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Computers, Statistics and Planning—Systems or Chaos?

by

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Ever since Professor Fogarty invited me to give this lecture, I have been wondering why he picked me when I reflect that Dr. Geary, in whose honour and name these lectures are being given, and Professor Sir Roy Allen, who gave the first Geary lecture last year, are both illustrious names in the world of statistics. They belong to the generation in which the foundations of the subject were, with immense labour, being laid, and indeed hacked up again and relaid several times. Dr. Geary's work has such an international reputation as to make any further description or comment on my part merely presumptuous: his early pioneering work as director of the Central Statistics Office here, his work at the United Nations and later as first Director of the newly formed Economic Research Institute in Dublin. To have my name linked in this way today with Geary's is an occasion of which I can well feel proud.

Just prior to the time when my own career in statistics was commencing, an important development took place in which I was therefore able to participate straight away, and which has since had a great effect on the development of the subject. I mean of course the invention of the computer.

When I first joined the staff of the London School of Economics in 1952, I was encouraged by Maurice Kendall and Roy Allen, both already there at that time, to take an interest in computing, which they both with great foresight realised was going to have a profound impact on the social sciences, and on statistics in particular. I had already visited the experimental computer at Manchester University and had met Turing, whose theoretical work has provided the basis of modern computer science. Shortly after joining the L.S.E. I was able to spend some time at the Institute for Numerical Analysis at Los Angeles. They had installed there at that time one of the early machines, the National Bureau of Standards Western Automatic Computer—called SWAC, because even in those days acronyms were fashionable, indeed even more so than today when computers are just given peculiar numbers. But then there was ENIAC, SEAC, MANIAC, ACE, and later the DEUCE, all highly individualistic experimental machines, and apart from the last, not meant for commercial production. Of course in the days I am speaking of it was something of an achievement to get a programme actually working. It was useful to have handy a screwdriver and scotch-tape, and to know where to kick the machine if it stuck. Naturally you had to operate it yourself, and I remember particularly in the case of the DEUCE you had to communicate with it in binary, punching all your instructions on cards coded in binary, and the binary numbers had even to be written backwards with the least significant digit on the left, presumably because this was the order in which the engineers had arranged the train of pulses to represent numbers in the mercury delay lines, the memory devices of this particular machine.

Nearly any problem was worth doing on a computer, because it would almost certainly not have been done before and would be useful experience. The first problem I was concerned with after I became interested in computers was a Monte Carlo problem. Alan Stuart and I were interested in the statistics of the breaking of records—like the 4-minute mile—and Dan Teichroew had recently written his thesis on the generation of random numbers by computer. So we collaborated on writing a programme to simulate by computer situations in which records are broken. The results of this were eventually published in the Royal Statistical Society Journal.

Developments since that time have been spectacular, that is over the last 15 years or so. Some of the early machines now reside in science museums. Two major areas of development have been first *software* and more recently *time-sharing* (coupled with *on-line real-time* computing). Software has been defined as the part of the computing system you cannot actually kick—the other part being the hardware. In the beginning to use a computer you had to have a fairly good idea of what went on inside it, and the way in which you presented instructions to the machine was complicated and primitive indeed. This constituted an effective barrier between the uninitiated user and the machine. The developments of automatic programming, or what are now called higher level languages, have improved this situation. Time-sharing also has effectively eased the bottle-neck in providing to all intents and purposes for a number of users to have simultaneous access to the same machine.

Linked with both these developments has been the recent appearance of so-called *conversational* computing. This mode of computing enables a user to communicate, as the name suggests, in a more flexible, informal manner with the machine. Instead of, for example, writing a complete programme of instructions, he can transmit one instruction at a time directly to the machine, by such conventional means as a typewriter keyboard, obtaining an immediate response as the instruction is carried out, before going on to his next instruction. This provides a flexible, trial-and-error method of computing, very useful for certain types of problems. Compared with the older form of communication it is like the difference between a telephone conversation and correspondence by letter. The whole history of computing in fact can be seen as a gradual erosion of the man-machine communication barrier. Originally, one had very much to take into account the computer hardware. Gradually the developments in software enabled the user to take the hardware for granted. Now the user is beginning to take the software for granted, with consequent greater freedom to concentrate on his own problem, rather than on the means of communicating it.

