SESSION 4B

PAPER 3

TO WHAT EXTENT CAN ADMINISTRATION BE MECHANIZED?

by

J. H. H. MERRIMAN and D. W. G. Wass

BIOGRAPHICAL NOTES

Mr. J. H. H. Merriman was educated at King's College School, Wimbledon, and King's College, University of London. He obtained his B.Sc. (Hons.) in 1935 and did Postgraduate Research at King's College London obtaining his M.Sc. in 1936.
He entered G.P.O. Engineering Department, Radio Research Branch, Dollis Hill, in 1936 and was associated with development of long distance radio communication systems. He was Officer-in-charge Castleton radio research station 1940-8, and from 1948-53 in the Office of Engineer-in-Chief G.P.O. and responsible for microwave system development and planning. In 1954 he went to Imperial Defence College; in 1955 he became Head of G.P.O. Engineering Department O & M unit. In 1956 he joined H.M. Treasury, and is now Deputy Director, Organisation and Methods Division.

Mr. D. W. G. Wass was educated at Nottingham High School and St. John's College, Cambridge, where he obtained his M.A. in 1947. He served in Admiralty as Scientific Officer 1943-45, and entered H.M. Treasury as Assistant Principal 1946. He was Private Secretary to Sir Wilfrid Eady 1948-50, and Head of Civil Service Establishments Manpower Statistics Unit 1950-53. He was in the Overseas Finance Division of Treasury 1953-57, and is at present on a Commonwealth Fund Fellowship at Princeton University studying "U.S. Monetary Policy".

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SUMMARY

MOST current examples of automatic data processing (A.D.P.) may be regarded as slightly advanced mechanical models of tasks performed by clerks. The paper examines the extent to which a less mechanistic approach may be possible and suggests limitations that may be imposed not only by human limitations but by difficulties of correspondence and significance between machine and manual situations.

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1. INTRODUCTION

LET us assume that automatic data processing (A.D.P.) can do the things that we are planning for it to do at present, such as payroll, stores accounting, and statistical analyses. There will, of course, be many problems to be solved before these tasks can be regarded as satisfactorily completed, and before we can speak with confidence out of experience. But these problems do not appear to have any fundamentally insuperable content. The difficulties are manmade rather than intrinsic. They originate in part from the difficulty of adjusting the organisms of office life to new rhythms, new environments, new relationships, in part from imperfect understanding and appreciation of the power and range of new techniques, and in part from a lack of perception of the limitations and deficiencies of these systems. We may reasonably suppose that, during the course of the next five years, these difficulties will be overcome and that, throughout Government Departments and Industry, there will be a growing number of installations at work on these jobs. With this perhaps over-simplified premise, it is not too early to start thinking about a possible future form of A.D.P. in Government Departments in, say, ten or fifteen years' time.

2. THE IMMEDIATE FUTURE

2.1 *The move towards integration*

Although computers were developed as an aid to scientific work, and as such were general purpose, maid-of-all-work mathematical slaves to their scientific masters, most commercial applications have up to now been planned as single purpose installations. In Government Departments we are, by and large, installing equipment which will do only one or, at the most, a few jobs. We have installations for pay, and to these we are adding statistical jobs. We have installations being planned for stores accounting, and to these we are adding provision and purchasing functions. These additions, however, are being regarded as secondary objectives and in most cases the installation is regarded as having a single main purpose.

We are, therefore, likely to see in the immediate future a movement away from the concept of single purpose automatic data processing installations to installations or systems of installations which, in the first place, will be multi-purpose and, in due course, integrated. At present though, we cannot achieve integration without human assistance and the written word.

