THE CYBERNETICS OF ORGANISATIONS

with implications for

A THEORY OF INTELLIGENCE

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March 1980

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1. INTRODUCTION

Organisations, of one form or another, have been a feature of society for an extremely long time, at least as far back as the beginnings of recorded history. It can also be claimed that organisation is a characteristic trait of human society, and fundamental to it.

Certainly, organisations are a striking feature of present-day life, to the point where the overwhelming majority of human effort is channelled by organisations of one kind or another, whether these be business firms, government bodies, charities, clubs, or others. Furthermore, organisations are tending to become larger, both in terms of their scale of operation and the numbers of people involved, and thus are becoming more complex entities. Examples of this are the growing band of international business enterprises and supra-national governmental institutions such as U.N.O., O.P.E.C., E.E.C. etc.

The proper functioning of organisations is thus a major interest of civilised society. It is readily apparent that all is not well in the institutions we have at present. There are many signs of increasing dissatisfaction with, and alienation from, present organisations. Yet the problems of organisations as such - to be differentiated from problems that organisations have to solve - have been the object of comparatively little attention, most especially of attention from a scientific viewpoint.

The major aim of this thesis is to make a contribution to the scientific study of organisations, in particular through the application of cybernetic ideas, principles and techniques.

To do this, an analytic model of organisation is developed in terms of communication and control networks embodying the specific features found in actual organisations. This model, although following the general features of previous work, is more detailed and comprehensive than in other studies. The consequences of this model are then examined, and some initial conclusions drawn. The practical results of the application of the model to one particular business situation are also reported.

This thesis also has a secondary aim, to explore how far studies of organisation, and particularly of managerial processes, can throw light on the nature of human intelligence. This aim is rooted in the notion of the organisation considered as an intelligent entity operating in its own environment. This notion has previously been used in attempts to prescribe solutions for some problems of organisations by drawing on studies of intelligence. In this thesis, the process is reversed. An attempt is made to apply conclusions from the analysis of managerial processes to account for observed features of human intelligent behaviour. The purpose of this endeavour is not so much to provide a comprehensive theory of intelligence as to demonstrate that insight into individual human behaviour may be gained through studies carried out in organisations. It is suggested that, since communication channels and decision procedures are in principle much more open to investigation and analysis in the organisation than in the brain, useful work may be done in this field.

2. THE NATURE OF ORGANISATIONS

Organisations are so familiar in everyday life that their nature and behaviour may well be taken for granted, with little or no thought as to their characteristics. It is perhaps as well therefore to start with an examination of what organisations are.

A formal definition of an organisation sufficient for our purposes here has been given by Barnard (1948) as follows:-

> "A system of consciously co-ordinated activities or forces of two or more persons".

This is an extremely wide-ranging definition, sufficient to encompass the state, trade unions, religious bodies, industrial companies, and charities.

Other workers have provided essentially similar definitions of organisations. For example, Bakke (1959) sees an organisation as " . . . a continuing system of differentiated and co-ordinated human activities which welds together resources into a whole that has a character all of its own". The concept can be traced back to Aristotle who wrote, "Men journey together with a view to general advantage, and by way of providing some particular thing needed for the purposes of life . . . ".

Some aspects of Barnard's definition deserve comment. Firstly, it implies that the essential component of all organisations is a group of people and therefore organisation is an essentially human activity; any study which does not take appropriate account of this fact can be at best only an extremely pallid reflection of the truth. It is worth quoting a further remark of Barnard (ibid) on this topic, namely that " . . a co-operative system is incessantly dynamic, a process of continued readjustment to physical, biological and social environments as a whole". Not only does this encapsulate the essential nature of organised activity, it suggests powerfully that the disciplines of cybernetics, which are accustomed to treating complex dynamic systems, are appropriate tools to investigate the problems of organisation.

A second point about Barnard's definition is that organisations are characterised by shared tasks and hence, since tasks can always be construed as having a purpose, by purposes held in common by the group. A pedantic point here is that it is not necessary that the task (or tasks) are beyond the capacity of a single individual to accomplish:- thus although it is quite possible for a man to build his house through his own efforts, it is more common to find that houses are built by an organisation. A further observation, which Barnard himself makes, is that there is a sense in which the tasks of an organisation are quite specific (eg. "build this house", "cash this cheque") and its purpose is accomplished when the task is completed. Thus, in carrying out its tasks, an organisation accomplishes its purpose and, logically, should disband itself. For an organisation to continue, it therefore needs to adopt new objectives continually.