These developments in technology, of course, have had great repercussions in the field of statistics, and for the sake of brevity, I mean to include under this heading all the quantitative techniques that go under the name of operations research or more broadly management science. Statistice are concerned with the processing and analysis of masses of data and with the development of mathematical methods of extracting information from data. Combine all this activity with computer methods and you have something more than the sum of its parts. You have a new, powerful *information technology*. This is a growth area which I believe has the widest-ranging implications for society as a whole.

Now the basic point to be made here is that the whole concept of the computer has undergone a complete change over the last 10 to 15 years. In the early days it was a new instrument for doing complex numerical calculations very rapidly. The people interested in its development were pure mathematicians, like Turing, and numerical analysts, and they still tend to maintain their prior claims today, particularly in institutions of higher education. However, computers are now recognised as not being simply number crunchers. Indeed there is today not much point any more in discussing what they can do. They are capable of performing any structured task, from planning a hospital diet, retrieving a legal precedent, or controlling stocks in a warehouse, to playing a reasonably good game of chess. The bulk of computing carried out nowadays is routine data processing for the purposes of more or less sophisticated management decision making. The emphasis has switched from technical to economic feasibility. The picture one has is no longer that of the initiate approaching the computer shrine armed with esoteric instructions. The modern concept is that of the large computer utility, situated many miles from the users. The utility is operated by professional staff; the users will each be provided with terminals in their own offices, connected by telephone line to the distant utility. The terminal might be a teletype-writer, and the user can enter his data *via* the keyboard and instruct the computer to perform specific tasks and have the results printed out again at his terminal. He is able to do this at the same time as many other on-line users. One can envisage a national information grid of this kind, to which would be connected a small number of large utilities. The electricity generating station is replacing home-generated electricity. The emphasis is now increasingly on data transmission rather than simply computing as in the past. It is clear that an industrial economy will become increasingly dependent on an efficient information grid. It is very significant, for example, that the British Post Office is now contemplating entering the computer bureau business, and that on the other hand at least one large international computing utility is merging with a communications utility.

The application of computers in business management over the years has had a chequered career, involving many failures. In the early days it was just a question of setting a programmer on to a limited well-defined task, such as the ubiquitous pay-roll job. As the tasks attempted became more sophisticated so the incidence of chaos grew. Gradually it was realised that it was not enough to send a junior member of staff on a programming course and expect him to be other than a menace on his return, unless set to do very carefully specified jobs under very detailed supervision. The plumber could hardly be expected to design and erect the entire edifice and even take care of the landscape gardening into the bargain, but this was exactly what has often been assumed in regard to computer installations.

The real extent of the innovations being attempted has come to be realised, and the concept of the installation of a *system* rather than a computer has emerged. The computer is seen as one component only of larger organisational structures that include people as well. Human and organisational as well as the technical problems have to be solved. To leave the work entirely to the computer programmers invariably means that there is an undue concentration on technical problems to the exclusion of all else.

Everybody has his favourite story about how the manic, obsessive computer does intrude on, harass and infuriate the man in the street. Mine is the one recounted recently by Claud Cockburn about the householder who on returning after a long absence found an electricity account for £0. 0. 0., which puzzled him a little but he ignored it. At regular intervals he received similar accounts which he likewise tore up. Eventually he received a plaintive letter from the manager asking would he *please* send a cheque for £0. 0. 0. since nothing else would placate his computer. Not wishing to be disobliging, he did as he was requested. Shortly after, he had an urgent call from his irritated bank manager requesting him to please desist from writing cheques for £0 0. 0., since it made his computer go berserk.

An organisation is a structure of interlocking systems. To design a total system requires the experience and wisdom of everyone in the organisation from the top down. The model building techniques of operations research are needed, together with the various other management science skills. Computers change people's jobs, so personnel problems have to be tackled. There are problems of education and training, and so on. Most importantly of all, central to the design is the feedback control principle of cybernetics: the computer is part of the total closed-loop system, with people forming part of the loop. Cybernetics, the study of control in the animal and the machine, was so named by Norbert Wiener from the Greek *kubernetes*, the steersman, from which comes the English word *to govern.* Looked at like this, one does, I think, begin to realise that the endeavour which I have referred to as information technology is no longer something just affecting specialists, but is bringing about changes in society affecting us all. It is not my purpose here to make any value judgment, but simply to point out this fact which I think is important. The new technology brings about the possibility of all sorts of new ways of doing things in which we all participate. Basically it is a matter of more information being more readily and more speedily available, which at the least speeds up the pace of life, but may even mean a difference between life and death for the individual. We can make airline reservations instantaneously, soon our children in school will be receiving instantaneously from a library relevant information on any subject, our diseases will be diagnosed by computer methods, not to mention our taxes collected. We are witnessing the emergence of advanced cybernetic systems in society in which we all participate in one way or another without any special computer knowledge, and they will very soon be taken for granted.