2.2 *Prerequisites for integration*

In an automatic system, integration is achievable only if data are able to be exchanged readily and freely between the component parts of the system. One prerequisite of integration, therefore, is the existence or availability of a common language. In its simplest form, this language could be commonly agreed code marks on pieces of paper; in a slightly more advanced form, it could be agreed standard forms of punched cards and codes. In a still more advanced form, the common language could mean completely standardised programmes, order-codes and magnetic tape codes. Although the prerequisite of a common language is a desirable one, it is not essential. Civilisations have managed to exist and to communicate without such a common language, even though there have been excursions from time to time into the possibilities of one. If a common language is not practicable, then automatic translating devices (or dictionaries) must be considered. These seem to be inescapable premises on which to build integration.

The extent to which it is possible to achieve integration is, however, controlled by two other factors. The first of these is the ability to transmit data from processing centres in one part of the country to another without fear of error, and the second is the extent to which it is economical to build bigger and faster central systems. Up to a certain stage, the bigger the computer the cheaper. Beyond this point, however, there is a line of diminishing return, both in terms of price to be paid for the apparatus and the extent to which it becomes humanly possible to build in the necessary intelligence to manipulate very large installations and to

programme them. We may suppose that the price factor is not a substantive one. Changes in technology may reduce its importance.

The ability of most human minds to keep pace with the increasing complexity of integrated data processing may, however, in the end, set limits to the size and complexity of the installations themselves. If we are, therefore, to imagine large complex multi-purpose integrated data processing systems, we must imagine them to be serviced, to an increasing extent, by separate installations which will analyse the operations of the integrated system, determine the most appropriate operating conditions and which will, to some extent, relieve the burden of programming by automatic access to inbuilt programming routines. It is from this concept that we would expect major developments in overall economy and efficiency to stem as these "monitoring" computers assess the efficiency and failures of the processes being undertaken in the main system, and thereby "learning" from these experiences. It is from studies of the subjective probability of partial success or partial failure in various programming situations and in the way in which the machine complex may react to certain circumstances that the worth-while application of A.D.P. to tasks of management may evolve.

2.3 *The Technical Problems*

These developments for the immediate future depend upon techniques which, generally speaking, are available at present but need further development to bring them to points of commercial and economic reality. These techniques are:-

(i) The creation of data as an automatic by-product of other human activity. Techniques are required for the creation of data in a form which can be readily and directly assimilated by machines without intermediate translation processes. Techniques such as automatic character recognition are already possible, but clearly more work has to be done to convert them into thoroughly reliable commercial tools. In many situations, however, an organisation may have virtually complete control over the data at their point of origination and their final point of reception. Under such circumstances, therefore, it is necessary to consider whether automatic data creation by the recognition of written characters is necessary, or whether greater overall economy could not be achieved by the creation of a parallel chain of data in machine language automatically at the same time as the data is being created in a visible record form. There seems to be no reason why machine development should be constrained by the complexity of arabic or latin script when simpler coded forms capable of being printed at the same time as the arabic or latin characters would enable simpler machine processes to be adopted.

(ii) Techniques for the abolition of the written word as a means of data transfer from point A to point B. Analysis of the internal organisation of offices shows that the cost of letter preparation, enveloping, sorting,

franking, distribution in the office, filing, outweigh grossly the cost of transmission in written form through the mail or by private carrier. Great potential economy, therefore, exists in the abolition of written records at all points except those where access to information in written form is essential for the conduct of the business. Before these economies can be secured, however, the technicalities of data conversion, data transmission and data recreation require to be progressed further into commercial reality and economy.

(iii) Analysis of the A.D.P. systems being planned for Government Departments shows that over 30% of the cost of these installations is accounted for by programming. The essential technical problems of automatic programming may be said to be overcome, but much remains to be done before automatic programming and coding is an acceptable commercial device.

(iv) There is a growing demand for systems for very large information storage and associated with these systems versatile information retrieval. Before such systems may be realised in practice, considerable development is required on techniques of storage and the philosophy of its retrieval. Many techniques can be seen to be possible in this field. As yet, no problem has been sufficiently clearly formulated to enable the worth-whileness of the various techniques to be estimated.

