, meaning that organs important to the survival of the organism or its species are specially developed. Conversely, those specimens survive that have specially developed organs (in our case, sense) to receive and treat relevant information.

The same holds true for enterprises. They are situated in a competitive environment, for the most part; they normally survive only when their ability to receive, and react to, pertinent information is specifically suited to the situation.

It is often not well understood that even the technical facilities of, say, a manufacturing plant are influenced by the streams of information governing its operations. This is particularly noticeable in material handling or transport operations. Take, for example, the case of passengers boarding an aircraft. You, the traveller, must check in an hour and a half before take-off time. Your ticket is verified, your luggage weighed, labelled and carried off. Then you wait. When boarding is announced, a few pleasant ladies count all the waiting passengers, then the cabin crew repeats the procedure on board the plane. All this is information processing, and a simple illustration of batch processing.

Were it a flow process, you would have arrived at the airport, gone through the same procedures without delay, and boarded the plane (and taken off, it is to be hoped—but

1. For a transdisciplinary examination of how the human being processes information, see 'Brain, Memory and Learning', *Impact of Science on Society*, Vol. 28, No. 1, 1978.—Ed.

There are three eras to be distinguished. The first, from the beginning of time until about two hundred years ago, was limited by the speed of horse or ship. Even the famous 'pony express' separated people in North America by time measured in days or weeks. Management was decentralized, while letter-writing had become a fine art. The second age, that of the telegraph, was opened by visual signalling via semaphore, then followed by the advent of the telephone. Communication became very rapid, almost instantaneous. The third period, marked by communication satellites, offers world-wide telephone and other data transmission networks. Communication is now not only instantaneous, but data processing has become a reality because of the invention of the computer.

In real life, every solution to a problem can have its drawbacks. The gains obtained by the flexibility of management to react, on the spot, are frequently offset by petrification of the same management's structure and patterns of behaviour. To decentralize management, long indoctrination is necessary and strict rules of conduct must be enforced. By way of example, let us look at the case of the Chinese nation.

The great invention of Chinese writing made possible exact comprehension between peoples who spoke many different languages; it permitted central rule to be exercised over long distances. Decentralization of the central government evolved through long, careful education and indoctrination of civil administrators. This led to a stable structure capable of resisting many a storm, its collapse ensuing only as a result of confrontation with Western technology. The old structure had not been able to maintain its organization in face of new modes of communication and transport: its information environment was unable to change. Now, in our own lifetime, we are witnessing what it takes to alter socio-cultural structure.

Programming languages that make it possible to converse with a computer are like Chinese characters in that they are used and understood by people speaking many tongues.

It was during the second of the three eras that the great transnational firms of today originated. Their structures reflect many characteristics of the period, including two world wars, economic depression, revolutions, trade restrictions, and nationalistic protective measures of many kinds. Now, in the computer age, raw information is processed instantly over great distances for specific purposes. With decision rules built into the machine, managerial decisions are taken automatically. Only the exceptions, to which programs have not been prepared to reply, are presented for human intervention.

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this is another information handling operation). We have used this example to show that service counters, waiting areas, escalators, in fact the whole layout of airport buildings, all have been designed to handle passenger movements. Still closer ponderation reveals that the design corresponds to streams of information processing.

Once one has become alert to this cause-and-effect relationship, it is rather good sport to observe how much of the physical appearance of air terminals, or for that matter of warehouses and processing or manufacturing plants, is determined by the informational streams their employees were expected to handle at the time the facilities were designed. We may learn from these few indications, which the reader can easily extend from his own experience, that every organization is influenced, in both social structure and physical payout, by its informational environment—in many instances, even determined by this environment.

Effects on the transnational enterprise

As is every organization, the transnational corporation is strongly influenced by the information environment. But in this case, more than with national enterprises, historical development plays a role with each transnational institution. The growth of a firm, before it expands internationally, usually covers several decades. During early, rapid growth, everyone from president to youngest employee is so busy responding to day-to-day demands that any thought of expansion or diversification is impossible. When growth has diminished to a small annual percentage of turnover, internal forces previously occupied with rapid growth are then set free. The obvious reaction is a search for new markets abroad for the existing product range or, in other words, to export.

It is soon discovered, however, that manufactured products require adaptation to specific markets, a motive supplementing the corporate desire for selling in a foreign, national market through existing channels. Specific demands will then flow from the new market to the parent firm which, more often than not, lacks sufficient structure to design and produce all sorts of local adaptations and styling. The enterprise will then begin to have the required work, design and production, executed by a newly established unit in the country concerned.

When the parent firm acquires a local facility through purchase, use is made, of course, of the facility's existing capability. There is also a further category of processing industries (e.g. petroleum refineries), whose broadening range of end-products justifies the serving of regional and national markets by local installations.

In all these cases, technical know-how is the binding force of the enterprise, flowing up and down the entire organization. The oldest transnational organizations, exploiting know-how accumulated over several centuries, are banking and trading houses stretching from Florence to Osaka.

Some reasons why MIS fail

Given today's environment, existing structures and the layout of technical facilities are not always optimal. Structures change slowly, as we have seen, and the same is true for facilities. Designing new machinery takes time and, for every enterprise, design capacity is adjusted to economic growth and depreciation periods of capital investments. There is, furthermore, a subtle reason why (with few exceptions) MIS are not as successful or revolutionary as was believed when the decisions were made to build or inaugurate these systems.

If we take snapshots of the formal structure of an enterprise, we find the whole split into departments and sections, perhaps grouped in divisions or companies spread over many countries. These organizational units are specialized parts of the whole, headed by the middle and lower managers we have discussed. These supervisors inevitably look after their parochial interests instead of those of the entire organization (an interest with which they are often only vaguely familiar).

Departmental interests by no means coincide with those of the whole institution. The accounting department, organized along the same departmental lines, may provide managers with wrong indications. This becomes painfully clear once information streams are formalized, the flow of materials steered from the purchasing units, guided through warehouses and plants, and finally directed towards the customer. From our earlier analysis, many of the classically organized departments should disappear—or at least be restructured drastically in order to reach optimal functioning after the MIS has been implemented.

It is beyond the responsibility of middle and lower management to grasp such changes in advance. On the contrary, the lower ranks of management will almost invariably influence the design of MIS so that the system will help them better to perform their tasks. When this happens, the resulting MIS is often useless. Because large MIS are expensive, general disappointment follows. So managers should not be consulted in the design of MIS since there is no one who can describe, in necessary detail, how the organization and its performance will look after installation of new MIS.

A paradox and its resolution

So we have a powerful new technology, information processing, that has a strong influence on society—specifically, on those elements exposed to competitive forces. Use of the new technology is essential to survival of the enterprise. Yet, when the new technology is put to (vital) use, there is no one in the organization to specify what is needed. The people who do specify, being subjective, offer wrong solutions to problems.

The system to be implemented must be compatible with existing modes of operation, so that it can be worked in gradually. But this means that precisely the managers we found to be incompetent a moment ago are the principals in the introductory phase of putting the system to work. And, since these same managers will be the system's users, their active co-operation during the implementation period is obligatory.

The reader may now be thoroughly confused, but he will also understand that other ambient factors do not ease the situation: working with many national cultures, using long lines of communication that must pass through numerous decision points with different levels of sophistication. These are all characteristic of the transnational enterprise.

To resolve the paradox, we resort to system analysis [10] in order to discover where organizational changes are likely to occur or even certain to happen—without knowing what the institution will look like later. After the analysis, we use system engineering [11] to search for viable solutions to our problems. System engineering originated with the mother of the electronic industries, the telephone networks. These utilities had, quite early, to reconcile continued technological progress with the proper functioning of their existing systems.

System engineering is a collection of somewhat heuristic methods, building a system from known (and sometimes unknown) elements. The unknown elements need to be invented or developed before the system can be designed. In this way, compatibility with the existing, overall system can be ensured and the target specifications of the desired, new system met. Many designers, even in non-technical areas, use this method without knowing its name.

A slow process

The guiding principle in designing MIS is to comprehend the innovative aspect of the new technology. This means that the relevant, i.e. processed, information must reach the manager concerned, or cause automatic reactions, without appreciable loss of time—although, as we have seen, no one has asked for it and some may even consider the process to be wasteful. Real-time processing to replace batch-processing is almost always, in a word, cheaper.

Under the influence of the new information environment, management will begin adapting itself and its structures to the changed situation. The managers will bring about modifications in procedure, technical planning and personnel requirements that might have been envisaged but not actually devised. The process may be slow, but it helps us resolve the paradox. One must unbalance the organization so that those responsible in changed circumstances can adapt themselves accordingly.

This unbalancing, in contradistinction to optimization, should be the main aim in designing and introducing MIS, whatever the institution in which the system is to be used. The goal applies in particular to the transnational enterprise. Making full use of the powerful technical means that exist nowadays, it seems possible to reap the full benefit of transnational operations—all the while practically eliminating their disadvantages. □

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Computer science, computers and education

Blagovest Sendov

Referring to similarities between computer science and energetics, a specialist in the field of education recommends that instruction in computer science be integrated into the general teaching of mathematics.

Computer science is related to all the sciences and is linked with science teaching at both the school and the university levels. Its role in social and economic life is continually growing. Computer science is an offshoot of mathematics and is developing in direct relation to the latter. The role of mathematics in the development of computer science is comparable to that of physics with respect to energetics, which also confirms the well-known analogy between information and energy.

It might be tempting to subsume any scientific, social or economic activity which is concerned with information under the concept of computer science. In that case, computer science would be expanded to such an extent that it would be emptied of its concrete content. The same would apply to energetics if one considered everything related to energy to be part of energetics—since any activity in our world necessarily entails the consumption of energy and the transformation of one type of energy into another, energetics would cover absolutely everything.

Progress in physics and mechanics has made it possible to build ultra-powerful systems for the transformation of energy, and this was the basis upon which energetics became a scientific discipline and, at the same time, an economic activity. Energetics is not only a science of energy; it also represents a complex of basic economic activities which make use of progress in physics, mechanics, chemistry and other sciences. For this purpose, various advance techniques are used to produce energy or, more precisely, to transform it into a form which is more suitable for consumption.

