THE USE OF COMPUTERS IN BUSINESS INFORMATION PROCESSING

a review of the state of the art in the U.K. in 1965

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INTRODUCTION

1 This paper will not attempt to discuss in any technical detail just what a computer is. But, before discussing the computer in its business context, it would be as well to describe briefly the main features of the computer, since these have a fundamental influence on the use that can be made of the computer for business information processing.

Processing unit

2 As in every scientific or other application, the business computer system has at its heart an assembly which does the actual arithmetical processing of data. The central processor contains the electronic circuitry for carrying out arithmetic and other operations on data; for interpreting the coded instructions that must be placed in storage to direct the operation of the system; and for controlling all of the other parts of the system as a result of the interpretation of these instructions. It also contains the operator's console, which provides a certain amount of access to the information in the computer and allows for manual control of the system when it is started.

Input

3 In order to communicate data to the computer for processing, there is usually a punched card or paper tape reader; but readers capable of reading characters printed on a document with special ink or in a particular type-style are also available.

Output

4 When processing of data has finished, the results must be made available for use. This is normally done by line printers which produce normal printed documents. Other output units are paper tape punches, card punches or typewriters.

Storage files

5 In the same way as ledger cards provide the storage in a keyboard accounting system, a computer needs to have the ability to store large amounts of business data.

6 These computer files at present take four forms, punched cards; magnetic tape; magnetic discs or magnetic cards. The magnetic forms offer very much greater processing speed than the punched card file.

THE DEVELOPMENT OF BUSINESS COMPUTERS

7 About 15 years ago the first machines with internally stored programs were constructed. The first use of a computer for data-processing work was in the 1951 Census in the United States.

J. Lyons & Co. Ltd. - LEO

8 Development was proceeding simultaneously in several countries including the U.K., and J. Lyons & Co. Ltd. started using LEO I (their own development) in 1954 for accounting work. This was the first use in the world of a computer for business data processing.

Univac and I.B.M.

9 Later in the same year the first commercially produced computer, a Univac Machine, to be used by a commercial organization (American G.E.Co.) was installed; and by 1955 I.B.M. had installed an I.B.M. 702 at the Monsanto Chemical Company.

First commercially produced U.K. Computer

10 In 1956 the first commercially produced U.K. computer (a H.E.C. made by the British Tabulating Machine Co. (now I.C.T.)), was delivered to the Morgan Crucible Co. Ltd. An early sign of things to come is the fact that this machine was replaced at Morgan Crucible by a later machine only two years later in 1958.

First generation of machines

11 These early machines were fairly simple, consisting of a central processor, a card reader, or a paper tape reader, and a line printer. The central processor was a fairly slow unit and the internal store was normally a small magnetic drum. Some of these machines were not capable of storing alphabetic information. The limitations on processing were stringent and these early computers were really a simple example of combining a punched card calculator with a tabulator.

12 These first machines were valve machines, such as the I.C.T. 1201/2, the National Elliott 405, the Ferranti Pegasus, the L.E.O. I-II, and the I.B.M. 650. A typical machine of this type would cost about £ 50,000 to £ 70,000 to buy.

Magnetic tape or film

13 The immediate need to increase the power of the early machines was for some form of backing store to be developed. By 1957 magnetic film units were available with the National Elliott 405, and I.B.M. had added tape units to their 702 and 650 computers.

14 Now instead of having all master data and files on punched cards it was possible to use the higher speed magnetic devices to hold all historical information.

15 It also became possible to attach more than one of each of the peripheral devices to the central processor, so that a typical set of computer equipment would cost about £ 150,000 to £ 200,000 and would consist of a 200 line per minute printer, a 200 card per minute reader, a store with a drum and four tape units capable of reading and writing information at 15,000 characters per second.

A second generation of machines

16 These early machines were rendered economically obsolete by the announcement of a second generation of machines in 1959. A few of these were installed in 1960 but the main impact was felt in the years 1961-65. These were machines such

as the E.M.I. 1100, I.C.T. 1301, I.C.T. 1500, Ferranti Orion, L.E.O. III, K.D.F. 6, the I.B.M. 1400 series, N.C.R. 315, Honeywell 400.

17 In the first place, the valve was replaced in the computer, as in most other electrical devices, with the transistor. This led to much greater reliability in computers and secondly, to a reduction in size, thus making the machines more attractive to commercial organizations by reducing both the area required for an installation and the extent of the air-conditioning requirements.

18 Storage of information within the computer was improved by the development of core stores, although these did not always replace drum stores as in some machines the two types were used in conjunction. A typical combination was a core store of, say, 1,000 words with a backing drum store of 8,000 words.

19 Disc stores had been used to a limited extent prior to this as a Random Access Store on I.B.M. machines like the 650 and 305. These were not removable and were limited in capacity.

20 Disc packs were then produced which were removable and provided similar ability to process data randomly or serially at choice. The ability to change both cartridges of magnetic cards and disc packs enabled the volume of information stored in this way to be greatly expanded.