3. LONGER TERM PROBLEMS

3.1 *General*

We must now assume that the technical problems posed in the foregoing paragraphs have been solved, and look to the impact of these developments upon even longer term planning, so that the possible form of A.D.P. systems of 10/15 years hence may be assessed and courses of research and development postulated. By such examination, we may be able to lay down, if not the philosophy of systems design of the future, then at least the constraints within which those system designs may operate.

3.2 *Problems of Symbolism*

It seems possible that the growing complexity in A.D.P. systems will lead to a situation in which the relationship between symbols as they exist in the machine and the symbolism of a real world will be progressively more difficult to trace. This is no new problem. Business is, after all, now generally conducted by the making of marks upon a piece of paper. In most cases, these marks bear a definite relationship (usually a unique one) to objects or symbols in the real world. For example, descriptions upon a ledger relate to physical identifiable items in a stores bin. The problem is, however, made more complex in the A.D.P. system of the future, since

the symbol relating to a particular external object may no longer be humanly identifiable without the aid of a machine interpretation process. The relationship between the two is therefore dependent upon the behaviour of the machine, which in turn is dependent upon the programmer and the designer. Knowledge, therefore, of the characteristics of objects both in the real world and in the machine will tend to become restricted to a relatively few people. This will create difficult problems of access to that information under certain conditions and may therefore impose, of itself, constraints upon the universality of application of these machines.

3.3 *Problems of Interrogation*

The greater the volume of information held in mechanical or electronic form, the greater will be the task of making that information available in cases other than those where a direct "Yes"/"No" answer is sought. Before information can be held in machine code form, it must be translated into that language. The translation process depends critically upon the extent to which there can be a unique one-one relationship between the external meaning of the information and the machine meaning. In many cases, information to be encoded in this way is not capable of being defined uniquely on a one-one correspondence basis and there, therefore, has to be a subjective assessment of the information content of the data subjected to filing. Clearly then, these data cannot be satisfactorily interrogated unless the same subjective translation process is followed. If it is not followed, then the interrogation can, at best, only be partially successful. Partial success, however, may not be recognisable as such. It may, therefore, be increasingly difficult to determine the degree of precision with which interrogation is being answered unless the form of the questions is rigidly related to the form of the filed data.

3.4 *Problems of Rigidity, Resilience and Feed-back*

Clearly, the greater the absorption by A.D.P. of an organisation, the greater will be the dependency of that organisation upon any constraints imposed by the A.D.P. system. In practice, most systems will be designed and programmed to meet the specific requirements of the organisation. If these requirements change, there is no guarantee that the A.D.P. system will be able to accommodate them. Unless the A.D.P. system, therefore, is a resilient one, it may be found that it is imposing constraint upon organisational changes that are admissible. Either, therefore, A.D.P. systems will have to be made sufficiently flexible to accommodate the estimated degree of change, or else a knowledge of the constraints of the system will have to be fed back into administration and brought into the consideration of changes of policy.

3.5 *Human Problems*

The development of A.D.P. systems will lead to a gradual absorption of the routine, easier and more mechanical tasks. These tasks have, in the past, been one of the training grounds for the less routine, more difficult, more advanced operations. Training techniques will, therefore, have to be modified to take account of this changing situation. This will exist, not merely in the mechanistic field of A.D.P. system operators, but will affect those coming into contact with A.D.P. systems.

There is also a potential human problem in determining how best to organise an A.D.P. system to meet the unexpected demand. Whereas, in the past, it has been possible, for example, to aggregate a considerable volume of human experience in clerical and executive tasks and to evoke from that experience considerable skill in dealing with the occasionally unusual, in the future experience in the routine operation will be contained within the machine system in machine language. The difficult problem will, therefore, have to be solved (if it cannot be solved by the machine) de novo. This problem may become acute for example in very large information storage retfieval systems at times when it is not known in precise terms what question should be asked of the system and, indeed, the degree of precision necessary cannot be reached until there has been considerable browsing. The provision of the machine equivalent of browsing (i.e. the tentative, testing, probing search that is sometimes divergent and only in moments of rare success, convergent) seems difficult to visualise.