Information and cybernetics

In the course of the last century and at the beginning of the present one, the extreme copiousness of the physical notion of energy led to a so-called energetic approach for explaining natural phenomena. The notion of energy is to be found at the very basis of all the natural sciences. It is hardly possible at the present time to imagine any research on living or inanimate nature which is not based upon the principles of the conservation and transformation of energy. The energetic method is not, of course, a panacea, nor can it be. To confer an absolute value on energetics would result in 'energeticism'.

What is exercising our minds today is less the philosophical concept of energy than energy itself—that energy which is needed by society and which is at the centre of economic and political problems. The consumption of energy for industrial and domestic

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use provides the chief index for measuring a country's development. Energeticism is outdated, but energy gives rise to problems of enormous topical importance: such as, for instance, how to find new sources of energy, how to satisfy the growing demand for energy which is manifested in all societies, how to reduce and eliminate the pollution of the environment resulting from the production of energy.

During the 1950s, another concept came to preoccupy the minds of many scientists and another way of explaining many phenomena began to predominate. It was information and the informational approach which led to important scientific results in the areas of biology, psychology, linguistics and management. The notion of information plays a central role in cybernetics. The cybernetic vision of the world can basically be defined by the role of information in the functioning of living organisms and machines. The notion of information is closely related to the notions of structure, order and system.

It was not purely by chance that, at the very moment when this informational approach to an explanation of the world was taking definite shape, a start was made on the creation of automatic calculating machines, that is, powerful artificial transformers of information.

The origins of computer science

At the present time, information occupies a central place in almost all branches of science. The informational method has deservedly come into vogue, for it opens up unexpected possibilities for explaining a great number of natural and social phenomena. Increasingly powerful computers are making it possible to utilize this method to an ever-greater extent. Again, this method is not a panacea, although for the blind followers of fashion there may be a temptation to attach an absolute and universal value to it. Just as energeticism came into being, it may be supposed that 'computerism' will appear on the scene, and may perhaps already have done so.

Without paying too much heed to the foregoing parenthesis, we cannot today ignore this notion which forces itself upon us in the most diverse situations—situations more diverse, indeed, than those covered by the notion of energy. In defining the content of computer science, one should not make the mistake of including everything which has to do with information. Computer science encompasses solely those problems that are related to the automatic processing of information, more particularly by means of computers.

In practice, a new science was born with the appearance of electronic calculators. In English-speaking countries, this science was called 'computer science'. The French were the first to react against this designation which very quickly spread abroad. They adopted the word *informatique* to convey the meaning of computer science. In the course of the discussions over this term, which soon came into international use, it was quite correctly argued that it is illogical to use the name of the tool to designate the science for which it is used: thus, it would never occur to anyone to refer to astronomy as 'telescope science'.

The term *informatique* was taken over in German [1][1] and it has been adopted in Russian [2] as well as in other languages. The programming of the computer is still an important element in computer science (or 'informatics'). It might be added that in 1968 an attempt was made—albeit in vain—to apply the term 'informatics' to the new branch of science which deals with the automation of information, namely, to modern library science [3].

Information, messages and linguistics

I shall refer briefly to the notion of information which we accept as a basic notion requiring no definition. The notion of message is also a basic notion, but it is not identical with the notion of information. The same information can be transmitted by means of different messages, and the same message can communicate different information to different receivers of the message. A message is the physical vehicle for information. It can be spoken, written, expressed in one language or another, mechanically recorded by magnetic or other means, carved in stone, cast in metal or inscribed in a genetic code.

The information conveyed by a message does not constitute an isolated property of the message. The various receivers of the same message derive from it different information. The relationship between the message and the information depends upon the ability of the receiver to interpret the message, that is, to understand the language in which it is expressed. This is most obvious in the case of coded messages. To enable information to be transmitted by means of a message, an arrangement must be established between the sender of the message and its receiver. Where the arrangement is purely formal and only one meaning exists, one can speak of a code or formal language.

The magic of modern languages that form the subject of linguistics lies largely in the mechanisms used to reach this arrangement which makes it possible to transmit information by means of messages using these languages. In this case the arrangement is not formal and it comprises more than one meaning; it changes in time and takes on different shades of meaning with almost every pair of interlocutors. When two people converse in the same modern language, it is not certain that they will always understand one another, that is, that they will be able to transmit to one another a given information.

Modern languages are highly complex phenomena comprising aspects and problems of a physiological, psychological and social nature, as well as others. To fathom the secret of modern languages, it is first necessary to ascertain their most general common features, in other words, their invariants. For this purpose, a comparison must be made of the various symbols and structures of these languages. This task falls within the sphere of comparative linguistics.

A theory of receiver attitude?

To ensure that a given type of message can only be interpreted in one way, special formal languages are used. Saying that the interpretation has only one possible meaning is tantamount to saying that the information contained in the message does not depend on the receiver. In these circumstances, one can speak of the quantity of information contained in a message, because the information has only one possible meaning and that is determined by the message.

The quantitative theory of information was formulated about thirty years ago. This well-defined theory is extremely important

1. Figures in brackets refer to the references at the end of this article.

for communications technology. It is an essential component of cybernetics but is also applied in other fields. The theory of information is a purely mathematical theory; it only reflects one aspect of the notion of information, but it is nevertheless very coherent. It is interesting to note in this connection that there is a very close relationship between the mathematical description of the quantity of information and that of the quantity of energy in a system.

Attempts are currently being made to create a theory of information which takes account of the attitude of the receiver towards the message he receives. Such a theory would much better reflect our intuitive idea of information and could be applied in a large number of cases. However, experiments, though numerous, are far from providing satisfactory solutions.

The lack of a solution to this problem does not call in question computer science because the latter is chiefly concerned with the automatic processing of information—in other words, with the transformation of messages recorded in a formal language.

Language and mathematical rules

The first formal languages made their appearance in the realm of mathematics. The enriching history of these languages cannot be recounted here, but it should be mentioned that they played a decisive part in the development of mathematics and of human knowledge in general. Thus, for example, the position of written numbers, and especially the position of numbers in the decimal system, constitutes one of man's greatest inventions, for this made it possible to effect calculations according to the well-defined formal rules known as algorithms.

Mechanical computation is based entirely on the judicious choice of the language in which the numbers are recorded. The history of the mechanization and automation of computation is very interesting. It has to a large extent been influenced by the level of technology available in various periods, while the level of technology was itself dependent on the advances made in mechanics, physics, chemistry and other disciplines.

An important point in the history of the mechanization of computation was reached when the rules were established which made it possible to effect arithmetical operations with a pencil and paper. The originator of these rules, Abu Ja'far Mohammed ben Musa al-Khwarazam, of the town of Khwarazam in what is now Uzbekistan (in the Soviet Union), wrote the first work on algebra at the beginning of the ninth century. The word 'algorithm' comes from *al-Khwarazam* and was used to designate the rules of arithmetic. Today, the term, which is among the most important in the area of computer science, applies to the formal description of the procedure for processing a given type of information.

The first automatic calculators were designed to solve the mathematical problems encountered in the field of physics. Technological development and continuous improvement of this equipment very quickly made it possible to increase the speed of electronic calculators and to increase the capacity of their memories. These machines, computers, today operate at a speed which makes it possible for them to execute thousands of millions of operations in a single second, and their memory capacity is practically unlimited. The original purpose of these machines, which was to solve mathematical problems by processing exclusively information in the form of numbers, has been expanded without too much difficulty to include the processing of information in the form of letters. These operations which include the processing of information in the form of letters, are, of course, no longer arithmetic operations, but rather text processing operations. Computers have become powerful and universal data processors.

Highly adaptable machines

Because the programme followed by the machine is described in a formal language, it constitutes in itself information which can be processed automatically. This property, which provides computers with extreme flexibility, constitutes the very core of computer science. The fact that it is possible for the machine itself to transform the programme it is carrying out opens up unexpected prospects for the automation of the processing of information. It is this that enables computers to adapt themselves to practically any formal language.

Anyone who needs to process information automatically can have recourse to a computer. For this purpose, the information must be presented in the form of a coded message and the mode of transformation must be recorded in the form of an algorithm in a language which is also coded and comprehensible to the machine. The formal language in which the order to process the information is given does not exclude others because, as was mentioned above, the machine can be adapted to practically any coded language.

In order to use the possibilities offered by computer science, it is necessary in the first place to be aware of them and to understand them. In those branches of science which traditionally make use of mathematics, it was quickly possible to master the methods of computer science and to include them in university curricula according to need. And computer science, which allows of the solution not only of purely mathematical problems but also of any problem which involves the processing of information, can be of assistance to every researcher in his own field.

Scientific creation, like any other form of creation, entails non-formal processing of information, but in the pursuit of its ends it now passes through many stages of research, and this constitutes a formal part which can be entrusted to machines. As a result, the productivity of any researcher can be increased considerably. The researcher must, however, be aware of the possibilities available to him through computer science. Every student should therefore be acquainted with the theoretical aspects of computer science and its practical applications.

Preparing students for computer science

A knowledge of the principles of computer science will soon be part of everyone's general culture, for it is a fact that this discipline is playing an ever-greater part in our daily life. Indeed, it will soon seem to us indispensable for our existence, as is the case with energetics. To pursue the comparison with energetics—without, however, slipping towards energeticism—one might wonder about the harmful consequences that might ensue from the development of computer science.

The damaging effects of the development of energetics are well known, whether it be the pollution of the environment or the destruction of a number of natural assets. They have not, however, led us to forgo the considerable advantages deriving from energetics, though they do lead us to reflect seriously on the necessity of a rational consumption without waste.

Could the development of computer science have harmful consequences? A wholly negative reply to this question would set us on the road towards computerism.

There is one sphere of activity which is particularly deserving of our attention. This is the teaching of computer science at the general education level. Fortunately, research and experiments have been conducted in this respect by a number of teachers and technicians who have made the results of their work known at conferences, round tables and seminars. Mention may be made, in particular, of the productive activity of the Third Technical Committee (TC3) of the International Federation for Information Processing (IFIP).