21 In addition, the speeds of readers, punches, printers and magnetic tape were all substantially increased, so that the net effect was that the new machines were at least twice as fast as the old in most applications. Thus a typical computer system during this stage would consist of a 600/1,000 lines per minute printer, 400-600 cards per minute reader, a core store of between 8,000 and 16,000 characters (or alternatively a core store of 1,000 words, together with a drum storing 15,000 words) and 4-5 tape units capable of reading information at about 20,000-30,000 characters per second. This set of equipment would cost about £ 150,000 to £ 175,000 to buy.

THE THIRD GENERATION COMPUTERS

22 1964 saw nearly all the major manufacturers announce completely new ranges of equipment of which a few will be delivered in 1965, but the main impact will not be felt until 1966. These ranges of machines have been called the third generation of commercially available computers.

23 The third generation are so called because they render the second generation obsolete rather than because of any single dramatic technical development comparable with the introduction of transistors and the use of core storage. Examples of this new generation are the I.C.T. 1990 series, the I.B.M. 360 series, the Bull G.E. 400 series, the Honeywell 200/2200 series and the R.C.A. Spectra 70, and the System 4 series announced in 1965 by English Electric - Leo - Marconi.

24 The third generation render the second generation obsolete by offering on average two to three times the power for the same price, in addition to some other advantages. The ways in which these advances are achieved are considered below.

Core storage

25 The speed of the core storage is increased (roughly two to three times) and the price of core storage is sharply reduced (by roughly one half) which means that it is easier to justify larger core storage. The increased speed and size of storage increases the power of the computer.

Processing power

26 The power of the processor is increased because even the medium-sized machine has the ability to carry out read in/read out operations (e.g. punched card to magnetic tape, magnetic tape to printer) at the same time as it is carrying out a main processing operation (e.g. a payroll *or* stores control). This is best described as "*time sharing*".

27 In the larger machines it is possible to optimize the use of the power of the computer by carrying out two main processing operations at the same time (e.g. a payroll *and* stores control). This is called "*multi-programming*".

28 In either of the above cases, to ensure that the two main processing operations do not interfere with one another, the manufacturer provides either special control circuitry or special control programs (or both) to ensure that there is no possibility of one of the programs interfering with another. In the very large machines it is possible to have up to seven independent programs operating at the same time.

Input and output

29 Because of the time sharing ability, the computer is able to read in data from punched cards, paper tape, or magnetic files, and read out data to a line printer or to magnetic files very much faster than was possible on the second generation machines.

30 This increase in power is enhanced by the greater provision of buffer stores between the peripheral devices and the computer so that communication between the peripheral device and the buffer occurs at the peripheral speed; whereas the transfers from the buffer to the core store take place at electronic speeds.

31 Finally the input/output power is increased because the communications between the central processor and the peripherals is handled by a kind of automatic telephone exchange device which enables the five or so lines into the computer to be allocated to whichever peripherals want to use them.

32 All this said, the speed of the peripherals is, in the main, very little different from those available on the previous range.

Range of peripherals and processors

33 The final factor contributing to the improved power/cost ratio is that there is a range of processors and common to all these processors there is a far wider choice of peripherals available than hitherto. These peripherals offer a range of speeds in card/paper tape reading and punching; in printing; in magnetic tapes; in random access stores. This wider choice enables the user to match the equipment more closely to his requirements than was hitherto possible.

Additional advantages

34 In addition to the factors contributing to the improved power/cost ratio the third generation machines offer some additional advantages, as follows.

General purpose machines

35 Earlier a distinction used to be drawn between scientific and commercial machines and specific machines used to be categorized as being commercial rather than scientific or vice-versa. In many of the third generation machines, this distinction is either blurred or eliminated.

Expansibility - the plug-in approach

36 Claims were made for second generation machines that they were built on the building block principle and that you could add new units as your needs expanded. However, with some honourable exceptions, this was not quite as easy as it sounded since it often involved handing the machine over to the engineers for a week while they made the necessary connections. Now it is genuinely possible to plug new peripherals in and start working.

Expansibility - compatibility of programming

37 In the second generation range of machines the total span of requirements from small to very large was met by four or five commercial machines and a similar number of scientific machines. Each of these machines differed slightly in the way they were programmed and the very small differed radically from the very large. In addition, the peripherals available with each processor varied significantly.

38 In the third generation ranges, this complete span of requirements is met by between four and seven processors. Each of the processors is programmed in exactly the same way, with very few exceptions has exactly the same peripherals, and the way in which the transfers from peripherals to the central processor is handled are the same.

39 Because of these similarities, a program written for a specific machine will work on any larger machine and, with certain of the systems, will work on a smaller machine with the necessary storage and number of peripherals.

Expansibility - general

40 These two features, plug-in ability and compatibility, offer very real advantages to the user in that he can make a five-year plan for data-processing. These two features enable the user to expand his power in step with his needs far more closely and over a much greater range than has hitherto been possible.