Occasionally, this process can be observed in action. A recent example has been the activities of C.A.M.R.A. (the Campaign for Real Ale). Formed originally to promote the availability of particular types of beer in public houses, it was largely succesful in this aim. It then moved on to other (though related) activities, actually running public houses, and also became more involved in political issues such as trading monopolies. More recently, it has started to consider brewing its own beer.

It is more general, however, for organisations to overcome this paradox by adopting a statement of purpose at a more generalised, abstract level such as "to make motor cars" or "to provide a banking service", which allows fresh tasks (and hence purposes) to be generated on the completion of a given task. This is an important point from a philosophic point of view, particularly when discussing the objectives of an organisation. It implies that organisational objectives are not fixed for all time, but are themselves evolving as part of the " . . . process of continued re-adjustment" referred to above. It also offers an explanation of why many workers in the field of organisation, particularly of business management, find that definition of objectives is a recurring theme. Grainger (1964) goes so far as saying that objectives " . . . should be periodically reconsidered and re-defined, not only to take account of changing conditions, but for the salutary effect of re-thinking the aims of organisation activities". In similar vein, Humble (1968) has written "It is always stimulating and constructive to look afresh and critically at the company's forward plans, particularly as the range of objectives is often found to be dangerously restricted".

Yet another aspect of the topic of organisational objectives, which again is recognised by Barnard, is that not all individuals within an organisation will be fully committed to them - in fact some may be opposed to them. Furthermore, this degree of committment may be expected to vary through time.

A quite separate aspect of the definition of an organisation is the emphasis that it places on "consciously co-ordinated activities". This is a key feature, one that differentiates an organisation from a mob or a haphazard, accidental collection of individuals. Additionally, it brings into focus the clear need for a means of dividing work between individuals, and a mechanism of communication and control to achieve this co-ordination. This aspect is of such primary importance to the success or otherwise of an organisation that the term "organisation" itself is frequently used to denote exactly this, i.e. methods by which work can be divided up and subsequently controlled. The word is then used as an abstract, rather than a concrete noun.

Most writers in this field tend to use the term "organisation" in this more abstract sense, and comment on the nature of "organisation" from a variety of points of view. There is such a wide range of material published under this general heading that it is not practical here to review it all in depth. However, it is possible to pick out some of the main strands of thought and progress, each associated with a particular group or school of individuals.

As with most topics, it is possible to trace discussions of organisation back to very early times. For example, Plato makes reference to the organisation of the State in "The Republic", particularly in Books II and VIII and says much which is still of relevance today. However, modern approaches to organisation can be seen to start to emerge at about the beginning of this century, and it is convenient to review it under five main thematic headings. Before doing so, it should be pointed out that most of the work referred to deals more or less explicitly with industrial and/or business activities.

Whether these are an appropriate model for other types of organisation is a question which is examined below.

The five main themes which can be discerned are as follows:-

2. (1) The Structure of Organisations

The term "structure" refers to regularities that can be observed in activities such as task allocation, supervision, co-ordination and communications. Cameron (1948) has defined it thus:- "The framework of duties and responsibilities through which an undertaking works". There is no one unique way to arrange these activities, and consequently two companies carrying out broadly similar activities may have completely different structures. Indeed, it could be maintained that each and every organisation has some features of its structure that are unique to itself. Nevertheless, several writers have investigated organisational structures to see if there are any general forms or principles that can be extracted.

One of the early workers in this field was Weber (1930:194 whose prime concern was to postulate classifications of types of organisation structure, particularly in relation to the authority structures within them. Perhaps his principal contribution was his analysis of the basis of the exercise of authority by one person over another, where he distinguished three main principles which he labelled "charismatic", "traditiona and "rational-legal" - which last has subsequently been re-labelled as "bureaucracy".

"Charismatic" is a term which can be translated as "leadership", the quality or qualities which enable one man to inspire others to do as he wishes. Organisations based on this type of authority do exist, but, as Weber points out, they tend to be unstable. Once the charismatic figure passes on, or loses his charisma, the basis of authority has gone.