Deciding on the content of computer science courses in the context of general education presents some difficulty. This stems chiefly from the fact that it is not easy to determine what fundamental branches of knowledge will not be quickly outdated and will prepare students for a world in which computer science will play a part even greater than that of energetics. In my view, it would not seem desirable for computer science to be taught in school in the form of a new discipline. Rather, it would be desirable for this subject to be included, as far as its principles are concerned, in the area of mathematics; this would, moreover, introduce a fresh element into the teaching of mathematics in school. With regard to practical knowledge, this is bound to depend on the level of technical facilities available, and these are at present undergoing rapid change.

The multidisciplinary nature of computer science

If one wished to define a philosophy of the teaching of computer science, it would, it seems to me, be useful to return to the analogy with energetics. In our time, everyone needs a minimum of precise knowledge concerning energy and the possibilities offered by it. This knowledge is provided in school by the teaching of physics. With respect to the production and transformation of energy to meet society's needs, this is an activity coming within the competence of a large number of different specialists and especially that of physicists. The latter investigate the innermost structure of matter and discover new processes for liberating energy. But this is only the beginning. To make this energy available to consumers, there is a need for engineers, architects, builders and various other technicians.

The development of computer science will follow similar lines. It is therefore necessary that, in every country, tomorrow's students shall be enabled to gain a minimum of basic and clear knowledge regarding computer science, and it is natural that this instruction should form part of the teaching of mathematics. As for people concerned with computer science at a higher level, their training must be through the medium of a university discipline. Lastly, it has to be borne in mind that computer science, like energetics, is also a very complex economic activity which engages the services of a large number of engineers and other specialists. □

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The teaching of informatics: a few questions

Jacques Berleur

A specialist in the teaching of informatics raises questions which cover a wide range of epistemological, cultural, ethical and practical problems.

The teaching of informatics can be looked at in many ways. It can be approached from the standpoint of those who assure the training: public authorities, private institutions or manufacturers of computers. It can also be considered in terms of the various 'computer functions' demanded by the development of applications: system designer, system analyst, computer designer, system programmer, programmer, etc. [1].[1] Naturally, the questions that come to mind in connection with the teaching of informatics differ according to the aspect from which it is viewed.

We shall confine ourselves in the present article to examining various recommendations for graduate study programmes, leaving it to 'the informatics profession' to deal more comprehensively with the questions that are raised here if it so desires. In focusing our attention on graduate programmes, we are excluding from our field of inquiry the training courses sponsored by manufacturers of computers and certain functions such as programming.

We shall take as our point of departure the various curriculum recommendations made in the *Communications of the Association for Computing Machinery*. The influence of these recommendations has spread far beyond the United States and has played an important role in determining the directions taken by the teaching of informatics in Europe. Accordingly, the Association for Computing Machinery (ACM) recommendations seem to us sufficiently representative of current trends to serve as a frame of reference within which to raise a few questions about the teaching of informatics.

Is informatics a discipline in its own right?

From 1965 to 1973, the above-mentioned *Communications* of the ACM established three programmes that must be examined in the light of the preliminary or intermediate recommendations made in 1964 and 1972 and the recommendations subsequently put forward by the International Federation for Information Processing (IFIP) in 1974 [2]. Whoever is interested in the beginnings of this new discipline will then be fully enlightened, for the recommendations are quite explicit and are even supported by copious bibliography which will be reassuring to anyone who may imagine that the subject lacks a scientific tradition.

Despite the declarations made in 1964 to the effect that the programmes adopted must make a distinction between informatics and other disciplines, such as mathematics,

1. Figures in brackets refer to the notes at the end of the article.

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physics and the engineering sciences [3], the concrete recommendations of 1965 refer first of all to mathematics and physics. The presumption of a bias in their favour is confirmed by the fact that it is explicitly suggested that it would be advisable to implement computer science curricula within mathematics departments. When we analyse the content of these programmes—as we shall proceed to do below—at least two facts are established: (a) everything was still done 'very close to the machine'; (b) informatics at that stage was still predominantly concerned with numeric applications (and this also explains why these programmes attached so much importance to physics and mathematics).

The 1968 recommendations referred specifically to the preliminary recommendations of 1965 and noted that eleven of the sixteen courses included in the old curriculum had survived more or less intact; of the remaining five, two had been split up and three dropped; lastly, seven new courses had been introduced.

An analysis of these changes indicates that the report in question no longer regarded purely mathematical courses as an integral part of the informatics programme; it classified them either as supporting courses or as prerequisites. This is a clear sign that informatics was becoming a discipline in its own right; another sign of this tendency is found in the same report where it records the hesitations of the members of the committee dealing with the subject when they had to choose between the two terms: 'computer science' and 'information science'.

Systems and interfaces

The pattern of development reflected in this new programme seems to be distinguished by four main features: (a) mathematics continues to be a theoretical point of reference but is no longer specifically included in the programme; (b) there is a growing tendency to rely less on hardware; (c) interest is beginning to be shown in higher order languages, better adapted to new types of problems (other than numeric problems, for example), and at the same time in compiling problems, i.e. the 'translation' of these more sophisticated languages into machine language; (d) attention is being focused on large-scale problems and on the processing of great quantities of data, which make it necessary to define courses relating, for example, to data structures, information organization, etc.

The new recommendations made in 1972 (concerning graduate programmes) and 1973 (concerning undergraduate programmes) accentuate these trends. It is worth noting that the term, 'computer science', has been dropped in favour of 'information systems'. The word 'system' occurs throughout the programme: management systems, computer systems, communication systems, system design, system development projects, organization systems. It is true that these recommendations originated in the Committee on Computer Education Management, which is to say that informatics had become oriented to management.

Comparison with the previous recommendations is only possible on points which are clearly relevant to the courses concerned with what the new curricula call computer and information technology and development of information systems. In this narrower field, we find the same tendencies as those mentioned above, but see that they have become more marked. Questions relating to files inevitably have the effect of enhancing the importance of data structure problems, languages 'dedicated' to different types of application are multiplying, the problems of interface between the user's and the computer scientist's standpoints are developing and thereby further accentuating the trend away from the computers. But the most striking feature, in our opinion, is the emphasis placed on notions of modelling, structures, systems, as if the formal apparatus of mathematics ought to be replaced by a tool better adapted to the kinds of problems which are now claiming attention.

The recommendations made by the International Federation for Information Processing (IFIP) in 1974—which refer specifically to those made by ACM in 1973—sanction, so to speak, the tendencies reflected in the latter. The International Curriculum proposed for the training of system designers places emphasis on the problem of the man-machine interface (in line with the above-mentioned inclination to become more detached from the computer and to establish new relations between the user and the computer scientist), on problems of organization in the broad sense of the term (the computer is regarded in this context as one component among others in a more general system comprising human operators, users, other equipment), and on the internal organizational problems of informatics itself (hardware and software, choice of configurations). Here again, system theory is appealed to as if it were a *deus ex machina* and looms large in all curricula.

What initial conclusions can be drawn from this all too brief examination of the recommendations for undergraduate training programmes in the field of informatics?

Is informatics 'neutral'?

To begin with, we have been struck by the importance attached to the formal aspect of these curricula. When informatics was still a primarily numeric type of science, mathematics was the best frame of reference. But as it became increasingly oriented towards administration and management, the frame of reference was expanded to take in organization theory and the system theory, which came to play an ever more prominent role. No one can deny that the inclusion of this formal aspect in the recommended training courses proved to be an effective and fruitful development. At the same time, however, there is good reason to question the real usefulness of what may be described as a kind of infatuation with modelling when we are aware of the thorny problems that are encountered every day by informatics specialists.

Take, for example, the field of languages, where structured programming is still very rudimentary and experimental, or the field of operating systems, where it is quite clear that the descriptive aspect still predominates, the efforts towards synthesis having so far failed to produce really conclusive results, or the field of management applications (in data bases, for instance), where the productivity of the formal aspect has been fully demonstrated in only a few relatively well-defined cases.

The question which has arisen in our mind with regard to the recommended programmes may therefore be formulated as follows: Do not these courses tend to inflate the value of the scientific side of the new discipline known as informatics? Is it not possible that the effect of overestimating the merits of the formal aspect will be to obscure quite a number of serious problems that should be solved or, at least, posed? May not informatics be in danger of falling into the trap of 'neutrality' like the other so-called exact sciences, whereas the real questions (particularly where management informatics is concerned) lie on the frontier between the humanities and the positivistic sciences? In giving a spatial quality to time, the formal aspect eliminates the historical dimension in which informatics develops; it conveys a feeling of security by eliminating conflicts.

Manufacturer-machine-user relations

When restoring to its rightful place the historical dimension of the process whereby informatics has become a branch of scientific knowledge, we may ask ourselves the following question: Who have been the prime movers in the development of this new science? Is it from the users or the manufacturers that the incentive comes to slant the programmes in this or that direction? Or from someone else? Our rapid survey of the developments in training programmes makes it fairly clear that the expansion of the frame of reference for these courses is directly connected with the growing potentialities of the computers themselves.

Furthermore, anyone engaged in the teaching of informatics knows why he is too often compelled to limit himself to a descriptive approach. We need only recall that the numerous releases, in operating systems, for example, are not accompanied by an equivalent summary report; there is often a danger that the initial core may have become so complex that it is no longer possible to identify the principles underlying its development. The silence of the manufacturers as to their programmes for the five years ahead may in itself be eloquent and prove that informatics (and the teaching of informatics) is, to a large extent, in their hands. As regards the users, their influence is undoubtedly gaining ground. The above-mentioned trend away from the machine and towards the development of user-machine interfaces (higher order languages, dedicated storage, for example) can be interpreted in this sense. In our opinion, it is in the direction of the users that we can expect, sooner or later, to find a counterweight to the omnipotence of the manufacturers.

It is to be hoped that all those who occupy posts of responsibility in teaching or research work concerned with informatics, particularly in universities [4], will support and contribute actively to the efforts to develop this necessary counterweight. To that end, we must give fresh thought to the history of this discipline, demarcate its real limits and develop its formal aspects, not simply as an adjunct to its natural structure but as an intrinsic part thereof so as to increase its operative usefulness which all too frequently exists—even today—only in the vague dreams of deluded partisans.

These, then, are the first questions which emerge from our consideration of the special recommendations for undergraduate programmes in informatics; they concern the internal problems of the development of training courses. But it seems to us that other questions may be raised which stem, in the main, from what the recommendations have left unsaid.