The reality is catching up with science fiction. There are now actually in existence a number of commercially available systems. One example, beautifully tailored to a specific purpose, is the service for stockbrokers that is now being operated by a commercial company. Users rent teletype terminals linked to the central utility, which holds information extracted from the profit and loss accounts of a large number of public companies. Through his terminal, a stockbroker can interrogate the data held by the utility to obtain instantaneously information relevant to investment decisions.

Another field where much thought is being given at the present time to the design of new systems is *medicine*. There are many research units all over the world looking into the problems (which of course are much vaster than those of stockbrokers), but as yet nothing of very great interest is operational. In this city the Dublin Hospital Medical Records Committee was formed three years ago, consisting of physicians and surgeons of the various hospitals under the chairmanship of Professor Wilson of Trinity College. A study was carried out which established the feasibility of a computerised medical records system, in which considerable medical and hospital administrative interest has been expressed.

Progress however in the medical field does not compare at all favourably with that in other areas of business management. The reasons are not far to seek: old institutions set in their ways do not readily adapt to change. Nevertheless many medical activities parallel those in business for which the need for totally integrated systems is now recognised.

One ambitious project is under way in Sweden. Stockholm county is developing a totally integrated medical system to include every aspect of medical management, control and treatment, as well as the county's administration and financial control. When completed it is reckoned it will be the world's largest and most sophisticated medical computer system.

What will be the benefits resulting from it? The immediate availability of patients records kept on a central file on mass storage devices, any part of which is accessible on demand by the doctor for visual display on a terminal like a television screen; the general freeing of staff from clerical chores below their ability and training; speedier diagnostics due to more ready availability of information; statistical analyses of data readily provided. A medical system of this kind is not restricted to one hospital, or one region, or even one country. It is not essentially different from an airline reservation system which is already operational on an international level. So we could envisage a patient taken ill in one country having his medical record transmitted in a matter of seconds from his country of origin to the hospital where he is lying.

Another field which seems to be lagging even further behind than medicine is university administration. There is very little evidence of any activity in this area apart from occasional statements indicating some slight awareness of the potentialities and reference to input/output models of a university as a basis for planning. The analogies with other organisations is quite apparent: students, faculty and resources form the inputs, knowledge and service to the community are the outputs. In few universities have research departments been set up within the administration like the operations research or systems development departments of business companies. The university population explosion (with a population more than doubled over the last 10 years) now makes the need for good systems critical. Obvious areas in which to begin analysis are time-tabling, creation of a central file of student records, updating and dissemination of information on courses.

No doubt information technology will eventually lead to an educational system covering the individual from pre-school to retirement, and large data banks will develop statistics for the guidance of policy makers. Unfortunately researchers who have attempted to apply management science to university administration report the familiar frustrations: lack of co-ordination, haphazard decentralisation, lack of receptiveness to new ideas, and so on. A recent article on this subject ended with the words: "Our ability to apply management science to education still ranks with Mark Twain's analysis of our ability to deal with the weather. Not only do we not do very much about the problem, but when we say anything we don't really say very much." But the problems of universities are becoming critical, and clearly something must be done, as student revolts all over the world are showing. These old inflexible institutions must learn to adapt, or they will become extinct. All organisations in resisting change claim that they are different, and many in universities would resist the analogy with a business organisation, just as many would deny that there is any analogy between a business organisation and a government. Of course organisations of different types differ in many fundamental respects, but surely all are subject to the same principles and natural laws, such as that they should have objectives, and that their systems should serve and be subservient to these objectives. An organisation without objectives will disintegrate, and the universities at the present time seem to me to be in danger of just this. It is surprising when you think that universities which were originally responsible for so much of the hardware of computers should now be so backward in applying to themselves the logical consequences of this research.