Remote communication with computers

41 The ability of the third generation machines to time-share input and output (see paragraphs 26, 30 and 31) has meant that it is now practical to connect distant points directly to the computer via telegraph or telephone lines so that it is possible to input data from remote points, make inquiries from remote points and even run programs from remote points. At the moment, the capacities of the lines available in U.K. and the cost of high-speed readers and printers at the remote points restrict the value of this ability but it is reasonable to expect that both these will be

overcome in the next few years. In the United States there are already cases of large organizations where a number of small computers and one large computer are used in which problems which are too large for the small computer are switched to the larger computer over high-speed transmission lines which enable data to be transferred directly from one computer to another.

Range of random access devices

42 In the past, the range of random access devices available with any one machine has rarely been wide enough to meet all needs. The range of devices now available fall into four categories:
(a) cheap, "low" capacity, slow access;
(b) medium price, "low" capacity, fast access;
(c) medium price, "high" capacity, slow access;
(d) expensive, "high" capacity, fast access.
Different applications require all of these and in the past, it has sometimes been necessary to select the machine with the particular type of random access device required. This is no longer necessary.

Reduction of data-preparation

43 It is already possible by the use of magnetic ink, redesigned types of printing and the use of marks instead of numbers on forms, to read data directly off original documents.

SYSTEMS ANALYSIS AND PROGRAMMING

Systems analysis

44 However, before a computer, no matter how advanced its hardware, can be introduced into an organization to process the firm's data and provide management with relevant information, a very large amount of work is needed to define exactly what has to be done and to decide, firstly in broad terms and then in complete detail, how the computer will do it. Systems analysis can take anything from a few weeks or months to several man/years. Even when the system is defined, the end of the road is not reached, as the computer still needs to be instructed.

Programming

45 This is not the place to describe in detail the way in which programming is carried out in order to provide the computer with the precise instructions on which it can operate. All that needs to be emphasized now is that programming can take anything from a few hours to several months depending upon the size and complexity of the task and a further similar period is needed to "test" this program until all errors have been eliminated.

46 When the program has been completely written, it will be converted into punched cards or punched paper tape and as required will be read into the internal storage of the computer.

47 Altogether, systems analysis and programming may cost as much in salaries and the cost of computer time for testing as the purchase of the computer hardware itself.

48 In order to ease the job, help now comes from manufacturers themselves in the form of programming support or "Software". These are sets of programs that can simplify the user's job of programming and using the computer. However, it should be emphasized that they do not affect the problem of systems analysis at all. This still has to be carried out just as before.

49 Manufacturers today are expected to supply five broad categories of programming assistance and these are:-

a. Fairly simple assembly languages which make it possible to instruct the machine without recourse to machine code of noughts and ones;
b. High-level languages which enable jobs to be programmed in a bastardized form of English for commercial jobs and in the language of mathematical formulae for scientific applications;
c. Operating routines which help the user firstly, to feed jobs through the machine without too much human intervention; and secondly, to control operations of machines when carrying out time-sharing or multi-programming;
d. Utility routines which will do the standard commonplace tasks such as sorting, writing information from cards to magnetic tape, etc. and also sub-programs to do common routines such as payroll tax calculations;
e. Program testing aids which are routines to help programmers prove the accuracy ("debug" or get the bugs out of) their work.

Operating routines

50 In the early days no attention was paid to the problems of operating the computer. Jobs were run one by one with considerable human intervention in between runs. This led to 5 minute gaps between each computer run and with the average run being only about 20 minutes a 20 % wastage element on running a computer. Most commercial installations are still run on this basis.

51 This delay becomes unacceptable on large machines and routines were written to cut out these gaps and pass a large amount of the operating responsibility to the machine itself.

Time-sharing operating routines

52 With the advent of time-sharing central processors, control routines are required to control these multiple operations. A large number has been sold of computers which are not yet due for delivery which depend on these operating systems completely in order to work. One can only hope the operating routines arrive as promised in the next few months.

Utility routines

53 There are a large number of common jobs which occur in data processing installations. The commonest one is the sorting out of data. Every installation needs to sort, and since about 1959 every reasonable manufacturer has provided sort routines with the machines to save each installation writing their own. All manufacturers now offer a reasonable range of utilities with varying degrees of efficiency.

Package deals

54 So far, this discussion of programming has assumed that unique programs must be in the main written for each individual commercial organization. These programs are written after a detailed systems investigation of the companies' functions. Maybe as much as 60-70 % of the programming effort in a company will in fact go into the system for dealing with the 5 % exceptional data of that company.

55 This approach assumes that the system requirements of each company are different to all others. This is obviously untrue. If companies could adapt a general-purpose program to meet the 5 % exception for routine data processing applications enormous amounts of money and effort could be saved.

56 Packages have been used to a small extent in some industries in the U.S. notably Savings Banks, Hospitals and some American stores for whom N.C.R. have developed packages.

57 In addition a start has been made at developing general-purpose application packages to be applied in a number of industries. Example of these are the MOS product planning and IMPACT inventory control packages being successfully used by several organizations.

58 Rumours are current that packages are soon to be released for an Airline booking system based on computers and data links and also for a Multiple Store Inventory Control System.

59 If package systems can be developed and accepted the spread of computers would increase extremely rapidly and the manpower released from planning the routine processing jobs could soon develop management sciences and computer usage far beyond the present bounds.