Computer applications: the realities

Informatics today has a social image which seems to be neglected in the study programmes so far proposed. It is fairly obvious, for example, that the classification of computer functions given at the beginning of this article is not perceived as such by anyone except the specialists themselves. Accordingly, the computer scientist, is always expected to be capable not only of resolving technical questions *per se*, but also of communicating more effectively with people working in other disciplines; he is expected to be both a competent user of the computer familiar with its applications and a high-level technician. We are not likely to find that the recommendations we have examined meet these requirements. Does this mean that the teaching of informatics should be interlarded with courses giving a smattering of knowledge of several other subjects? Not at all, but the principle of interdisciplinarity should be applied by providing courses for the in-depth study of at least one subject which does not specifically fall within the field of informatics.

Communication between users of informatics and specialists in this discipline is often described in terms which imply that the user must become familiar with a minimum of technical details. This can hardly be denied! But it is surely a one-sided approach to the problem to expect every user to become computer-minded—whereas it would be equally important for the informatics specialist to be really application oriented with a view to meeting the needs of the user.

As a matter of fact, underlying these positions there are a number of quite fundamental options concerning perception of the place of the computer specialist's work in the real world. Great emphasis has been laid, for example, on the successful use of informatics in modelling. But has this success not been achieved at the cost of a 'reduction' of the reality perceived in the model? Accordingly, the computer specialist's approach to reality must be regarded as valuable in a specific context and not as the only acceptable mode of thought. Otherwise, we might witness a resurgence of all the apprehensions concerning the effects of scientism, which were once prominent in philosophical thought [5].

We have a duty to put some awkward questions to those engaged in the teaching of informatics. Others have done so, and the weighty body of material they have brought to our attention merits serious consideration—even if their line of approach has obvious ideological overtones. Thus, some writers maintain that informatics is one of the latest inventions of capitalism to counteract the economic law of falling rates of profit [6]. Even if we do not agree with this way of presenting the situation, it has to be admitted that informatics is clearly involved in the so-called rationalization processes of our societies and teachers of this discipline would be well-advised to examine the implications of the fact. They bear a heavy responsibility in this matter.

Information and power

In our opinion, it is equally important for teachers to take into account the need to elicit an appropriate response to the misgivings that have arisen regarding various aspects of informatics. From this standpoint, there are two problem areas which seem to us to warrant a particularly searching study. The first concerns what may be described as the inordinate growth in the quantity of information available; the second concerns the safeguarding of the freedom of individuals. We shall not dwell on the second, which has commanded such wide attention on account of its self-evident importance that it has led to the enactment of special legislation in many countries. We wish, nevertheless, to make the point that, apart from questions relating directly to the safeguarding of freedoms and of privacy, these various laws see in the 'informatics phenomenon' a possible means of changing traditional power structures [7].

As for the inordinate growth of information, it reflects a tendency in our society to sanction the idea that in order to arrive at a better decision it is necessary to possess a maximum of information and, consequently, that the possession of information is the weapon of power. Here again, other awkward questions have to be asked. Is this belief borne out by an analysis of the actual processes of decision-making? Or is it not rather one of the new myths that tend to be propagated in order to justify certain fashionable ideas? Would it not be more to the point to remember the danger of filling one's head with so many facts that one cannot see the wood for the trees? Far be it from us to obstruct efforts to improve the processes of decision-making, but there are limits beyond which the processes become clogged through saturation. This is another area in which we consider that the responsibility of teachers of informatics is quite deeply involved.

The range of questions raised by the social applications of informatics could be extended indefinitely, for this new discipline has undoubtedly invaded numerous spheres of activity in everyday life. Common sense compels us to check the process of dispersion by concentrating our efforts on widening the scope of training rather than on multiplying the adjacent areas of information work. The temptation which has to be avoided is, of course, that of amateurism. But, if we take a close look at informatics curricula, we have to admit that the majority have not yet reached saturation point as regards the fields of inquiry which could be brought within their scope.

The words of Eric Ashby come to mind here. He has observed that while most professors of technology in the United Kingdom are delighted to train engineers who have ceased, by the time they are 40, to deal with questions related to the training they have received, this does not mean that they have introduced any changes into the programmes which would equip their students to assume their responsibilities.

Let us quote Mr Ashby:

> The university may offer voluntary lectures on humanities and social science for scientists and technologists, but it is still uncommon to find, as an integral and examinable part of an engineering course, material on industrial history, social psychology, labour relations, or political institutions; and it is very rare to find any obligation on students in technology to reflect on the ethics of leadership or to consider in a scholarly way such values as justice, magnanimity, virtue, and the whole traffic of relations between man and man [8].

By way of conclusion

We must draw attention to the work of IFIP, the largest international association of computer specialists, and recall that its activities (apart from its congresses) are pursued by a number of working groups and technical committees. The latter include a TC9 which was recently set up by IFIP to study 'The Relationship between Computers and Society'. We think that its main objectives deserve to be widely known, and we therefore list them below in the form in which they were established by the General Assembly of the federation.

Communicating social consequences: promote communication between computer-related professionals and others on relationships between computer technology and society.

Promoting social accountability: help computer professionals to develop increasing awareness of the social consequences of their work, within IFIP and the profession at large.

Facilitating research: encourage studies on the effects of the uses of computers on individuals and society.

Humanizing information systems: examine how the needs of individuals and society affect the design of technical systems involving computers.

Enhancing the quality of life: identify and promote those uses of information processing which improve the quality of life of individuals and of society as a whole.

Encouraging responsible long-range planning: promote forecasting studies to disseminate early warnings on human consequences of the use of computers; encourage the development of long-range social plans to ensure that the use results in human benefits.

These objectives require no commentary [9], but they raise a fundamental question. Can the teaching of informatics remain aloof from the problems which are a source of concern to computer professionals? □

Notes

1. This classification was suggested by F. Bodart, 'Recurrent and Permanent Education and Training', *Training Policies for Computer Manpower and Users*, Paris, OECD, 1975. It is given here only to serve as an illustration but has the advantage of dealing with functions more especially oriented towards the applications and techniques of informatics.
2. See *Communications of the Association for Computing Machinery*: Vol. 7, No. 4, 1964, p. 205; Vol. 8, No. 9, 1965, p. 543; Vol. 11, No. 3, 1968, p. 151; Vol. 15, No. 5, 1972, p. 363; Vol. 16, No. 12, 1973, p. 727. See also IFIP, *An International Curriculum for Information Systems Designers*, Rome, Intergovernmental Bureau for Informatics, 1974 (Report of Technical Committee 3).
3. The recommendations identified four topics: study of the organization and interactions of data processing equipment; development of software for controlling communication with this equipment; study of procedures and fundamentals of process specification; application of software systems and informatics procedures to other disciplines.
4. For a users' appeal to the universities, see G. Kapur, 'EDP Education—An Acute Crisis', *AFIPS Conference Proceedings*, Vol. 43, p. 321. Montvale, N.J., American Federation of Information Processing Societies, 1974. Their major complaint is to the effect that the only personnel they can find on the job market are what they call 'instant' programmers, incapable of adapting to change because they lack an adequate grounding in methodology.
5. In this context, we may think of some of Friedrich Nietzsche's aphorisms in *The Gay Science*, 1881–87, for example.
6. E. Janco and D. Furjot, *Informatique et Capitalisme*, Paris, Maspéro, 1972.
7. From a comparison of six texts we have identified certain themes which are the common concern of the legislation adopted in the respective countries. cf. J. Berleur, *Une Banque de Données Économiques Régionale? Aspects Économique, Informatique, Juridique et Sociopolitique*. Namur, Presses Universitaires de Namur, 1977.
8. E. Ashby, 'Technology in Education', *Dialogue*, Vol. 8, Nos. 3/4, 1976, p. 93.
9. We should like to add that the Scientific Congress of the IFIP held at Toronto in 1977 had on its agenda four topics on which the discussion was led by members of TC 9 (see the *Proceedings* of this Congress). The first studies undertaken by this Committee before it was formally established have been published under the title *Human Choice and Computers* (H. Sackman, E. Mumford, eds.), Amsterdam, North Holland, 1977.

Who will lead the way to the 'information society'?

Ole Engberg

The following is intended for specialists in industrialized countries—technocrats, senior officials, communicators (including teachers), those involved in influencing public opinion (whether by creating or withholding information)—but specialists in developing countries may also find the article useful. The author outlines the way ahead in a world determined to automate further its techniques of communication and production.

Increasing use will be made of automated production and information communication techniques in the years to come. The result will inevitably increase the ranks of the unemployed. We must therefore put more energy than we have done hitherto into changing our present work ethic. It is no good extolling the ennobling qualities of work if, at the same time, we are cutting down jobs through automation.

A long-term and innovatory project, beginning in primary school, is what is needed. And in the short-term, we must concentrate our efforts on ensuring continued free access to information.

The neglected information sector

The information sector employs half the labour force

In 1975, the Organization for Economic Co-operation and Development (OECD) published a report by the American, Edwin B. Parker [1],[1] in which, with Marc Porat, he analyses a number of problems that merit discussion. The report includes a graphical history of the evolution of the labour force in the United States since about 1850 (Fig.1). The curve indicated by the solid line represents the information sector, one which has trebled over the past thirty years. From employing 15 per cent of the country's labour force in 1945, it has risen to well over half.

The information sector is made up of all those in the three traditional occupational sectors—agriculture, industry and services—who work with information. An appendix to Parker's report, containing figures from the official statistics for 1970, indicates the labour force in 400 separate groups. Of these groups, 170 belong to the information sector, the largest being officials and managerial staff, teachers, secretaries, accountants and engineers. Authors, postmen, printers and archivists are also included. The smallest group is 'clerical assistants, social welfare'.

Even if this classification can be questioned—as Parker himself does—the general trend is highly convincing. A similar survey in other industrialized countries would very probably produce a similar curve, with the traditional two- to four-year time-lag in relation to the United States.

1. Figures in brackets correspond to the references at the end of the article.

Ole Engberg

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Automation of information processing

Just as the drop in employment in agriculture can be ascribed to mechanization and the drop in industrial employment to automation, increasing use of electronic data processing (EDP) techniques can be expected to result in significant structural changes in the information sector.