(Religious organisations are an interesting apparent exception to this rule). The organisation then needs to substitute some other form of authority, or it falls apart.

Weber's "traditional" organisation overcomes this problem by granting authority on the basis of precedent and usage. He drew upon mainly historical illustrations for this type of organisation, particularly feudal systems, but examples can still be found in modern society - it is not unknown for instance for promotion to senior executive positions in business to be the result of being related to the Chairman of the Board. Equally, and more openly, membership of committees can be granted on the basis of holding a certain position - membership "ex-officio".

Weber's third type, which he termed "rational-legal" comes closest to current concepts of organisation. Authority within bureaucracy (as this category has been re-named) is exercised through an accepted system of rules and procedures, and individual authority derives from the role or office which a person holds. In current usage, the term bureaucracy has become synonymous with hide-bound, over-formalised, inefficiency but this is not how Weber originally conceived it. In his view "The decisive reason for the advance of bureaucratic organisation has always been its purely technical superiority over any other form of organisation", because it is devised specifically for the purpose for which it is intended.

It is difficult to quarrel with this conclusion in the form in which it is stated, simply because his definition of bureaucracy is sufficient to include any form of structured, task-oriented, behaviour - i.e. any form of organisation. It is also fairly clear that Weber's three types are not mutually exclusive categories, and all three may co-exist in any given organisation at a given time.

Nevertheless, Weber made an important contribution, in that his was the first attempt to produce any organisational categories at all. Furthermore his categorisation gives some insight into an important aspect of organisational behaviour, the use of power and authority. Other work has followed on from his lead, such as that of Gouldner (1955), who expands on Weber's original single concept of bureaucracy and identifies three sub-classes, "mock", "representative" and "punishment-centred".

In a "mock" bureaucracy the rules are imposed by some outside source, rather than derived from the nature of the task and the authority - structure within the group, for example regulations imposed by public authorities such as the Factory Inspectorate. "Representative Bureaucracy" is much closer to Weber's original concept; rules are promulgated by "experts", whose authority is acceptable to all the members of the organisation. The rules are accepted by both superiors and subordinates, because they derive from values held in common. "Punishment-centred" bureaucracy, arises when values are not held in common, and rules derive from the efforts of pressure groups (which may be management or workers) to enforce their will on other groups. Deviations from the rules are punished by the pressure group concerned.

As analytic tools these categories also suffer from the fact that they are not mutually exclusive, and can co-exist in one group. Indeed, Gouldner's prime use of them was to study a situation where the organisation changed from one pattern to another, and to explain the tensions and disruptions that occurred within this framework of categories.

A quite different approach to organisational structure is presented in the work of Woodward (1958). This is an empirical study of organisation structures found in practice, covering 100 firms of medium-large size in south-east Essex. The variables in the study included the number of levels of authority, the span of control (i.e. the number of direct subordinates reporting to a superior), the degree to which duties were defined, amounts of written communication, and the use of specialisation. She attempted to relate these variables to the types of technology and production system used. Many relationships emerged, among the more significant being that the number of levels of authority increased with the technical complexity of the process. She also observed that difficulties were generated when (due to a takeover) it was attempted to replace an organisation suited to one scale of production with one applicable to a larger scale.

However, the main conclusion that Woodward drew from the many relationships she examined was there is no one best form of organisation. Organisation, she says, should be adapted to the demands imposed by the objectives and technology of the individual firm. Whilst this is not a conclusion to be contested at this point, it is difficult to see upon exactly what grounds Woodward bases it; she included no criteria of organisational effectiveness in her study. As far as can be gathered, the conclusion depends on the assumption that the firms in the survey had adopted the best form of organisation for their needs.

A further difficulty in interpreting Woodward's work is that it is comparatively narrowly based, in the sense that it was concerned only with manufacturing organisations. Commercial, or marketing, aspects were not included let alone non-business organisations.