THE FIVE TYPES OF APPLICATION

60 A computer is a tool and the computers used for business tend to be general-purpose tools since they can be used for a number of different applications. At present there are five basic types of business data processing application. Each type introduces a different idea or concept, and together they represent the ascending development of the use of computers. The five types are:

(a) Type I or Book-keeping Application;
(b) Type II or Individual Control Application;
(c) Type III or Management Control Application;
(d) Type IV or Planning and Optimization Application;
(e) Type V or Fully Integrated Application.

TYPE I - BOOK-KEEPING APPLICATIONS

61 Type I applications are referred to as book-keeping applications. The essential feature of them is that the processing is carried out in much the same way as the manual method. However, use is made of the fact that a computer can summarize data as a byproduct of the main process. Thus all statistics which are required from

the original data are calculated. A book-keeping operation can be represented by six steps:

(a) read latest transaction;
(b) refer to file for static and brought forward data;
(c) process transaction;
(d) update file (i.e. carry forward data);
(e) print results;
(f) summarize results as required.

62 Examples of Type I applications are payroll, invoicing and sales accounting. From the basic operations, statistics such as labour costs and sales analysis of product by area, by salesman are extracted.

63 The benefit to be gained by using a computer for book-keeping applications may be summarized as:

a. speed of preparation of results;
b. accuracy of calculations;
c. improved statistics which can be obtained from original data.

The limitations of using a computer are wholly economic. With current input devices, payroll or invoice data must be converted into cards or paper tape, and this effort almost cancels out the reduction of calculating effort. In the case of payroll, clerical staff must still be retained in the pay department to handle queries, batch cash into packets and pay staff.

TYPE II - INDIVIDUAL CONTROL APPLICATIONS

64 As well as being fast calculators, computers can distinguish between various situations, such as:

Is X greather than Y?
Is X less than Y?

Type II applications make use of this feature to apply the routine tests of simple decision-making to individual operations e.g. stock control. They have the same basic features as book-keeping operations but when processing has been completed a decision is made and the action thereafter depends on the result of the decision.

Management by Exception

65 Two important concepts arise out of the need to make a decision. The first concept is that of management by exception. If the result of the decision is satisfactory it is assumed that management does not need to be informed. If, however, the result is unsatisfactory an exception report is produced.

Feed back

66 The second concept is that of "feed back". This is simply a term used to describe the system whereby the latest information is "fed back" into the original calculation to see if it alters the forecast situation (e.g. comparison of actual expenditure with budget). In order to make a decision the computer must be given a value to test against. To be worth while, the limit must vary with changing circumstances and it is in the calculation of the test value that the idea of feed back is used.

Examples of Type II - Individual Control Applications

67 Examples of this type include credit control, stock control and progress control. The output of the system does not necessarily end with an exception report - for example in stock control the output would include an order to purchase new supplies together with a carry forward entry to progress the order. The value as well as the quantity of stock would also be included and this could equally well be controlled.

Benefits of Type II - Individual Control Applications

68 The benefits of using a computer for individual control applications may be summarized as:

a. speed of updating records, leading, for example to:
 (i) prompt collection of debts;
 (ii) prompt re-ordering and items less frequently out of stock;
b. improved control due to feed back of usage rates and subsequent recalculation of, for example:
 (i) re-order level;
 (ii) re-order quantity;
 (iii) credit limit.

The computer can undertake calculation which would be prohibitive on a manual system.

Stock control is often a very worthwhile computer application since the speed with which the computer controls the stock situation enables smaller stocks to be kept and hence offers worthwhile reduction in the money tied up in stock.

Limitations of Type II - Individual Control Applications

69 The limitations for using a computer for control are firstly, economic and secondly, technical. Transactions have to be converted into cards or paper tape and, as for Type I, book-keeping applications, this can involve a considerable amount of punching to be set against the advantages. Also, because the computer has to seek information from a file, the information must be coded in a way that the computer can understand. This means, for example, that a unique system of part numbers must be used and these numbers must in some cases be written on to requisitions - a clerical action before data can be punched. The technical problems are not attributable to the computer. In order to re-assess the test value, the method by which the original value was calculated must be known. This means that a mathematical model of the system must be made so that a consistent method of calculation is used. For example, if we consider the characteristics of a stock control system. It should:

a. tell when to re-order stock;
b. tell how much to re-order;
c. re-adjust the safety margin if necessary.

In order to provide reasonable answers to these questions the system must take into account lead times, machine loading, and future demands. However, answers to these problems depend on:

a. buying problems;
b. production capacity;
c. sales forecasts.

In some instances it is sufficient to make intelligent estimates of these effects and the resulting stock model can be quite simple. In other cases the model may be complex but in either case the limitation is not the computer but on man to assemble the appropriate data.

TYPE III - MANAGEMENT CONTROL APPLICATIONS

70 The management control application is really an extension of the individual control application. It consists of defining the management information necessary to control an organization and establishing the controls required to keep the organization running within a given plan. Broadly, there are two kinds of information required for this purpose:

a. "Action" information, which consists of orders, goods received notices, invoices, statements, job cards, stock requisitions, pay slips, etc.; action information can be either "input" or "output";
b. "Control" information which shows how the organization is running and forms the basis of information on which planning and policy decisions can be made.