Associated with all these problems is the problem of maintaining interest in a fully-mechanised relatively highly reliable system, so that the necessary degree of skill may be exercised at times of crisis and unreliability.

Underlying these 'human' problems of A.D.P. is, however, the greater problem implicit in all mechanisation, that of the growing dependence of the human race upon the complexities of technology, This dependence is defensible and, indeed, acceptable insofar as technology provides a greater degree of perfection or satisfaction to human ambitions. If situations develop where this is not so, then not only is the position indefensible but it may also produce worse result than had mechanisation not been attempted. In the field of A.D.P. it is possible to visualise a situation where dependence upon devices in a particular sector of human activity becomes complete and our premises of providing a greater degree of perfection or satisfaction of ambition were satisfied. A change of external environment, caused let us say politically, and not foreseen by the designer of the device, may then be supposed. The device is useless. But worse; the experience of the immediate past cannot be tapped. The situation may be retrieved only by a painful manual recollection of events leading up to the externally imposed change. The more perfect the machine, and the more widespread its acceptance, the

more explosively imperfect is the overall situation in the consequences of failure under conditions not foreseen by designers and administrators.

4. THE "UPPER" LIMITS TO A.D.P.

An attempt at this point in time to predict the extent to which A.D.P. is likely in the long term to supplant the human agency in 'Administration' would be most hazardous. It is perhaps possible, however, to make some assessment of the area within which, for one reason or another, a purely mechanistic agency would be unsuited. Broadly speaking, in any organisation, the higher one goes in the hierarchy the less routine becomes the type of work. By the expression "less routine" is implied "the less are decisions taken according to some formulated rule". In the highest reaches there may be a complete absence of formulated rules and many of the decisions are made "on merits", that is to say all the relevant considerations are taken into account and a conclusion reached to which, in the opinion of the person forming it, the considerations point. The decision is thus a subjective one and depends on the weight attached by the person concerned to the various relevant factors. Once the relevant considerations have been elicited and the weights to be attached to them assigned, the process of forming a conclusion is relatively simple.

The decisions of the higher administrator, therefore, tend to differ in two respects from those of the clerk:-

(i) there is far less scope for referring to an authority e.g. a code of rules; indeed, even where reference to an authority is made then this is usually oblique and indirect. (Were the references direct and unequivocal, it seems doubtful if the case merits the attention of administration), and (ii) there is less repetitive work.

Thus the two main features of clerical work which make it amenable to A.D.P. tend to be absent from higher administrative work. The actual process of administration may not be entirely unsuited to A.D.P., for, since it must have a logical basis, it may be executed by a computer. But the extent to which it may in fact ever be performed mechanically as an integrated process would seem to be limited by two factors:-

(a) there is an element of subjective judgment in every administrative decision as to what is a relevant consideration; and

(b) there is a further element of subjective judgment as to what weight should be attached to each relevant consideration.

It is difficult to conceive of a computer - of finite size - having the capacity to weigh what are normally called "imponderables" and balance them against other imponderables, unless a similar exercise with the same imponderables in the equation had previously been carried out. Yet this is what in the main higher administration amounts to.

But against this the possibility must be admitted that A.D.P. may provide administration with some most powerful aids to judgment. A good deal of the subjective judgment to which an administrator is driven by defects in his present equipment could be made objective if the means to processing were available. For example, decisions based on purely economic considerations are likely to be made more soundly and with greater realisation of their consequences as the theories of econometrics are developed and the formulation of accurate numerical equations in economics and their solution by A.D.P. becomes possible.

But in some ways this is only another way of saying that wherever possible objective judgments should replace subjective judgments. This is truth which would command general assent. It remains equally true, however, that in a world peopled by human beings the judgments which bear upon them inevitably have a subjective element, and that element can never safely be devolved upon a mechanistic agency, for to so devolve would deny in the last analysis the spiritual nature of man.