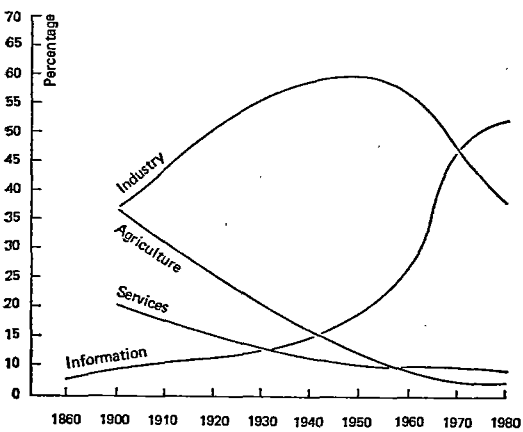

FIG. 1. United States labour force: four sector aggregation. *Source:* Edwin Parker and Marc Porat for OECD, 1975.

Figure 2 comes from a report recenlty published in the United States on the subject of technology and privacy [2].

This report contains corresponding curves for the actual calculation units, etc. A fall in prices can be expected for many years to come. New areas in which automatic techniques can profitably be applied are constantly being opened up.

Parker considers that there are already several areas within the information sector which are neglected from the investment angle with the result that full use is not made of possible applications: (a) expansion of the educational system so as to make the range of instruction offered independent of time or place, namely use of video tapes and programmed courses, to make instruction essentially automated and personalized and thus create an entirely new market (a new category of student) in addition to the present one; (b) automation of the payment system (despite the various risks involved, both as regards privacy and employment); (c) speeding up of business transactions through automation, especially of international paperwork; (d) improvement of consumer information as regards price, quality, speed of delivery, etc., by means, for instance, of setting up terminals, e.g. in libraries; (e) more effective public administration, especially at the service level; (f) extension and improvement of the public telephone system through video, teleconferencing, etc.; (g) improvement of the public health service. It is hard to contest this approach and Parker gives interesting explanation of why the necessary investments have not been made (see page 294) and points to the danger that this field may be taken over by commercial interests.

Future employment trends

Printers are well aware of the implications of automation. Secretaries, middle-grade managerial staff and several other categories are now about to be hit in their turn. This is

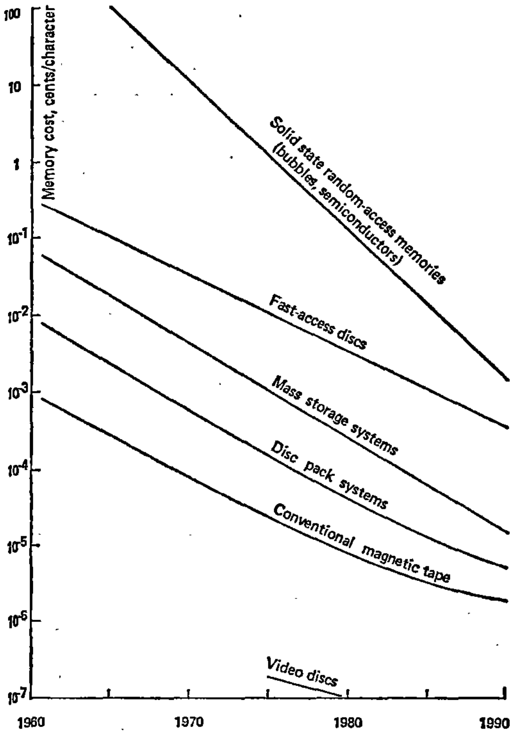

FIG. 2. Memory cost trends.
Source: Report of the Privacy Protection Study Commission. Appendix 5: Technology and Privacy. (Stock No. 052–003–00425–9.)

clear from the sales prognoses carried out by EDP suppliers in respect of text processing equipment. Such equipment is sold not only on the basis of promises of better service. It is financed partly by the savings made on salaries. In large companies with the necessary financial resources, staff dismissals can be reduced or avoided completely through a reasonable personnel policy, i.e. natural retirement. In smaller companies, such equipment is often a matter of life or death and EDP therefore ensures that the whole enterprise is kept going.

The 'fortunate', those who keep their jobs, cling to their carefully acquired rights and, for example, through the intermediary of the tax authorities, share the amount saved with those who are put out of work: unemployment compensation.

In short, local, national and international competition makes it necessary to step up productivity. The claim of the instigators of this drive that more work is created by automation 'if one looks at the economy as a whole' is understandable, though not necessarily correct. Nor indeed does this claim get much support except from the economists, even when it is made with great conviction, as was the case, for instance, when the EDP experts included this subject [3] on the programme of their own world congress (that of the International Federation of Information Processing), in 1977.

One of the most recent attempts to clarify this problem was made by the Swedish Central Bureau of Statistics [4], which notes, with many reservations, that EDP has taken over 60,000 to 90,000 jobs and created 30,000 new jobs. This amounts to a net decrease of approximately 1 per cent of the total labour force. The report estimates that much more could be done to exploit the possibilities for savings of labour.

Figure 1, from Parker, not only reveals the scale of the information sector but conceals a problem. The curve shows only the relative employment situation, and then only up to 1980. Figure 3 is based on Parker's four curves, as well as certain ILO employment statistics [5] relating to the total population of the United States in various years. A rough estimate is also made of working hours, age groups, etc. The trends indicated, rather than the precision of the information, are of interest.

Occupation in the information sector (curve I) is expected to drop. Investments will probably be made in the seven areas mentioned by Parker (items (a) to (g), page 285). The result of these investments will naturally be to slow the drop in employment somewhat, since development and installation require extra manpower—but afterwards there may, on the other hand, be a considerable drive to make such investments pay. Presuming, of course, that by then we have not revised our approach to work and money.

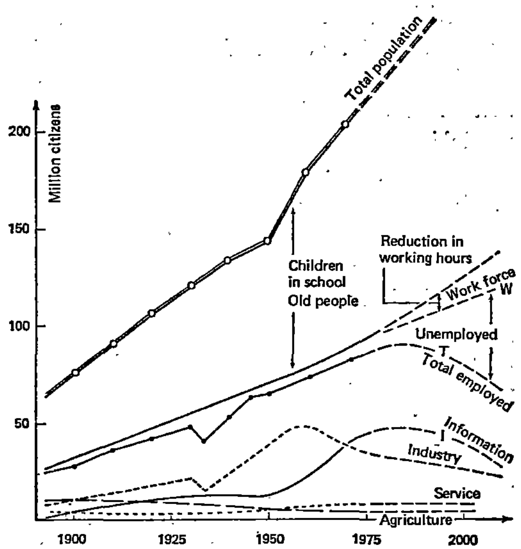

FIG. 3. Distribution of occupation in the United States.

Sources: Until 1970: Historical Statistics of the United States, From Colonial Times until 1970, Bureau of Statistics, Washington, D.C., 1975. (Part. 1, p. 8 and 139.) Information sector by Edwin Parker for OECD in 1975. After 1970: author's estimate, as of February 1978.

The other three sectors will also become increasingly automated, with the result that Parker's relative statistics in Figure 1 may be said to apply until the year 2000. If, however, one looks at the total employment figures for all four sectors as a whole, the drop in the total employed (curve T) will be quite significant. This forecast corresponds fairly closely to a Swedish prognosis [6] carried out in 1972, which anticipates that working hours will be halved. That was when there was a considerable shortage of manpower, and before anyone thought of the present unemployment crisis.

The outlook is therefore not particularly promising. Figure 3 shows the various possibilities open to us if unemployment is to be kept to a *minimum:*

We have probably exhausted our possibilities of increasing production through exporting goods to the less-developed countries. They are frightened that our essentially competition-orientated culture will accompany such exports; they prefer to keep control over development in their own hands. The only exception is arms—and here the industrialized countries exploit most production and export possibilities to the full.

We can also try to persuade our fellow-citizens to move from the available work-force category (curve W) into the top group: longer education, early retirement, with all their attendant problems.

Finally, W can be brought down even closer to T by expanding free time.

There would also seem to be no grounds for believing that our own consumption can continue to grow. Gunnar Adler-Karlsson has written, in a paper [7] for the Swedish Secretariat for Futurology (*Svenska sekretariatet för framtidsstudier*), 'To maintain full employment at a rate of eight hours work 48 weeks a year for 40 years, it is essential to commercialize free time to the full by making 80,000 Kr. worth of plastic boat an entirely natural material human need, calling for State subsidies.' This sentence figures in one of the chapter headings, and the paper as a whole is entitled 'NO to Full Employment, YES to Basic Material Security' and outlines some of the policy aspects as well as a model solution. This model specifies limits for the size of houses, the number of boats, and private aeroplanes, which may be produced by the automated factories. Both the shortage of resources and environmental considerations are increasingly imposing restrictions. The underlying reason is the need to start to think differently so that the information society can be run according to human, not only economic, conditions.

Towards an information society

What is the information society?

Parker does not deal with this matter in detail. He merely points out that we already live in an information society, since more than 50 per cent of the labour force works with the communication of information, even if we have not awakened to these facts and their consequences.

A detailed description of the information society has been provided by Japan, *The Plan for an Information Society—a National Goal Towards Year 2000* [8]. This plan, which incorporates a Japanese programme of action, is based on a theory advanced ten years ago by Kenichi Koyama [9].

The Japanese plan was prompted by several of the problems which are easier to detect in other countries than in one's own: steadily expanding towns, which become more and more difficult to run effectively, and increasing automation of production machinery, with the resulting unemployment and other national and international consequences—which do not need to be developed in greater detail in this article. Reference is also made to environmental problems and the shortage of resources.

Masuda [10] reproduces the main points of this plan in a short article. The above trend can be counteracted if we (a) make full use of EDP for individual selection of information (so far we have only been scraping the surface); and (b) create system-oriented information, i.e. automatic selection, combination and, if need be, concentration of information previously scattered. Clearly these applications should be accessible to the public and not be reserved for private owners or public officials.