Support for Woodwards main thesis can be found, amongst other places, in the work of Burns and Stalker (1961). They came to essentially the same conclusion through starting from a different, basically sociological, viewpoint. Their studies were again concerned with manufacturing industry, and particularly with the problems associated with major technological innovation. They came to the view that organisations can be categorised along a continuum the end points of which they called "organic" (or organismic) and "mechanistic". The "mechanistic" type, which in many ways corresponds with Weber's bureaucracy, is charactorised by clearly defined vertical hierarchies of command, with the overall task divided into specialisms. Tasks for individuals are carefully set out in detail, and great emphasis is laid on adherence to rules and procedures. The "organic" type is characterised by a much more flexible, informal, system where individuals' tasks are apt to be continually changing, dependant upon the nature of the problem of the moment. There is much greater emphasis on horizontal communication and interaction and correspondingly less on formal channels and formal authority.

Burns and Stalker relate these types of organisation to the stability of the conditions in which the organisation is working. "Mechanistic" organisations, they argue, are adapted to relatively stable conditions, whereas the "organic" type is adapted to unstable situations where new problems arise frequently, problems which cannot be slotted into an existing specialist role for a solution.

Again, this study can be criticised on the grounds that the criteria for an effective organisation are ill-defined. There is little attempt to assess the quality of management that was operating within the various structures described, and there is no attempt to disentangle the effects of this variable. However, the study is valuable in that it demonstrates something of the wide variety of structures found in practice, and provides a further dimension for the analysis and understanding of organisation. Furthermore, it is interesting to compare this work with that of Emery and Trist (1960). They report the results obtained with two different types of organisations working the same technological process. The types of organisation they classify as "conventional" and "composite" which appear to be similar in all essentials to the "mechanistic" and "organic" categories respectively of Burns and Stalker. They found that effeciency, in terms of variables such as output, hours worked, breakdowns, was significantly influenced by the type of organisation structure. Two cases were reported, one of coal-mining, one of weaving. The coal-mining study showed that the "composite" system was superior, and the authors comment that the task was complex due to the constantly changing underground conditions. In contrast (and Emery and Trist do not appear to have realised this) the weaving study showed superior performance with a much more "conventional" structure. This may have been related either to the more predictable nature of a weaving task, or to the level of technical skill and comprehensions amongst the operatives - the weaving study was carried out in India.

Studies such as these show something of the complexity of the structure of organisations. However, the predominent strand of managerial thinking on the structure of organisations has its origins in the work of Fayol (1908). He wrote from direct experience of managing an enterprise rather than from theoretical interest or experimental observation, but nevertheless his work has gained a wide and enduring reputation. He enunciated 14 "principles of management", several of which are concerned with organisational structure. Those most relevant for the immediate purpose here are as follows (using Fayol's original numbering):-

1. Division of Work. This, of course, is the basis of all organisational activity, although Fayol does not specifically say so. He sees the point of division of work as to increase efficiency - " . . to produce more and better work with the same effort", and he sees it as a principle applicable to work of all kinds, not simply manufacturing. Interestingly enough, he seems to have been aware that specialisation of work can be carried to excess. He says, " . . . yet division of work has its limits which experience and a sense of proportion teach us may not be exceeded".

2. Authority and Responsibility. Fayol distinguishes two types of authority, one derived from personal qualities, one derived from official position. (He makes no mention of Weber's third source of authority, the "traditional"). He sees as important aspect of a good manager as the fusion of these two types in one individual. Equally, he is insistent that authority and responsibility are co-extensive.

3. Discipline. Fayol distinguishes this quite clearly from authority. He defines it as follows: "Discipline is in essence obedience, application, energy, behaviour and outward marks of respect observed in accordance with the standing agreements between a firm and its employees . . . . . ". It is clear that he views discipline as operating within a set of (more or less) formally defined rules and procedures, and that discipline applies as much to managers as subordinates. Discipline should be exerted on an agreed basis, fair to all parties, and includes the use of sanctions where it is breached.

4. Unity of Command. This is perhaps the most fundamental of Fayol's principles of organisation structure. From it flows naturally the whole concept of the hierarchy of command and the typical pyramid structure of management. In simple terms, "unity of command" can be expressed as "one man, one boss", which is an exact paraphrase of Fayol's words "For any action whatsoever, an employee should receive orders from one superior only". He also says "This rule seems fundamental to me and so I have given it the rank of principle". It is clear that he recognised that his principle was not universally observed, and he illustrates some of the situations that arise when it is not.