DISCUSSION ON THE PAPER BY MR. J. H. H. MERRIMAN AND MR. D. W. G. WASS

MR. A. J. BROCKBANK: My interests in the computer field are connected with the practical problem of applying the use of a computer installation to a commercial organisation, and in that context I have an appreicable interest in what Mr. Merriman has just had to say. I was interested to have clarification of his definition of the "administrative level". I would respectfully suggest that so far as industry is concerned his definition is not wide enough. There are significant groups of people employed in industrial organisations who are classified as occupying administrative positions but are not concerned with these higher levels to which Mr. Merriman has made reference. I accept Mr. Merriman's contention that at the policy level the possibility of computers replacing intellect is unlikely to come into operation for some considerable time. In regard to the middle level group, I am, however, being driven more and more to the conclusion that in the relatively near future the utilisation of computing techniques is going to affect such groups very significantly. The ones concerned are those whose job is to bridge, from their experience, the lack of available information owing to inadequacies in existing data processing systems. In my view with the ability to have all the facts relating to a given situation before us, then the need for this human link becomes unnecessary.

The other aspect of this matter which I think is important is that in certain spheres of industrial and commercial activity, where even with all the facts available human judgment is exercised, a computer can be programmed to adequately take a number of decisions in this field.

On the question of rigidity, one aspect of computers which at least has impressed me, and I hope I have not here drawn a false conclusion, is that they appear to enable one to change organisational approaches and systems to meet changed requirements far better than is possible with existing mechanised type of equipment.

MAJOR E. J. GUTTRIDGE: When reading Mr. Merriman's paper I hoped to find a complete specification on Automatic Data Processing Equipment for industrial and commercial use in the next ten years.

Obviously this would have been a very bold action on his part and I would therefore like to congratulate him on the many sign posts which he erected.

The paper does create an impression that during the next ten years there will be a progressive move towards centralisation of Data Processing. No doubt there is unintentional. There is sufficient evidence to indicate that a movement away from over centralised administration is beginning and it is essential that designers of data processing systems take note of this in order that the smaller organisation is not neglected. The remote communication of input and output will only provide a limited solution.

It is my opinion that the major development during the next phase will be devoted to the requirements of small decentralised organisations. The first steps to be taken are of a systematic nature as distinct from sheer hardware development.

Most of the more novel technical advances are still on a research basis and the near future should be used for the exploitation of established techniques coupled with a truly integrated approach to the systematic requirements of business and industry.

MR. C. STRACHEY: I would like to take up a point Mr. Merriman made at the beginning of his paper, though I do not think he mentioned it again in his introduction. He said that he was going to assume that all the data processing problems we were giving computers at the moment were solved, and that they did not present any insuperable difficulties; he said, I think, that all the difficulties were man made. I am not sure that I agree with this, I think there are some data processing problems, particularly those concerned with timetabling, or shop loading, or works control, for which no adequate method of solution yet exists. These problems are essentially combinatorial and their complexity increases very rapidly with their size. If we consider the problems of organising any sort of time-tabling procedure - say loading machine tools - so long as the unit is small a human brain can make quite a good job of it, though the methods by which it works are not at all clear. As the organisation grows there comes a moment when the time-tabling gets beyond the capacity of the man who is doing it. It is then necessary to increase the proportion of people operating quite disproportionately because no one person can comprehend the whole field of the problem. The trouble really is that the complication goes up exponentially and for large problems becomes quite out of hand. I do not think we yet have any satisfactory way of tackling this sort of problem. Almost the only method suggested so far is linear programming, but for this type of problem it involves matrices which are far too large for any reasonable sort of machine to deal with. The whole of the area seems to me to be one of considerable intellectual difficulty and I am not at all convinced that we know how to tackle these problems yet.