Masuda goes on to describe how as a result of these developments the individual's dependency on time and place will gradually decrease. At the same time the need for grouping together in factories, schools and offices will also disappear. This in turn will affect forms of employment, bringing about a transition from the usual, permanent job to short work contracts, thus affecting forms of leadership and political standards. With good reason, Masuda devotes the last part of his article to the radical behavioural changes which life in the new society will require. A comprehensive survey of the adjustment process is perhaps shown most clearly in Table 1, taken from Masuda's article [10].

Bound for collision

The basic and most essential message of the picture of the information society presented by Parker, and more particularly by Masuda, is of a society where automation has eliminated the industrial society's competition for material possessions, rooted in status symbols or a craving for power.

Such a change of behaviour in the industrialized countries will cause many problems. Competition has gained a secure hold in our culture and the manner in which we have organized the leadership of both private enterprises and public authorities. Most people are, not without reason, fairly satisfied with this system which has given the industrialized countries a very high material standard of living and created a society where no one needs to be destitute. We are so pleased with the results that we overlook the fact that the industrial society is in the process of being replaced by the information society. Those of us who are engaged in activities influencing public opinion will be hit particularly hard. Our work makes it difficult for us to question the ethics underlying the present power structure, which guarantees us our influence.

None the less, we are being forced to it by the inevitable process of automation. Fewer and fewer people are able to place their trust in us as the discrepancy between what we say and what we do becomes more and more obvious:

We promise decentralization and the right of participation, while at the same time building up administrative EDP systems on a national scale to ensure total equality and improved statistics for the experts' use.

In a competitive society, the combination of liberalism and statistics creates the belief

TABLE 1. Comparison of information society with agricultural and industrial society

	Agricultural society	Industrial society	Information society
Production power structure			
Production power form	Land production power (farmland)	Production power of motive power (steam engine)	Information production power (computer)
	Material productivity	Material productivity	Knowledge productivity
Character of production power	Effective reproduction of natural phenomenon	Effective change of natural phenomenon and amplification	Systemization of various natural and social function
	Increase of plant reproduction	Substitution and amplification for physical labour	Substitution of brain labour
Product form	Increase of agricultural product and handiwork	Industrial goods, transportation and energy	Information, function and system
	Agriculture and handicraft	Manufacturing and service industry	Information industry, knowledge industry and systems industry
Social structure			
Production and human relations	Tying humans to land	Restricting man to production place	Restricting man to social system
	Compulsory labour	Hired labour	Contract labour
Special character of social form	Closed village society	Concentrated urbanized society	Dispersed network society
	Permanent and traditional society	Dynamic and free competitive society	Creative and optimum society
	Paternalistic status society	Social welfare type controlled society	Social development type multifunctional society
Value outlook			
Value standard	Natural law	Materialistic satisfaction	Knowledge creation
	Maintenance of life	Satisfaction of sensual and emotional desires	Pursuit of multiple social desires
Thought standard	God-centred thought (religion)	Human-centred thought (natural science)	Mankind-centred thought (extreme science)
	Ecclesiastical principle	Free democracy	Functional democracy
Ethical standard	Law of God	Basic human rights, ownership rights	Sense of mission and self-control

Source: Yoneji Masuda.

that everybody is to be above average. Those who can manipulate the letter of the law to their own advantage enjoy increasing respect. The politicians have no choice. They have continually to enact new provisions and see that these are put into effect. 'Millimetre justice' may forever secure employment for EDP specialists.

We say that the administrative use of EDP can ensure the necessary 'comprehensive picture' which has so far been lacking, yet at the same time we standardize and simplify descriptions of the private individual without explaining how this comprehensive picture is composed or what it tells us.

Once again this conflict may be explained by the need for effective administration. Fear of the personal identity number is an unfortunate expression of the resulting mistrust. Characteristically, hardly anyone has tried to explain that this number makes it technically possible to group together the various details that sum up an individual and thus obtain a more complete description as well as reducing errors. This will make it possible to show consideration for the individual, even in public administration and policy-making.

We say that job satisfaction increases when people are given sufficient time to carry out their work properly, yet at the same time we step up the tempo for reasons of competition.

The well-educated, well-paid employees in permanent jobs have found it necessary to set up their own trade unions to ensure that their particular group is not adversely affected. Such is the pressure from the less well-off. Once again, carefully gained rights are in danger.

We extol the ennobling qualities of work, the cornerstone of our industrial ethic, yet at the same time, in the name of competition, we are automating many jobs out of existence.

This conflicting attitude is so firmly entrenched that only the unemployed react by asking, 'Whose interests does this work ethic actually serve?'

In the well-off, industrialized countries, it is probably necessary to have only slightly higher unemployment or to risk slightly greater with the poor countries, for some of these conflicts to become obvious. We must therefore revise our approach.

Who will lead the way to the information society?

Our generation is hardly trained for the task

The purpose of the preceding sections was to emphasize three truisms:

Continued automation of production and information is inevitable. Very few people would wish to stop it, nor is the optimist at all interested in doing so. Almost everyone is concerned with having his basic material needs satisfied as quickly, easily and generously as possible.

Such automation can be a dynamic force in the information society by providing increasing options for the individual. This is desirable.

If we do not, meanwhile, manage to get rid of the present competitive mentality (focused on material possessions) and turn instead to individual creative use of information, automation may lead to a totalitarian society.

For many reasons the present generation is not prepared to make full use of the information society's potential. We are far too influenced by what we learned as children and our loyalty for our employers, customers, pupils and colleagues.

The trouble is that we really have learned to regard work as ennobling. At home and at school, as well as in our jobs. In the very first years of school the indoctrination starts with the idea of the recreation break, which was—or was intended to be—desirable. Anyone who thought otherwise was peculiar, an ugly duckling.

On the other hand, for most people to learn something, to work, to do something useful became a special activity, which had to be remunerated. This remuneration corresponded to the effort, which in its turn was measured in terms of hours. Unpaid work hours came to be looked on as lack of solidarity.

This expression sums up all the good old attitudes. The sacred cows of the competitive society and of the class war are at stake: 'It was necessary to fight to bring the working week down from 60 to 48 hours, and from 45 to 40. Similarly the 2–3–4 weeks summer holiday was no free gift! The capitalists have given away nothing. All this has been achieved through solidarity.' Gunnar Adler-Karlsson has also written [7]: 'On the consumer market the individual has unlimited freedom of choice. On the labour market he has exceedingly limited freedom of choice as regards his working time.' This struggle has been going on for so long that its very target—working hours—has disappeared from sight. The wear and tear of traditional work is vanishing with the advent of automation.

This distinction between work and free time would seem to be the motivating force of the competitive society. If this distinction can gradually be done away with, the democratic information society, as opposed to the authoritarian or even totalitarian information society, can be achieved.

Long-term work: schools

School attitudes will have to be changed even more. This will take a long time. The educational system would seem to be the heaviest and most inflexible element of society. It takes twenty-five years to change course.

Schools are at last getting round to preparing our successors to be good citizens—for the growth society of the 1960s! We are urged to be acquisitive, for competitive reasons. The only mistake is that today's pupils will be taking their place in society when the next decade is well under way.

Many, perhaps most, teachers are aware of this fact and do their best to instil in their pupils a critical attitude to the causes and effects of the competitive mentality, even if curricula, salary regulations, class quotas and other requirements as regards the teachers' own work make it impossible for these to provide a good example themselves. Their impact is therefore limited.

There are, however, examples of how it is possible to run a school without having every forty-five minutes to demarcate the difference between work and free time. One example is to be found at Tvindskolerne (name of locality) [11]. Here schools have pupils who are above the compulsory schooling age and operate under a special law governing private schools. Under this law, large subsidies are allocated (up to 85 per cent) to cover the operational costs and the staff have considerable freedom in planning the teaching programme. A number of particularly interesting features may be mentioned: (a) school hours can be spread over all twenty-four hours as the pupils themselves decide, since these schools are often boarding schools; (b) the pupils join in any tasks that may be at hand, including cooking, fishing, handwork, farming, etc.; (c) the teachers' salaries are pooled, and allocated by the collective teaching staff; (d) good economic management and growing student interest have allowed considerable expansion; and (e) the schools take a strong interest in developments abroad. In several cases the schools' programme includes cheap, rough-and-ready expeditions (in their own thirty-year-old buses), lasting several months, to other parts of the world.

The next step that can be hoped for is that the ordinary State secondary schools will open the way for experiments designed to free them from the tyranny of the school timetable and show that one is either busy or sleeping. The demarcation between working hours and free time is artificial and implies an employer-employee relationship which is replaced by very different bonds in the true information society.

A box with electronics

Once this difficult barrier—the rigid school timetable—has been broken down, the educational system can begin to train pupils in the technology they will have to live with and use in the information society.

What is needed is a large box with electronic components, some books on electronics, a roof over one's head, and a small measure of constructive interest. These experiments then become a local assignment, requiring help from local electricians, engineers, mechanics, radio enthusiasts and others who can read a blueprint and use a few tools. One also needs a boiler which has an automatic device to open and shut the heating system—as well as whistle—'in case'.

Alternatively, the local anglers' club may say: 'If you can make an automatic gauge which shows whether there is poison in the river, we will undoubtedly find a use for it.' Or an ordinary family may volunteer to act as guinea pigs for any invention.

To derive enjoyment from testing ideas (creativity) on one another, it is not necessary to be an organization. It is highly stimulating and educational when no specialist is in charge and there is full acknowledgement of mutual dependency. Such activities are so creative that most productive enterprises are likely to become interested. This applies both to the producers of electronic components and to those whose responsibility it is to control an industrial process, large or small. All that is needed is a constructive frame of mind.

The electronic box idea may be carried further: electronic components are the mechanical building materials of the information society. In my youth, they were called Meccano or Erector; today, they are known as Lego building blocks. The cost, manipulation and combination possibilities of the electronic box are on a higher level than those of the Meccano set and, thus, emphasize the distinction between the industrial society and the information society and the respective demands that each makes.

The most important and characteristic difference is that the Meccano set can usually only be used to make very rough miniature models of physical reality. The electronic construction is itself the real thing, since it works with information rather than with materials. The difference can be illustrated by a simple example. With Meccano I can build a lift. With electronic components I can build a machine to control the lift. It does not matter whether my electronic machinery is controlling a model or the real thing. The important thing is that this control machinery has a memory. Once it has that, it can be programmed to obey instructions in the order in which they are received or to change the sequence of the execution. Most readers will have had the opportunity to reflect why such an automatic device has not been installed as they observe an empty container passing in the right direction.