5. Unity of Direction. This is an extension of the "unity of command". It is defined as " . . . one head and one plan for a group of activities having the same objective". Unfortunately, Fayol does not make clear how it is to be established which activities have a common objective; his statement can be interpreted in at least two senses, one product-oriented (i.e. to produce and sell a given article or service) one process-oriented (i.e. to produce a range of articles or services). This is a theme in organisation structure which has received much discussion, and is still not resolved. Indeed, it seems that the question may never be answered, but resolved through progress to new types of organisation structure (See, for example, Newman (1973).

8. Centralisation. This is still very much a problem in current organisational design, and it is of interest that Fayol identified it so long ago. He defines it as follows, "Everything which goes to increase the importance of a subordinate's role is decentralisation, everything which goes to decrease it is centralisation". He also comments that the issue of centralisation or decentralisation is one of degree, not of principle. He interprets it in terms of the length of the "Scalar chain" (See below), and as being dependant upon the abilities and disposition of the managers involved.

9. Scalar Chain. This is the line of formal authority from the lowest operative to the highest authority, and is essentially an interpretation of the principles of unity of command and unity of direction into their hierarchical consequences. Fayol uses this to discuss the need that can arise to short-circuit the normal channels of communication. He apparently feels that communication within organisations should be basically "vertical" and that "horizontal" communication should be resorted to only in emergency.

Of Fayol's 14 principles, the foregoing are those most directly concerned with the structure of organisations. The balance are concerned more with the functioning of organisations, though the distinction is not always easy to draw. They are worth quoting because they form the foundation of a great deal of subsequent work. Furthermore, little of fundamental importance has been added to Fayol's principles, although they have been refined, re-shaped, and re-worded. This is not to say that there is a general consensus that Fayol's conclusions were correct, but rather that he identified with clarity the major issues to be resolved in structuring an organisation. The debate on their correct solution still continues.

Contemporary with Fayol was Taylor, (1903), who founded the Scientific Management movement. However, he contributed little to the theory of the structure of organisation; many of the principles generally acredited to him were in fact originated by Fayol. Taylor's chief contribution in this area (which is overshadowed by his contributions in other areas) was his concept of "functional management", particularly the "functional foreman". Under this scheme, every worker had several foremen in charge of him, each responsible for a specific aspect of performance, such as discipline, speed, and quality. Although this concept did not enjoy a long application in practice, it did serve to introduce the notion of "functionalism" into the analysis of organisations, where it has remained.

Several writers have taken up the themes initiated by Fayol and Taylor, among them Sheldon (1924), Lee (1925) Robinson (1925), Mooney and Riley (1931). Their views were synthesised in the work of Urwick, who has written widely on the subject of organisation and management. His views developed over the years, and perhaps the definitive statement of them can be found in his "Notes on the Theory of Organisation", published in 1952. In this, he identifies eight principles of organisation, as follows:-

1. The Principle of the Objective. Every organisation, and every part of the organisation, must be an expression of the purpose of the undertaking concerned or it is meaningless and therefore redundant.

2. The Principle of Specialisation. The activities of every member of an organised group should be confined, as far as possible, to the performance of a single function.

3. The Principle of Co-ordination. The purpose of organising, per se, as distinguished from the purpose of the undertaking, is to facilitate co-ordination, unity of effort.

4. The Principle of Authority. In every organised group the supreme authority must rest somewhere. There should be a clear line of authority from the supreme authority to every individual in the group.

5. The Principle of Responsibility. The responsibility of the superior for the acts of his subordinate is absolute.

6. The Principle of Definition. The content of each position, both the duties involved, the authority and responsibility contemplated, and the relationships with other positions, should be clearly defined in writing and published to all concerned.

7. The Principle of Correspondence. In every position the responsibility and the authority should correspond.

8. The Span of Control. No person should supervise more than five, or at the most, six, direct subordinates whose work interlocks.

9. The Principle of Balance. It is essential that the various units of an organisation should be kept in balance.

10. The Principle of Continuity. Reorganisation is a continuous process; in every undertaking specific provisions should be made for it.

The work of Urwick represents the conventional wisdom of managerial views on organisation structure. For that reason, these principles are worth some review.