DR. S. GILL: I think I would agree with Mr. Brockbank that we are more likely with electronic computers to be able to adjust the system to changing circumstances than with older forms of equipment. But I think that the problem will arise from the extension of the mechanised system to cover more and more of the enterprise. This of course will lead to the problem of rigidity which Mr. Merriman has pointed out. And I think it is important that when we do mechanise a large system we should arrange the mechanisation so that suitable data is printed out which can be readily comprehended by humans, so that some one, or two or three people preferably, can keep themselves familiar with the progress of the enterprise and are in a position to take over control if the mechanised arrangements look like failing under a certain change of circumstances.

With regard to the problem of centralisation which Major Guttridge raised, it does seem to me that the problem of communication between a number of different places is likely to set a limit to the practical size of a computing installation, and this factor, together with the factor of reliability, seem to be the two things that will limit the useful size of computers that we are likely to be able to build. The two factors mentioned in the paper, namely, the price factor and the difficulty of programming a large job on a computer, seemed to me to be somewhat irrelevant. In fact, if anything, I would say the price factor operates the other way, and tends to favour a larger installation.

MR. B. R. ASTON: I would like to start with the first point Mr. Merriman made, as to what is an administrator. The way we are looking at this is that an administrator is someone who makes a decision, and he is going to make that decision on the basis of information that is handed up to him. When he makes the decision he will then hand an instruction down, and very rapidly we feel we are getting a situation very similar to the closed loop of a control mechanism - certainly a loop effect, and I would like to ask Mr. Merriman what he thinks about this idea.

MR. R. BENJAMIN: I have a small comment on Mr. Strachey's remark, concerning the point where the loading of the machine "gets out of hand". It gets out of hand quite as much for the man as for the computer. In each case the number of possible solutions in the matrix becomes excessive, and some sort of short cut is required. However, it is fairly easy to think of reasonable short cuts: as a first approximation, one could classify manufacturing tasks in order of importance or difficulty, and classify the machine-tools in order of desirability of use - that is roughly the inverse of versatility -, so that if the most urgent problem is solved with the least versatile combination of machine-tools that are otherwise sensible for doing the job; you will then have preserved the maximum flexibility in deploying your remaining machine-tools for the next urgent job, and so on. By doing this sort of thing

you can keep the growth of complexity with problem size roughly linear- instead of a square law, and you can still get a very good approximation to the best loading; although I admit you cannot guarantee to get the best possible loading of your workshop. It is quite feasible to refine this general approach to take other factors into account, without getting excessive complication in your computer programmes.

MR. M. A. WRIGHT: Mr. Benjamin says that short cuts are needed to solve machine loading problems: I agree. He says, that one method of doing this involves classifying work-pieces and machines. It is possible to imagine that work-pieces could all have different prescribed priorities and if so Mr. Benjamin's suggestion would lead to a useful solution. If some artificfal classification system were introduced, the number of possible solutions of the problem would be reduced; but the restrictions imposed by using the classification system would exclude the possibility of finding a large number of solutions. The remaining solutions could all be very inferior to the true optimum solution. Thus, the method of classification may be very important.

It is interesting to note that methods of classification are important in many other applications. They offer prospect of a simple, but often a poor, solution unless the appropriate classification method is chosen.

In their paper Mr. Merriman and Mr. Wass say (see p.817) that there is an element of subjective judgement in every administrative decision as to what is a relevant consideration. I am not very clear on what this means so to begin with I have assumed the following definitions:- a relevant consideration is one which affects the decision and a "subjective judgement" is a judgement on what will affect the decision, which is made without knowledge of the decision. I would guess that decisions based on this kind of subjective judgement would be likely to be wrong. However, our decisions are often right and I suspect we are able to make them because we have some experience of similar problems. We may use a classification technique and may not be conscious of the processing. For example, we may make a tentative guess at the answer so that we can check whether we have included all the "relevant considerations". If we have not, then we change "considerations" and repeat the process. Dr. Selfridge has explained a machine which works on similar principles. His machine does not require an "infinite" store so it is possible that the selection of relevant considerations may not limit the application of ADP to administrative decisions as is suggested in the paper. The other limiting factor, mentioned in the paper, is the "attachment of weights" to relevant considerations. It is possible to measure some considerations either absolutely or relatively; but where human reactions are involved, this is difficult. But even these difficulties may not be insoluble even with relatively small computers. If this were, perhaps the main difficulties in using ADP for decision making would be the time taken by a machine to gain experience.