It is apparent that this information is the same as that which is either input or output of the book-keeping and control applications previously described. A management control application can therefore be defined as a combination of bookkeeping and control applications arranged so that the inputs and outputs are integrated to give the information required to control the overall systems, according to a given plan.

71 Applications such as these were planned as long ago as 1958. Very few have achieved their aims and most have failed because the sheer size of the problem was under-estimated and insufficient planning had been done. The approach to management control problems must be gradual and step-by-step. In this way the problems can be brought to reasonable sizes.

72 It must be realized that in these applications the human problems are very real, since these applications cut right across departmental boundaries. This gives rise to many problems which only a firm and dedicated top management can resolve. Not a few management systems have failed because top management has been deflected by departmental objections.

73 Who controls the systems - accounts? production? sales? or should it be a separate unit? The answers to these problems are now thought to be known but five years ago when many management systems were being planned they gave rise to many private battles! To a certain extent the early examples of management systems were limited by hardware, due to the sheer size of the job and the fact that certain computers designed around 1959/60 were not delivered on time. There are now quite a few examples of production control problems (which can be considered as simpler versions of management systems), but virtually no examples of integrated management control systems as described. The problems lie more with man than with hardware.

74 It must be remembered that a management organization structure is only a decision taking mechanism. Therefore as soon as computers start to play a part

in the decision making process, they impinge on the organization structure, - and therefore on human beings. Once a business installs a computer, it is probably true to say that it will never be the same again.

Example - Type III - Management Control Application

75 A typical manufacturing organization would have three divisions - sales, production and accounts. To the managing director the three divisions are linked - a sales plan is agreed, it is passed to production to manufacture, and accounts cost it and receive and make payment. In practice, each division acts on its own and builds up its own plans and control systems to monitor progress. Each division handles data which is of use to the others, though they frequently require it in different forms. If the data can be recorded so that one transaction is used to update the records for each division there can be a great reduction in effort and considerably improved accuracy. It is possible to achieve this flow by manual or mechanized methods. However, above a certain size the problems are so large that a computer is the only effective way of achieving this. Consider the example of a combined production control/stock control/product costing/payroll system.
Starting from a sales programme the system:

a. produces a manufacturing plan for the next period, showing what products are to be made;
b. analyses this plan to calculate:
   (i) stock demands;
   (ii) machine and labour demands;
c. schedules the work on the machine shops;
d. issues production orders;
e. controls the progress of orders;
f. controls stock;
g. controls the purchasing of materials and bought out parts;
h. calculates labour and material costs;
i. produces payroll from labour costs.

The term Integrated Data Processing is often used to describe those systems used. For the purpose of this paper "Integrated Data Processing" is reserved for a wider use, as described later under Type V - Fully Integrated Applications.

Benefits and limitations - Type III - Management Control Applications

76 The advantages of using a computer for management control applications may be summarized as:

a. a reduction in clerical staff due to elimination of duplicate effort;
b. a reduction in the amount of prime data input to the computer, by using the computer to pass data from one position to another;
c. increased business resulting from improved delivery due to reduction in manufacturing cycle;
d. reduction in products costs through better loading of labour and machines;
e. improved management information for future planning, due to accurate knowledge of work-in-progress and current costs.

The limitations of such applications arise:

(i) from the sheer size of the problem;
(ii) from the human problems.

TYPE IV - PLANNING AND OPTIMIZATION APPLICATIONS

Definition of Type IV(a) - Planning Applications

77 Most problems have to be carried out within a fixed time or with fixed resources. There are often many ways of carrying out the work. Each method requires an analysis of at least three factors:

a. cost;
b. time;
c. resources.

There will be bottlenecks in each and its not always possible to foresee where and when they occur. One method of tackling this problem is the bar chart. This is adequate for simple projects where sections are undertaken one after the other. Where there are a number of interrelated activities being progressed at the same time, the bar chart becomes ineffective. The relationships may be then expressed graphically in the form of networks.

Example of Type IV(a) - Planning Application

78 Typical applications of network analysis are large "one-off" operations, such as the control of building sites and the control of factory maintenance programmes. The United States Government has made use of network analysis a contractual condition for defence projects.

Benefits and limitations of Type IV(a) - Planning Applications

79 Although not a strict requirement for network analysis, it is fair to say that the development of this technique has been dependent on the availability of computers to carry out the tedious and involved calculations. The benefits which network analysis on a computer offers are:

a. the detailed calculation of the network;
b. the printing-out of reports showing:
   (i) events behind schedule;
   (ii) events on which there is slack;
   (iii) a list of projects by completion date;
c. the speed with which alterations to the network can be fed into the computer and the effects determined;
d. the ability of the computer to "store" the network and revise it in the light of actual data.

A 37 % reduction in shutdown time required for maintenance of a chemical plant, resulting in extra production worth £ 1 million has been attributed to network analysis.