The first point to be made is that they accept implicitly an authoritarian and hierarchical structure. The possibility of any other form of organisation is not even admitted, let alone discussed, and the line of descent from Weber's bureaucracy through Fayol and Taylor is clear. Rather than principles of organisation they are perhaps best viewed as a summary of the characteristics of one particular dominant form, essentially Weber's "rational-legal" system or Burn's "mechanistic" type.

From a more philosophic viewpoint, Urwicks principles are bedevilled by lack of definition of terms. Thus, "The Principle of the Objective" founders on the problem of defining an organisation's objective, as discussed above. This is particularly so when one attempts to discern an overall objective through a review of an organisation's activities, for then by definition, " . . . every part of the organisation must be an expression of the purpose of the undertaking . . . . ". In a situation where objectives are bound to be underspecified, the use of Urwick's first principle as a tool of organisation design is extremely limited.

Similarly, the use of the second principle depends upon being able to specify exactly what activities constitute a function. Since a function is an abstract concept that can be built up to any desired level of generality, it is difficult to see how the work of an individual can fail to be " confined to the performance of a single function", given adequate ingenuity in finding the appropriate descriptive phrase. Thus, the usefulness of the second principle is open to doubt.

The third principle, that of "co-ordination" is perhaps unexceptional in itself as an expression of good intent. Again, however, it is of little practical use as a guide when actually designing an organisation.

The "Principle of Authority" is a statement about the nature of hierarchies, and does not greatly advance understanding of this subject. Furthermore, as stated, it does not give any lead as to where one might expect to find the ultimate authority nor whether it rests with one individual or a group. Equally, it does not explicitly acknowledge

Fayol's "Unity of Command", though one must assume this is through oversight rather than intent.

Urwick's fifth, sixth, and seventh principles do not seem relevant to the topic of organisation structure. They are much more concerned with managerial practice within a structure.

The eighth principle, that of "Span of Control" is the one statement that is directly and practically useful in organisation design It is interesting that Urwick does not dignify it with the title of "principle". Whether it is a reliable guide in practice is more doubtful, for it is built on a rather dubious base. Two sources can be traced for his statement, the first in the work of Lee (1925) as an empirical observation, - "It seems from practical experience that in no case should a manager have more than five representatives of divisions in touch with him, whether these divisions are what one may call territoria functional, or technical."

The second source is in the work of Graicunas (1933). In essence, his conclusion was based on the following line of argument ;- With n subordinates, a manager has nP1 direct relationships with them as individuals, nP2 relationships with pairs of people, nP3 relationship with trios of people. and so on. The total number of relationships is the sum of all these. Graicunas expressed the results of his calculations in a table, as follws :-

No. of Subordinates	1	2	3	4	5	6	7	8	9	10	11	12
No. of Relationships	1	6	18	44	100	222	490	1080	2376	5210	11374	24708

(The above table is a greatly simplified version of Graicunas' original). He then invokes the psychological notion of "span of attention", without quantifying it, and states that his (Graicunas's) opinion is that 222 relationships (= 6 subordinates) is about the maximum that any individual should be expected to enter into. He also bore in mind that the rise when a seventh person was introduced (to 490 relationships) was considerable.

It is evident that Graicunas' conclusion is extremely speculative. It scarcely considers the realities of any given situation such as the nature, extent and importance of such relationships (particularly in view of the "Principle of Specialisation" referred to above). It is an extremely interesting and original attempt at analysing a complex problem, but its validity must remain in doubt. It is perhaps remarkable that it should have survived so long in organisational theory - perhaps because it is one of the few definite statements that have been made. It is a statement that has not been widely transferred from theory into practice.

However, to return to Urwick's principles, the remaining two are the "Principle of Balance" and the "Principle of Continuity". These are stated in such abstract terms that it is difficult to know how they should be interpreted in specific circumstances. Indeed, the "Principle of Balance" can be construed as a re-statement of the "Principle of Co-ordination" in a different guise.

Furthermore, the "Principle of Continuity" could almost be taken as a statement of failure, in that it might imply that organising along the lines suggested by the principles would lead to the need to re-organise ! However, a probably more accurate interpretation is that Urwick recognised that organisational tasks and objectives are subject to change, and this can result in a need for re-organisation to maintain efficiency and effectiveness.