MR. J. A. GOSDEN: I would like to ask Mr. Merriman about his statement that 30% of the cost of an installation is accounted for by programming because he claims that the techniques of automatic programming will make large savings in the costs of programming. Before commenting on this statement it is necessary to be sure that programming is properly defined, putting a task onto a computer takes three phases

(a) Defining the Task.

(b) Planning how the Task is to be effected.

(c) Translating the Plan into Computer Language.

It is possible that Mr. Merriman includes all three of these in his estimate of costs. I would like to make a distinction between (a) and (b) which are Programming, and (c) which is Coding. I would say that the automatic programming that exists and has been discussed here this week, is only automatic coding. The problem of automatic programming is still largely unsolved. Systems such as FORTRAN have introduced techniques to optimise the organisation of a single programme within itself, but nothing has yet been done about deciding how to organise a suite of programmes to tackle one task. The high costs are associated more with phases (a) and (b) rather than (c), and I do not think that a significant reduction of their costs is near at hand.

Finally, I should like to reinforce the remarks made by Mr. Strachey about the complexity of combinatorial problems. There has been a large amount of work done on one particular problem, playing chess, and it has not yet been possible to attain the ability of an average human chess-player, and the most recent programme *(ref. 1)* expects to take 8 - 10 hours making a move in the middle game. Machine shop loading is a similar type of problem. Humans can get a solution that works but is probably a long way from the optimum.

MR. J. H. H. MERRIMAN (in reply): Three points of substance have been raised in the discussion:-

(1) Rigidity and flexibility in A.D.P. systems. To say that "computers appear to enable one to change organisational approaches to meet changed requirements" is to overlook the growing number of systems that are being built around, not general purpose, versatile computing centres, but special purpose, custom-built units, the logical content of which is closely matched to the tasks they have to perform (for example, on-line control of continuous flow chemical processes, air-line seat reservation systems, air traffic control assistance, banking). In such cases, unless the direction and rate of possible future change can be guessed at

REFERENCE:

1. NEWELL, A., SHAW, J. C. and SIMON, H. A. Chess-Playing Programmes and the Problem of Complexity. *IBM Journal of Research and Development*, 1958, 2, No. 4.

reasonably accurately, and provision made now to accommodate this change when it occurs, the A.D.P. system may in fact be as difficult to convert as were the earlier broad gauge railway systems to narrow gauge. General purpose A.D.P. systems, however, with their usual large volumes of logical redundancy present somewhat less difficulty provided programming changes can be accommodated.

(ii) The pressure of A.D.P. to centralise processing. Moves that there may have been away from centralisation during the last two decades have now mostly halted or reversed as a result of the growing economic pressure in favour of centralisation - at least of the processing element. To decentralise, say the 'logistical' control of a large organism is to predicate such a large increase in two-way, near simultaneous, closely dependent data flows between the component parts for any, say optimising, operations as to make the operation impracticable by presently foreseeable techniques at least. Centralising, in contrast, calls for, in the main, simple, (though bulky) unidirectional independent data flows.

(iii) Administrative decisions and their nature. To attempt to assign to such decisions a value to indicate "rightness" and "wrongness" must itself be a subjective process and incapable of expression in other than transient terms. A more fundamental difficulty would seem to be that because the value scales tend to be transitory (in that they depend in turn upon human reactions) the labour of encoding, both logically and in machine terms, isn't worth it.