80 The real problem and limitation of network analysis lies in building up the network in the first instance. This requires careful definition of objectives and the selection of events, followed by careful definition of the relationships between events.

81 Network analysis was developed to control time dependent projects, but it is being developed to include cost and manpower dependent projects. In practice, real problems involve time, cost and resources and computer programs are being prepared to handle these together. At present, time dependent networks can be

used by buying time on a manufacturer's computer and using his network analysis program. Programs for the other factors are still made for a particular job and have not been developed in general form. The limits to the use of networks again falls in man's ability to provide a network.

Definition of Type IV(b) - Optimization Applications

82 The use of planning techniques which show up bottlenecks in time and resources frequently places extra problems on management. If a bottleneck occurs there is often a choice of action and the choices are often not mutually consistent. Even the objectives of the various departments within a company may not be mutually consistent. Production probably wish to minimize the cost of production by long runs on few products. This may lead to large inventories. Sales may wish to have large inventories of many different products in order to meet every order as it comes in. Finance department, however, normally wishes to keep its investment in stock at a minimum! This type of problem can be called the "executive" or optimization problem. The executive has the problem of mediating between the conflicting interests, and of selecting the best course of action for the organization as a whole. The first requisite in finding a solution is to construct a mathematical model of the problem. The procedure may be summarized as:

a. select the effective components of the system;
b. give each component a symbol;
c. construct equations which express the effectiveness of the situation in terms of variable components;
d. identify the variables which are under management control.

The solution of the problem depends on whether it is possible to solve the equations. If they are simple they can be solved and one such technique is known as linear programming.

Example of Type IV(b) - Optimization Application

83 An example of such an optimization problem is an oil company which draws its raw materials from several sources and refines it at several refineries to produce a range of products which must have a fixed quality (octane value). Taking into account transport costs, refining costs and possible sales outlets and revenue, the problem is to find out what is the most profitable operation for all refineries for a given set of conditions.

Benefits and limitations of Type IV(b) - Optimization Applications

84 The solution of the mathematical models in any practical case involves so much calculation that a computer is essential. The advantages of linear programming to oil companies are large. At a guess the United States oil companies spend about 5 million dollars a year on renting computers, but the benefits may be around 50 million dollars. No other computer application offers anything like this return at present. The limitations to this work are basically mathematical problems, since only certain types of models can be solved and not all these models coincide with realistic situations.

85 The development of these problems, as has been stated, depends on the development of mathematical techniques and not upon computers. However, a considerable amount of research work is being carried out and the larger organizations,

which can afford to employ operational research staff, are using models to represent their own businesses. There is a danger in the development, which seems to be spreading, of using somebody else's model without knowing *all* the facts of the case. These fields are strictly for the O.R. man, and not for enthusiastic amateurs.

TYPE V - FULLY INTEGRATED APPLICATIONS

86 The essence of fully integrated data processing is that all data relevant to a company's business is fed into a single system, and all numerical output useful to the company is produced by the system without intermediate intervention. The techniques of optimization and planning produce the best plan. The plan is converted into manufacturing and purchasing plans which are continuously monitored. From the initial input data all book-keeping operations are produced, mostly a by-product of other operations.

87 It is impossible to give a real example of this type of operation since there are no examples of any significance in the world.

88 The benefits of a fully integrated application include all those that have been attributed to the other types of application. The real benefit, however, is that probably only a fully integrated system will make it possible to predict the future in such a way that the right decisions can be taken quickly enough to meet changing circumstances in the most profitable way. A firm may make assumptions about its operations and decide the most profitable course of action. However, the decision is only correct if the assumptions are correct and these inevitably involve assumptions about the operations of the firm. It is essential that these assumptions are not only correct but that they are constantly monitored to see that they are following prescribed course.

89 The limiting factor on the concept of fully integrated systems is the ability of man to devise a mathematical model of the whole system. An integrated system appears to require one model of the whole system but in fact, it is a series of submodels.

90 However, as was said above, there is no organization in the world with a fully integrated system. Approaches to such a system are being made from both the top and bottom of the overall model structure. Decision making models (the highest level) are being developed by the largest organization for steel manufacture, chemical products, oil refining, site evaluation and by the Treasury for the country's economy. At the other end, stock control models and management control systems are being developed, and these systems will ultimately supply basic data for the final decision model. The approach to fully integrated systems must inevitably be a long one. As in all the other applications, man himself and not the computer is the limiting factor.

SUMMARY OF THE STATE OF BUSINESS APPLICATIONS

91 The state of development of business applications can be summarized as follows:

a. book-keeping and individual control applications are well developed;
b. computer management control systems are not yet fully operative;
c. useful benefits have been obtained:

(i) as by-products of book-keeping and individual control applications;
(ii) from planning and optimization techniques;

d. a start has been made towards decision-making models;
e. few clerical savings have been made;
f. the future development of book-keeping and control systems is limited by input problems;
g. the development of all applications is limited by the ability of man to:
(i) change his methods;
(ii) develop mathematical models.