It is perhaps worthy of comment that, if Urwick's principles are difficult to apply when considered in isolation from each other, the problems are increased when they are viewed as a set. Some appear to be in conflict one with another. Thus "The Principle of Specialisation" (taken in the sense in which Urwick appears to intend it) is at odds with "The Principle of Co-ordination"; the further specialisation is carried, the greater the need for effective co-ordination, which in turn implies more "generalists". Clearly, if Urwick's principles are to be accepted, there is a need for a balance to be struck between these requirements (a point which Fayol (op.cit) appreciated), but there is nowhere any indications of how this balance can be found.

The root of this dilemma, the balance between functionalism and generalism, can be traced back to Plato, particularly to "The Republic," Book II, p. 369, where Socrates says "Consequently, more things of each kind are produced, and better, and easier, when one man works at one thing, which suits his nature, and at the proper time, and leaves the others alone", (Which, incidentally, is an excellent statement of the underlying philosophy of functionalism). The trouble with it, a trouble which still has repercussions today, is that it is an inadequate statement of the nature of people. It is not true, by and large, that a person's nature (to adopt Plato's term) is such as to suit him for one activity only; most people are equipped to be more than adequately competent in a variety of different fields. Indeed, some people have achieved outstanding results in what are normally regarded as quite separate areas. Instances which come readily to mind are Charles Dodgson (mathematician and children's writer), Dr. Johnson (lexicographer and wit), C. S. Lewis (theologian and novelist), Jackie Stewart (driving and clay pigeon shooting), Winston Churchill (politician and historian), Chris Chataway (athlete and politician), Josiah Wedgwood (businessman and scientist), and there are many others. Perhaps the most outstanding example is Leonardo de Vinci. However, at a more mundane level, people come equipped with an array of more or less developed talents not a single functional skill. Any organisation which neglects this, as the functionalist school does, can at best hope to utilise only a fraction of the human resources at its disposal; at worst, it can expect its members to be frustrated and less than fully committed to organisational objectives. The functionalist view is founded upon an extremely limited view of human abilities and can therefore not hope to be fully successful. Perhaps the enduring attraction of the functionalist view is that it gives rise to tractable and readily manipulable organisations. Whether it is the best view for achieving organisational objectives is open to doubt.

To return to the theme of Urwick's principles, the logical consequence of "The Principle of Responsibility" and "The Principle of Correspondence" should not be allowed to pass without comment. It is the most elementary exercise in logic to deduce from those two that every superior has absolute authority over his subordinates. That this is an unacceptable state of affairs is demonstrated by many examples in history, most specifically perhaps by Magna Carta, and more recently in the rise of Trade Unions. It is unfortunate therefore that it should be encapsulated in what is still to a great degree the fount of modern managerial thinking.

It is not the contention here that Urwick believed in absolute authority - it is clear in context that he accepted limits on organisational authority, though these are not spelt out precisely. The point is that, taken out of context, as one should be able to do with fundamental principles, his statements lead to an unacceptable conclusion.

Much further work has been reported in this field, for example Blau and Scott (1963) Littever (1963), Edwards and Townsend (1961), Miller and Rice (1967), amongst many others. It is not possible to review all the literature in depth here, but the general overall content of the majority is further exploration and refinement around the principles expounded by Urwick. Amongst the more interesting contributions has been that of Brown (1971), who amongst other issues, introduces the concept of more than one structure of roles being required within an organisation, for different purposes. He identifies in particular operational systems, representative systems and legislative systems. He also makes a very careful analysis of role structures and role relationships, laying great emphasis on accurate role descriptions.

Another development of interest has been the realisation that organisation structure is interdependent with information flow networks. Since it can be argued (though perhaps not entirely successfully) that this has arisen from the influence of cybernetic concepts, discussion of this development will be postponed.

Thus, the overall managerial view of organisation structure is one still based on specialisation, either functional or process-oriented (though there are some experiments with project-oriented organisations), and that the organisation chart is an adequate tool for its design. Whether acknowledged or not, Urwick's work still exerts a major influence in this field.

In view of the difficulties with his approach outlined above, it is encouraging to find that some of the problems are being acknowledged. Thus, for example, Newman (1973) writes "Furthermore, I think that the stage has been reached in some situations where the organisation will have to be changed, away from what is desirable in purely organisational terms, in order to enable real human managers, with their fallibilities, their limitations, to be relatively competent, relatively effective in their work".