Nor have university teachers for their part been quick either to realise or implement the potentialities of the computer as a pedagogic aid. The confusion of thought between teaching computing and using the computer to assist in the teaching of other subjects still persists. For example in the field of statistics teaching, it is usually assumed that students must first learn about computers and take a course in programming before the computer can be introduced into a statistics course. Traditionally teachers send their students to a separate course in programming in the hope that something will rub off to enrich their statistical experience. This is really nonsense. The main problem in teaching elementary statisical methods is to quicken up and make more interesting the process of exposing the student to the analysis and interpretation of data. By use of computer technology this can now be done in a revolutionary way.

Using the conversational mode with access to the computer by typewriter keyboard, the student is able to type in his data, and follow through the processing step by step if he so wishes in a very flexible manner. At each step when he issues instructions he receives back an immediate response printed out on the typewriter printer. The procedures for giving instruction are easily learned and the concept of programming in the customary sense of Fortran or Algol disappears. The student has at his command a library of statistical programmes which he can call up to process his data. He can even demand a complete listing of the available programmes, and this will be printed out for him. Having called up a programme he may if he so wishes modify it in any way he pleases to suit his own special requirements. He can also, if he so wishes, write his own programme, run it or have it stored for later use. This introduces an entirely new dimension into the teaching of statistics. At the present time limitations on numbers of available terminals would make their use feasible only for smallish classes. But one terminal for example might be sufficient to meet the requirements of classes of 10 or 12 students meeting together. A class of 150 could be split up into 12 to 14 groups and meet for an hour at different times of the week. In total on the basis of a 7-hour day and 5-day week, one terminal might meet the requirements of between 350 and 400 students, each having shared access to the terminal for one hour per week. This is an educational system which I believe could produce a new generation of statisticians with a real understanding and appreciation of the fundamentals of the subject, and it is a system with which, given the facilities, I should certainly be interested to experiment.

You may not have been aware of it, but so far in this talk what I have been trying to establish are two equations, namely: computers+statistics=information technology, and information technology×planning=systems. This is the theory. In practice, the end product is often pretty fair chaos instead. Very careful planning is required to avoid chaos. The whole field of computers is now grimly preoccupied with planning. A computer programme itself is a meticulous plan, and even more so in implementating a cybernetic system involving people as well as equipment, a highly skilled planning function is involved.

All this is by the way of stimulating a great deal of thought about the planning process itself: not only economic planning, or regional planning or computer systems planning, but just planning as an activity in itself.

One particular area where attempts at planning in the computer industry are being made at the present time is in standardisation. Systems spanning a group of companies, and becoming industry-wide or even national, bring in their wake acute problems of standardisation. For example, I was myself involved in a project to design a standard coding scheme for the unique identification of books, which has now been adopted throughout the British book trade for order processing, by publishers, wholesalers, retailers, also by the British National Bibliography and by public libraries in their computerised operations. Interest in the international extension of the scheme has been generated, and an international committee is being formed to look into the possibilities. The data bank idea of a central file of records covering all the many commodities and products of a country demands consistent codification for firms, their locations, their materials, products and so on. The problem is most acute in the collection compilation and analysis on a national scale of statistics for the common use of government and business. National commodity coding is a subject attracting much attention in the United Kingdom at present: it is the big headache in the application of computers in government, and the British Central Statistics Office, now headed by Claus Moser, my former colleague at the L.S.E., is being given a larger scope and is beginning to tackle the larger problems involved in achieving better integration and co-ordination of government statistics.

Standardisation in this field is something of a nightmare, on account of the vast number of authorities, institutions and organisations with a say in it. In Britain, in addition to the CSO, there are the various ministries like the Ministry of Technology, Ministry of Defence, Board of Trade, the Defence Codification Authority, the DEA, the CBI, the GPO, the UKAEA, the British Standards Institution. At the international level, there are the European Computer Manufacturers Association, the International Organisation for Standards, and so on and so forth.

Another area where planning is just beginning to be applied is *software production.* It used to be that programmers' work was on a completely *ad hoc* basis. They were highly individualistic people like artists. Now they usually work as part of a team. Software production is becoming standardised, and the term "software factory" is beginning to be used. The production has to be managed like any other job, based on principles and procedures, only quite recently and very slowly and painfully evolved.