92 The position can be illustrated on the following table:

TABLE I - SUMMARY OF THE STATE OF DEVELOPMENT OF BUSINESS APPLICATIONS

APPLICATION TYPE	POSSIBLE CLERICAL SAVINGS	GENERAL BENEFITS	STATE OF DEVELOPMENT	FUTURE DEVELOPMENT
I BOOK-KEEPING	Nil	Improved Speed: Improved Accuracy: Improved Statistics.	Approaching limit as currently defined.	Rethink Basic Problems Improve Input.
II INDIVIDUAL CONTROL	Nil	Improved Control, therefore better planning, less stock, fewer debts.	Simple systems developed: Stock control models well developed, but few in use.	Rethink problems. Improve Input. Develop Models.
III MANAGEMENT CONTROL	Some	Considerably improved control and statistics: Provides data for Higher applications.	Only parts of systems working.	Improve individual systems and link together. Overcome human problems.
IV PLANNING AND OPTIMIZATION	Some	Improvement in completion dates: Large potential savings for right applications.	Used by large organizations: Rapidly developing:	Extend to costs, and all resources. Limited by Mathematics.
V FULLY INTEGRATED	Large	Optimization of whole organization	Very much experimental: Some limited decision models.	Limited by Mathematics, and by need for accurate data from Type I, II, III and IV Applications. Also limited by Humans.

Hardware

93 The basic underlying trend in computer developments in the past years has been for the hardware to get cheaper, faster and more reliable.

Improvement in performance/cost ratio

94 An illustration of the cost of doing a simple punched card job on three small computers first announced in 1955, 1959 and 1964 is given in the following Example. This shows that the speed for this operation has increased 8 times and the job-cost decreased by a factor of 16.

EXAMPLE I - COST EXAMPLE

1 The job considered is the very simple one of reading 1,000 punched cards, punching a further 1,000 cards and printing 2,000 lines.

2 Machine A was announced in 1955 and consists of:

STORAGE	Drum of 2,000 words
INPUT	A Card Reader speed 250 c.p.m.
OUTPUT	A Card Punch speed 100 c.p.m.
OUTPUT	A Line Printer speed 150 l.p.m.

Only 1 unit would work at any one time and the cost was £ 90,000 or £ 18,000 per annum rental.

3 Machine B was announced in 1959 and consists of:

IMMEDIATE STORAGE	Core Store 4,000 chs.
INPUT	Card Reader 800 c.p.m.
OUTPUT	Card Punch 250 c.p.m.
OUTPUT	Line Printer 600 l.p.m.

Only 1 unit would work at any one time and the cost was £ 60,000 or £ 12,000 per annum rental.

4 Machine C was announced in 1964 and consists of:

IMMEDIATE STORAGE	Core Store 8,000 chs.
INPUT	Card Reader 600 c.p.m.
OUTPUT	Card Punch 300 c.p.m.
OUTPUT	Line Printer 600 l.p.m.

Although the peripherals - input and output devices - have not increased in speed, compared with Machine B, due to more advanced central processor, all 3 operations - card reading, punching and printing - take place simultaneously. The cost is £ 45,000 or £ 9,000 per annum rental.

5 If we consider the rental figure and a usage of 200 hours per month we arrive at the following costs per hour of machine time:-

	MACHINE		
	A	B	C
Cost per hour	£ 7.50	£ 5.00	£ 3.75

6 The theoretical time to do the job on the various machines is:

	MACHINE		
	A	B	C
	Mins.	Mins.	Mins.
Card reading	4.0	1.3	1.7
Card punching	10.0	4.0	3.3
Printing	13.3	3.3	3.3
Total	27.3	8.6	*3.3
Cost at rental appropriate to the machine	£ 3.41	£ 0.72	£ 0.21

* As all 3 operations can be performed simultaneously the total theoretical time is the time for the longest operation which in this case is either punching or printing which both take 3.3 minutes.

Number installed

95 The spread in use of business computers has been increasing rapidly in the last few years as can be seen in the following table:-

TABLE II - BUSINESS COMPUTERS DELIVERED IN THE U.K.

Year	Number of Machines installed during the year	Cumulative number installed	Number of different types installed	Number of Manufacturers delivering machines
- 1955	3	3	3	3
1956	7	10	5	4
1957	20	30	9	7
1958	40	70	12	9
1959	50	120	13	9
1960	80	200	14	11
1961	120	320	25	11
1962	220	540	32	14
1963	290	830	40	14
1964	About 500	About 1,330	38	10
On order	About 600-700			
E. & O.E.				

96 It seems reasonable to expect that this development will continue and that in the year 1968 nearly 2,000 machines may be installed and the cumulative total will be nearly 5,000 machines.

THE FUTURE:

Input of hand-written and typed documents

97 A breakthrough that everybody has striven for is the direct input of hand-written and typed documents. The savings in time and money from the abolition of punching would be enormous. This has proved remarkably difficult to accomplish.

98 At present a few mark readers which will recognize pencil lines on certain positions are available. The best of these is probably an English development, the Auto-Lector and its offline version Lector designed by Leo Computers now merged into English Electric-Leo-Marconi Computers Ltd.