The exciting, challenging, stimulating aspect to all this is that what is important is not the machinery or the electronic component but the programmer's ability to look into the future and decide what is going to happen, 'if'. Only imagination and local conditions set the limits. Memory and ability to calculate are no longer stumbling blocks. What matters is the ability to anticipate what might happen, 'if'. Here creative abilities and correct analysis of local conditions have their chance. Practical limitations vanish. In the expert's professional terminology, this is called modelling.

The most important contribution that can be made by our generation is—as I tried to make clear—to urge that schools continue to experiment so as to find educational forms that make it possible for our successors to feel the necessity of living in a democratic information society. If our generation makes no such demands, an autocratic system may gain the upper hand.

Christiania—the free town

Alongside such school experiments, there is a need to learn more about societies which have not combined industrialization and free competition in the same way as our own. There are a number of examples. We have read about societies which are treated as developing countries even if their present script dates back several thousands of years. There are also religions which do not place emphasis on the collection of material possessions.

However, such groups can be found in our own pressured industrial society, where those who have jobs envy those who do not have the freedom to enjoy a sunny day, or to complete what they are doing or let an interesting conversation draw to a natural close. And where the unemployed are ashamed at being out of the race.

In Denmark the best known society of this kind is Christiania [12]. This is a former military establishment, 0.3 kilometres square, 9 minutes' walk from the centre of Copenhagen. It comprises 150 buildings: workshops, dormitories, the commander's residence, ramparts, trees, moats, etc., all dating from the seventeenth century, when Christian IV was king. Hence the name.

When this area was abandoned in 1971 by the army, squatters broke in and within a short time there were at least 1,000 inhabitants who declared this district 'the Free Town of Christiania'—free from outside society as regards its police, courts, specialists and professional guardians. The inhabitants, to a large extent, consist of society's outcasts and individuals wishing to protest against the majority's way of living. Some no longer have the energy or ability to manage by themselves outside Christiania. Others have so much surplus energy that they can disregard traditional standards and norms.

The inhabitants of Christiania live off unemployment benefits, social welfare, local crafts, and a number of environmental tasks such as the upkeep of the area. Some have permanent jobs in the city. The main feature of the Free Town would seem to be a lack of respect for steady work. In Christiania one only works in order to live, or when it is amusing. The inhabitants make few demands as regards basic comforts.

The Free Town lives beyond the pale of law. Fencing has been knocked down and over a period Christiania has infringed on property rights and thus undermined a form of society which, with the help of industry, has achieved such a profusion of material goods that no one needs any longer to starve or freeze. In the Free Town people live the whole year round in a way which most of us can only envisage during the summer holidays, when we ourselves choose how we want to use our time.

Opinions about Christiania are sharply divided. Some wish the area to be levelled to the ground—if necessary with the support of the police—'this dangerous irresponsibility must be crushed'. Others hope that the plague will spread.

Almost everyone is agreed that these divergent views and wishes are dictated by what people think is best for those who come after them. Very few people believe that their own existence will be changed significantly by what happens to the Free Town. Yet the fight by the inhabitants of Christiania for the right to decide themselves how to use their time is a matter of keen interest to the courts, the government and the outside population. It can be hoped that this interest will continue for many years to come, though it may of course result in the Free Town's being razed with bulldozers. Alternatively it may just wither away with the good wishes of an unconcerned outside world.

Unfortunately no EDP firm has yet had the courage to install an operation in Christiania. The far-sightedness of these firms cannot be doubted. Perhaps, however, the inhabitants of Christiania will not give their permission—unlike our higher educational institutions when they received a similar offer fifteen years ago.

It would have been interesting to be able to say what use the Free Town had made of EDP, and for what purpose. It would have been equally interesting to see how the outside world would have reacted to requests, e.g. for official data or transfrontier data transfer [13]. These questions will be dealt with in the following paragraphs.

Automation on the user's terms

A characteristic feature of almost all EDP systems is that they have been established on the administrator's terms. Their purpose is to enable the administrator to achieve greater efficiency, save money, and provide better service.

Hardly any EDP system is set up on the basis of what the user requires. User participation experiments are currently being carried out in the private sector but so far little progress has been made. This is due not to lack of goodwill but to lack of training and experience. In public administration, it will take a long time before the politicians, who ought to act as the citizens' representatives, acquire an overall view of these problems.

In hardly any case has the question been asked from the start: 'What human needs, apart from the traditional administrative functions, can be served by EDP?' Little has been written about experiments of this kind. One of the best illustrated examples is a Canadian tourist service system, a project which provides data on tourist attractions, eating places, open hours, which was progressively expanded. In 1974 it already covered several other needs, including the local Chamber of Commerce directory and information on conditions for getting children into day nurseries [14]. A similar system exists in California. This system is noncommercial, which may be the reason why it has been difficult to get exact details of it.

It is easy to imagine how such systems are likely to develop. For example, terminals could be installed in libraries where anyone (preferably anonymously) could go in and ask, for instance, about their social rights. It is possible to programme such a system so that the terminal prints the necessary questions and the person seeking information only needs to answer 'Yes' or 'No' or give commonplace information so as to obtain the following results: 'If the questions have been answered correctly, you are entitled to . . .' 'You may apply for . . . at the office (address), to which you should present the following papers . . .'

EDP on the user's terms is an undertaking for which we should prepare ourselves already at this stage. This type of system is becoming an obvious consequence of our adjustment to the information society. This adjustment is expressed in the fact that it is considered natural and reasonable to let machines carry out work which people would prefer to avoid. Our entire present-day work approach will therefore be changed so that people spend their time and abilities on tasks that machines cannot perform. It will, however, take a long time to get the information society to function.

Until then we must, as experts in automatic techniques, expect there to be less and less enthusiasm among a large section of society over our motives and our work, and its results [15]. This can be good cause for trying to introduce systems which operate on the user's terms and not just concentrating on getting the experts' closed world to function better.

Free access to information

Is money to determine access to information?

Parker starts by asking: 'Who is interested in investing in information?' He himself answers this question: Given the present economic theories and ethical standards, no one is interested. First, the private investor has to have guarantees against illegal copying. At best, information can be invaluable when it is secret. Once it is made public, there is no reason for paying for anything other than retrieval, transmission and presentation.

In the old days (only a few years ago), this process could be guided through distribution of the paper on which this information was printed and the price asked. It was considered a human right that the information made public (reproduced) should be accessible to everyone through the libraries.

Today, in the space of seconds, EDP makes it possible to retrieve, transmit, present or copy almost all printed information. This information is increasingly available in machine-readable form. Information has thus been released from the confines of its traditional packaging (paper). There is a general call for new rules of conduct. Patents, copyright, legislation on public records, satellite concessions, radio legislation, transnational data flow [13], opposition to the charging of fees for library documentation services and payment for EDP aid in education and research are all relevant to the discussion. If commercial interests gain control over even one of the essential components of the information flow, they are clearly better placed to assess the value of particular information and carry out investment calculations. With good reason one can share Parker's fear for '1984 situations', as depicted in Orwell's novel forecasting the future [16].

A task for specialists: freedom of information

The above remarks are a gentle challenge to the competitive society, namely a challenge to the decision-making authorities to give the next generation a reasonable chance to take charge of their own lives. Despite the fact that many committed experts [17] are already studying this subject, there is little interest on the part of the electors and consequently the politicians. Not until the problem becomes political can any stand be expected.

The problem is free access to information, which today is regarded as self-evident. There is no censorship. On the contrary, we have libraries serving everyone free of charge. If a library cannot satisfy anyone's wishes, it will get hold of the particular book or a facsimile. One of the greatest and cleverest industrial tycoons in the world was among the first persons to champion the idea that use of a library must be free. Most of Andrew Carnegie's fortune was used to set up free public libraries while only a small part went on recognizing heroic deeds.

This idea—free access to published information—is now threatened. Not because anyone wishes to charge for borrowing a book or a periodical. That can continue as before.

Payment may, however, become the determining factor for access to information when it comes to retrieving information in a steadily increasing information jungle. Anderla [18] has studied this matter on OECD's behalf.

From a slightly longer-term angle, there is the risk that the help provided by public libraries in tracing documentation will become dependent on private commercial documentation centres since the library services themselves cannot provide sufficiently effective service.

The publisher's obligation to supply libraries

In most countries publishers are required by law to supply one or more copies of all printed material published, whether books or newspapers. Copies are supplied to the national libraries, which are responsible for registration and for producing catalogues showing what the country has produced in the way of printed material as well as ensuring that such material is available to the public.

These catalogues, which require a great amount of work, are developed on an international scale and previously provided a sound basis for the help libraries gave in tracing documentation and obtaining relevant material.

For several reasons, private (commercial) documentation centres are starting to offer a service on which researchers are dependent and which the libraries are finding it increasingly difficult to provide: (a) the volume of documentation has grown to such an extent that the individual research centre can no longer keep up on its own with what is happening in the international field; (b) the specialized documentation centres can find potential users all over the globe; (c) they can use EDP for both communication and especially tracing purposes. These tracing systems have over the years become unbelievably sophisticated [17, Appendix XI] and time-saving. The libraries therefore will eventually have to install such systems and pay for them. This, however, is not the whole story.

Researchers and libraries will gradually become increasingly dependent on these systems, without having any real influence over their content. Research can be directed in an undesirable manner if the researcher's actual access to information is determined by the policies of documentation centres in other countries. Operation of a documentation centre can be compared to operation of a publishing company or editing a newspaper. It is impossible to include everything. Someone has to lay down guidelines for what is to be omitted. Which interests are going to decide what we, as borrowers, can get hold of in an information society?

Libraries have taken an interest in these problems on an international scale for many years. Most significant are the efforts made to ensure smooth exchanges of the traditional catalogue data in a machine-readable form, so as to avoid unnecessary duplication in connection with cataloguing. This work is, however, only the first step in this direction. The really exciting and significant stage is the exploitation of magnetic tapes, which are increasingly being used for the editing of texts and preparation for printing—photosetting. These tapes can, after 'typesetting', be used for automatic analysis of the entire text and can therefore be of considerable objective assistance in the classification and selection of keywords, the two most expensive and demanding tasks when it comes to use of the sophisticated documentation tracing systems.