It is an interesting thought that the whole computer industry depends on such logic factories for the production of their *knitting patterns,* or if you like canned plans for future use. The software industry is enjoying a tremendous boom. It is labour intensive, and will be for the foreseeable future. It requires nothing but the application of intelligence and imagination. These considerations have naturally not escaped attention in a number of countries, with the obvious implications for a potential export industry. At least one small country, Israel, is already well advanced in the setting up of such an industry. Naturally much planning is required, and the backing of all sorts of training facilities are required, and also of course a good computing environment. One begins to wonder indeed whether the right attitude for a small country might not be to regard its computing hardware environment as simply a back-up for its software industry, in much the same way as its scenery is a back-up for its tourist industry: to be enjoyed incidentally by the local inhabitant. In a country of the size of Ireland, for example, it would be perfectly feasible for this environment to take the form of one big computer utility serving the needs of the whole country, the public sector, business, educational institutions, the lot.

I have referred to the need for education and training in this expanding field. The demand for staff is not anything like being met on a world-wide basis. We do not of course in this part of the world regard educational establishments as having the prime function of turning out just the product that industry needs. The most interesting document on education that has appeared for a long time—the Dainton Report—puts it very nicely: national requirements determine the opportunities for individuals. The authors of this report came out in favour of an education that meets the needs of the individual, wider curricula, less specialisation, later choice of career, and emphasis on the key rôle of mathematics; but mathematics taught to show its relevance to everyday experience, as a means of communicating quantifiable ideas, as a training for logical thought, as a tool in activities arising in the developing needs, naturally of science, but also of organisation, economics, sociology and other studies. The Dainton Report might have been expressly written for an enquiry into the educational needs of Information Technology.

Certainly there is a universal need for mathematics to be taught as a subject central to our culture. It is the key to technology. And if education is a matter of achieving an awareness of the forces at work in society, then a general, common knowledge of the basic thought processes of technology is absolutely essential in this age.

To achieve an educated society, there is a need for mathematics to be taught with more imagination, and less arid scholasticism, throughout the school curriculum. And I do not believe the answer lies in the "New Maths", which seems to be based on some bright ideas, not adequately baked, planned or implemented. One imaginative step that has been taken in several countries is to introduce computers into schools. Like any good visual aid, this really stirs the imagination of children. And it might be pointed out that the costs are not so great as might be thought: a good second-hand computer can be bought for less than £1,000, the price of a modest motor car. But why should schools be fobbed off with second-hand equipment? More ambitiously, I should myself like to see schools linked up with the national utility I spoke about just now.

Of course, everyone is saying nowadays that education is the key to all our problems in society, from racial integration to efficient government. I myself believe this is obviously true, and that therefore it cannot be stated too often. And it is not just a matter of technical training. The demand for technologists is there all right, and is so obviously there that there really is not much doubt but that the demand will be met eventually. The less insistent more hidden need for the proper management of technology is much more important. I believe that the information technology I have been describing is having a profound effect on society. But this can be for good or ill, and there is really not much evidence at the present time to make one have faith that it will lead to good systems rather than pretty fair chaos. The technology has to be planned, and in the last analysis it can only be properly planned by an educated society, that has assessed its own needs. Their education must include a fluency in the language of mathematics and an appreciation of the principles of cybernetics. The new problems facing complex modern society are not technical, they are organisational and managerial, they are problems of *how to govern*—which is what cybernetics is all about.

The trend towards the social sciences detected in the Dainton report is happily, and perhaps not fortuitously, a trend in the right direction.

We need a society which can distinguish between good and shoddy systems, but is not afraid of innovation and change. Technological innovation will then be drawn out, insisted upon, from above, by society, not foisted on society from below, by the technologists. The technologists will then be kept firmly in their places.

As Ireland enters, a little bit late, the twentieth century, the problems to be tackled are great. But so also are the potentialities. The goal of affluence is becoming so easy as to be hardly worth the attainment, were it not as a means to an end. And as a means to an end, so also are good systems, tailor-made to the needs of this particular society, and they can then be quietly taken for granted, in pursuit of the good life.

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