99 A development was on show at the World Fair of a machine that would satisfactorily read hand-written numbers but this machine has not yet been announced as available in commercial production. The announcement of a cheap machine that would do this, would certainly give E.D.P. another enormous thrust forward.

Effect of hardware development

100 The principal effects of hardware development may be summarized as follows:

a. development to existing computer units will simply affect the throughput speed and hence the economics of the application, but they will not affect the basic applications;
b. new developments in input devices would make possible significant changes to the simple basic computer applications, both in economics and in the whole approach;
c. bulk storage devices will affect the basic computer operations but, even more so, the associated paperwork systems. They open up a new approach to the problem of information retrieval;
d. improved internal processing speed does little to help the business use, but affects engineering and scientific problems and, in the long term, assists in the solution of decision models;
e. the display unit with the light pencil opens up new possibilities in linking design (hitherto almost outside a control system) with production.

101 The position can be illustrated on the following table:-

TABLE III - THE EFFECT OF HARDWARE DEVELOPMENTS

DEVICE OR IMPROVEMENT	EFFECT ON BASIC APPLICATIONS	EFFECT ON NEW APPLICATIONS
Document Readers	Improve Book-keeping and Control Applications, especially in Banking and Finance. New approach to paperwork problems possible.	
Document Readers and Large Storage Units	Improve throughput of Management Control Systems and large file Book-keeping Operations. New approach possible to Paperwork problems.	Information Retrieval.
Telecommunication Links	Improve Input to Control Applications and make "on line" Systems possible. Allow computers to be shared, thus improving Economics.	
Calculating Speed	Improve throughput by sharing operations	Allows more complex Engineering and Scientific problems to be solved. Help in solving Decision Models.
Display Units (with and without Light Pen)	Improve output in Banking and Control Applications. Improve presentation of Data to management for decisions.	Link in fully integrated Systems between Design and Production.

Effects of software developments

102 The principal effects of software developments may be summarized as follows:

a. the early computers were tedious to program, and programming was a hindrance to the development of economic application;
b. the present programming languages have eliminated many of the minor programming details, but the problem of converting a description of the work to be done into a computer program is still considerable;
c. because the mathematician and scientist haver their own logical and unique language (mathematics), considerable developments have been made towards converting, automatically, mathematical problems into computer language;
d. attempts to do this for business uses have not proved very successful, since it is difficult to define uniquely the terms used in business;
e. if and when this is achieved for business problems,
   (i) there could be a considerable reduction in programming effort for bookkeeping and control applications, and hence it would be more economical to put them on a computer;
   (ii) it would be possible to communicate common problems and to carry out processes of reasoning in the business language. This would simplify the development of integrated business systems.

The effect of human beings on future applications

103 The first and obvious uses of computers on the ordinary routine and low level decision making applications are well developed technically. They can be improved by new input devices, but there is still much which could be altered by human beings changing their approach. Management may learn to change its approach, but the customer reaction is not known - will all workers accept monthly cheques? - can we dispense with statements and not incur vast increases in bad debts? The answer to both of these in the long run is probably in the affirmative; but meanwhile even we, as customers, object to small details such as not having alphabetic data on bank statements and having unusual figures on our cheques.

104 The use of planning techniques such as network analysis is rapidly developing, and can be said to be affecting the field of middle management. Also affected are the sub-contractors who are suddenly faced with a contractor who is really controlling progress. From these simpler techniques the use of computers is advancing into the field of higher management and the Government. Directors, employees, rival organizations and the man in the street can all be affected by decisions taken by computers.

105 The applications of computers are developing at a rapid rate and man will probably prove to be the limiting factor in almost all of them. From the simpler applications (by a stubborn refusal to accept new methods) to the management applications (by an inability to express the problems), man holds the balance.

106 At the very higher levels of decision making, the fundamental difference between man and machine is reached. The machine works through a known system of circuits, by a series of "yes" - "no" decisions, and a quantitative answer is reached. Man works by an as yet unknown circuitry of far greater complexity.

Computers have developed so fast that the study of the interrelations between man and the computer lags far behind.

107 Man must therefore set in motion an educational plan which will not only train the present employees and managers in the knowledge of computers, but also the school children who will grow up into the world which has already been referred to as the age of the computer. The educational progress must be rethought so that man learns to take a more quantitative approach to problems, whilst at the same time being given a basic grounding in the arts.

CONCLUSION

108 The conclusions on the state of the art, as far as concerns the processing of business data can be summarized as:

a. technical progress in computer applications is well under way;
b. hardware developments will considerably improve basic applications;
c. hardware developments have been, and still are, ahead of applications;
d. it is time to rethink many of our traditional problems;
e. few computer applications have shown savings in clerical costs but improvements in control and statistical information have been significant;
f. the higher order applications, such as linear programming and network analysis have shown substantial benefits;
g. decision models are already in prototype form and developing rapidly;
h. it is the higher applications allowing an integrated approach from which the largest benefits will derive;
i. man in general is not ready to accept these latter applications; only a long-term training plan will rectify this.

109 As an epilogue, it must be emphasized that man has just learnt that he must learn about how to use computers.

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