If society wishes the library service to be able in the longer term to ensure research and business circles and the ordinary citizen access to documentation uninfluenced by private interests, it is necessary (a) to enact laws requiring publishers to supply libraries with magnetic tapes; (b) to make major efforts to ensure standardization; (c) to extend international co-operation between libraries as regards the use of documentation systems; and (d) to ensure increased political understanding for this work, which will inevitably require considerable resources, in particular library staff and EDP equipment.

Communication of information [19] is becoming one of the most important activities in the information society. One can only hope that those who work with libraries will guide future developments. The EDP experts are trained first and foremost to respect efficiency and think in quantitative terms. Their influence therefore often operates in the wrong direction. Those who are in charge of the libraries must ensure that quality is also guaranteed. They must therefore learn something about EDP which can best be achieved by working with it.

Summary

'On the consumer market the individual has unlimited freedom of choice. On the labour market he has extremely limited freedom of choice as regards working time.' This statement, which I have already cited on page 290, points to perhaps the greatest weakness of our present society: admiration for the natural sciences in particular has become so great that electors and consequently politicians have been induced to discuss future social relationships on the experts' terms. There is no reason to believe that this will work to the advantage of a democratic social system.

This situation leads us to the question: 'What interests are we serving through cementing respect for a work-oriented ethic which is incompatible with the automated society—the information society which we have already created? The interests of our own children?' □

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Letters

The following letter has been received from Dharamjit Singh, whose articles have already been published in this journal.

Your issue on 'Science and the Islamic World' (Vol. 26, No. 3) and the letters it adduced (Vol. 27, No. 3) are replete with errors. G. R. Saini's attempt to correct M. A. Kettani's appropriation of India's zero system is not factual. Kettani questions Saini's Arabic but is not aware that *handasah* is only a variant of *hind-sa*, and that both are derived from the Arab borrowers of the Indian system, *hindi-satt* (the Indian art or science, signifying zero-system mathematics). Kettani quotes Rom Landau, who is woefully wrong too.

Kettani dismisses the concept of *sunya* (void) as a vague notion of nothingness, but the void is the axis of Buddhist thought—its analytic system. There exist 3,000 pages of discussion on the void, dating from the sixth century A.D. The void is also zero, meaning not empty but full: it is empty of extraneous factors and represents consciousness in its totality. The zero also figured in the Buddha's exposition of the universe as a mathematics of the infinite and the finite. The zero is also involved in explaining time as the first structural movement in space. The Veda knew the zero before 2000 B.C. and the Sulva-Shastra used the zero for the construction of mathematical altars. Indian atomism, including the Jain (ninth century B.C.), Buddhist (sixth century B.C.) and the Vaishesika schools, used the zero system. Your correspondent has been reading some curious Victorian myths about India.

The impact of Indian science and civilization on Arabia and Mesopotamia began with the earliest Indus civilization. The Arabs acquired the zero system long before the birth of Islam, through trade with India's west coast (notably Gujrat). Lacking the necessary intellectual environment, the Arabs were unable to make use of the concept. But the Indians of the time abhorred inscriptions, the few specimens extant being atypical. The Veda, for instance, was not written down for several thousands of years.

The earliest inscription or textual reference dates from A.D. 346, at Bharukaccha. In A.D. 520, the Vasvaddta used both 0 and a point (.) in the zero system. The earliest known manuscript to bear the fully developed zero system is the Baakhshali arithmetic text, A.D. 320. One of the world's great mathematicians, Brahmagupta, described the zero system in his *Brahama-sphota Siddhanta*, A.D. 610; he included solutions of determinate and indeterminate equations of the first and second degrees, and a study of cyclic quadrilaterals and rules concerning permutation. Then Al Khawarzimi translated, before Kettani's date of A.D. 873, Indian works on numerals.

India's cultural influence on Islam

Islamic science began with the conquest of Alexandria, A.D. 640, where flourished six schools of Hindisattava or *handasah*, together with that of Ptolemy. This was also the point of origin of Muslim mathematics. After the Muslim conversion of Hindu and Buddhist Afghanistan (eleventh century), and the impetus this lent to Islamic science, the general decline of Islamic science set in, withering completely by the fifteenth century. Without roots and a panoply of other disciplines attendant on mathematics, the latter speciality cannot survive, just as it cannot spring from a vacuum.

Indian numerals, called 'arabic', are derived, as is the Brahmi script, from India's Indus period. There were four modes of expressing calculation in ancient India: there were the public inscriptions, those used for purely mathematical work, a third system for accounting, and a fourth devised by Aryabhata (in A.D. 499). It is to be noted that Abu'l-Hasan al Ahwazi translated Aryabhata as Al-Arjabhad, hence algebra. There is no *al-jabbar*, except as a corruption of the term already noted.

Your correspondent should be aware of the relentless influence of India on the Arab world. The word zero comes from the Hindi root *kha*, and *khara* or *kharo* is empty (but not void, *sunya*). India has no less than fifteen words for zero, each belonging to the synoptic vision which produced the zero system. There is a term which passed from the Brahmi to Arabia as *sifr* (or *chiffre* in French, *cipher* in English). The Brahmi word, *chidra*, means figure rather than numeral; it can also signify limb or planet; these varied connotations stem from the Indian mind to which mathematics is not merely an abstraction but an instrument, as well, to plumb the universe.

The derivation *hind-sa* or *handasah* means, in ancient Arabic, geometry or engineering, as meant *hindi-sattva*. And the word hand, in English, *is* derived from the Sanskrit *hatth* or *hanth*. (*Hathi*, or elephant, means beast with hand.) Similarly, *kessaram* or the colloquial *kesar* is saffron, or Kettani's *zafran*. Scholars have noted more than a thousand comparable derivations in ancient Arabic.

DHARAMJIT SINGH

The following is the riposte of author Kettani to the letter from Mr Singh.

I read with stupefaction the letter of Mr Singh. The writer seems to be so infatuated with all that is pre-Islamic India that he virtually claims (without a shred of evidence) that Islamic science is no more than translations of pre-Islamic Indian work. His statements go against the most glaring evidence and against the findings of most historians of science who, in their majority, are neither Muslim nor Hindu or Sikh. In his enthusiasm, Mr Singh goes so far as to find for almost every Arabic word an origin in Sanskrit—forgetting, in the process, that Arabic is a Semitic rather than an Indo-European language.

The most glaring example of this is his claim that the Arabic word *al-jabr* is a corruption of *aryabhata*, a word meaning in Arabic 'setting a broken bone'. It comes from the classic book by Al-Khawārizmī, *Al-Jabr wa Al-Muqābalah*, the first volume ever written on algebra (and copies of which may be found in European libraries).

Your correspondent says that 'the Indians [meaning pre-Islamic ones] of the time abhorred inscriptions'. I wonder how Mr Singh could claim that Muslims copied all their science from the Indians centuries later. Further, and to one's great astonishment, when the correspondent contends that 'without roots', meaning thereby pre-Islamic roots attributable to the conversion of Afghanistan to Islam, 'Islamic science cannot survive, just as it cannot spring from a vacuum', he seems to succumb to the temptation of resorting to purely subjective speculation born of ethnocentrism.

M. ALI KETTANI

Further discussion on the origins of zero comes from Anthony Michaelis and Romila Thapar, respectively editor of Interdisciplinary Science Reviews *and professor of ancient Indian history at Jawaharlal Nehru University (India). Both correspondents can be reached in care of Dr Michaelis, Spectrum House, Hillview Gardens, London NW4 2JQ (United Kingdom).*

The origins of zero tend to evoke arguments based on either the representation of a zero sign in a record of some kind or the presumed use of zero in mathematics (implicit in the notation of decimal place). The earliest record in India of a date written in a system using nine digits and a zero, with place notation, comes in the form of an inscription from western India.[1] The inscription, as edited and described in *Epigraphia Indica*, Vol. II, p. 19, records a grant made by an early Gurjara king; its date is written as follows, both in words and numerals: *samvatsara-śatatrayam-ṣatcatvārirśottarake* 346. The date 346 is presumed to be in the Chedi era beginning in A.D. 248–9, which would date the grant in the year A.D. 594–5. The only other possibilities of eras which might have been used, but which are unlikely, would be those of the Vikrama (57 B.C.) and the Saka (A.D. 78). These would place the date of the record in either the third or fifth century A.D.

The figures used for '346' are quite clearly recognizable as Sanskrit numerals. That this was not an isolated example is evident from a later inscription, also a grant from the same area in which the date is given in words and figures. This Raṇagraha grant, edited in *Epigraphia Indica*, Vol. II, p. 21, is dated as: *samvatsara-śatatraye-ekanavatye* . . . 391, which, on the reckoning of the Chedi era, would give us A.D. 640.

As Basham has rightly observed, the use of this system in inscriptions would tend to be later than its use in mathematical texts since inscriptions recording grants of land would use an established, conservative system of dating because these copper-plate records on which the grant was recorded were in fact legal documents. Familiarity with the zero and its use among mathematicians can be assumed from the contents of the Bakshali manuscript, dated towards the end of the fifth century A.D.

As regards the actual occurrence of zero, the earliest record in India is that of the inscription of Bhojadeva at Gwalior, fixed at about A.D. 870. Here the zero is shown as a dot (*bindu*), the conventional form in which it was used. Earlier inscriptions of the seventh century in South-East Asia (Cambodia and Champa) also record the use of the dot for a zero in the decimal system. An inscription of the same century from Banka Island uses the closed ring for a zero, thus considerably antedating (A.D. 873) the manuscript in Arabic.[2] It is historically reasonable to suggest that the mathematical system used in Cambodia and Champa would have been derived from Indian mathematical systems.

ROMILA THAPAR
and ANTHONY R. MICHAELIS

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In response to reader inquiry...

The following are the themes to be published by **impact of science on society** during the subsequent fifteen months:

Vol. 29, No. 1 (January–March 1979):	The Einstein Century
Vol. 29, No. 2 (April–June 1979):	The Sea as Resource
Vol. 29, No. 3 (July–September 1979):	Research and Human Needs
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