A more comprehensive condemnation of current organisational theory and practice is difficult to find. Nor is it an isolated view. Duerr (1971) writes "The need to escape from the hierarchy straightjacket is getting more and more common in business (just as it is in the army) as time goes by, with the introduction of more and more staff jobs, themselves made necessary by the advancing complexity of modern corporations . . . . ". It is perhaps significant that Newman and Duerr represent two quite separate schools in the study of organisation, what might be termed the "academic" and the "practical" view respectively. When two such disparate views emerge with the same general conclusion, it is fairly sure indication that the conclusion reached deserves serious consideration.

Perhaps the only general view that emerges from the study of organisation structure is that the structure needs to be adapted to the particular needs and circumstances of the individual organisation. Unfortunately, there appears to have been no attempt to be specific about what circumstances imply the need for certain types of organisation. (Woodward's study (op.cit) comes closest to doing this, but it was very restricted in its range, and, as mentioned above, had very little in the way of yardsticks for effectiveness of organisation).

In view of this lack, it is worthwhile to attempt to categorise at least some of the variables that might reasonably be expected to have a significant role in determining the type of structure appropriate to a given organisation. Such an attempt does not necessarily imply acceptance of the view that optimum structure is specific to local circumstances, but it is a necessary step in examining the truth of the proposition.

There would seem to be at least five major variables that could be used in classifying organisations. These are (a) the degree to which it is self-financed, (b) the degree to which it is "authoritarian", (c) the degree to which its sub-units communicate, (d) the degree to which its operations are continuous, and (e) the degree to which the environment is stable.

The degree of self-financing appears to be of importance, if only because it encapsulates a distinction that is generally held to be important, the distinction between business and non-business activity. Virtually every organisation needs finance to support its activities; it can obtain this either by the sale of goods and services (business activity) or by grant of funds from some external body. This would seem to be a distinction of degree, not of kind.

Businesses obtain funds from external sources (bank loans, government grants, etc.) as well as from profit from operations, and equally grant-aided organisations may derive some income from their activities (Arts Councils, and nationalised industries, for example). The principal different that this would seem to make to an organisation is the extent to which it can make its own antonomous decisions without reference to an outside authority. Thus, one significant role of profit in a private enterprise is to allow it to continue to determine its own future course of action. Exactly what influence, if any, this will have on its organisation structure is difficult to say without further investigation, but until evidence to the contrary is available, it would be as well to include it as a parameter of organisation structure.

The second proposed variable, the degree to which an organisation is authoritarian, requires some explanation of the term used; "authoritarian" is not used in its generally accepted sense, but no reasonable alternative seems available which is not subject to equal confusion. The basic distinction which it is intended to convey is between the type of organisation which has been set up to serve the purposes of one individual (or a small group of individuals) and where authority basically resides at the top of the hierarchy, and a different type of organisation set up by a large number of individuals in order to further some common purpose, where the authority basically resides at the base of the hierarchy. This latter type is typified by Trades Unions, though it is a category that in principle includes all forms of democratic representative bodies, including the House of Commons (but not, interestingly enough, the House of Lords). Once again, in practice this is a distinction in degree rather than in kind, it is rare to find an organisation that is purely "authoritarian" or purely "democratic". Additionally, although the extremes of the dimension represent quite different needs, it is again not immediately apparent that they require different structures. This is perhaps in part due to the fact that basically there is only one model of structure available, that of hierarchy.

The third proposed variable, the degree to which the sub-units communicate, seems more immediately relevant to organisation structure. That there are differences in communication between operating units seems reasonably clear. For example, in naval operations, it may well be the case that two vessels will not interchange any communication, although both are carrying out the same mission. On the other hand, in a business operation, the sales force and the production process may be in virtually continuous communication (though it is tempting to be facetious and remark that there may well be occasions when it is open to doubt whether sales and production are attempting anything in common). Clearly, the communication needs in such disparate circumstances are quite distinct, both between co-operating sub-systems and as regards reporting procedures to higher levels of control and command. If organisation structure and communication needs have any bearing on one another, then it is logical to conclude that differences in structure are to be expected, and may well be justified.

The degree to which operations are continuous (the fourth proposed variable) does not seem to have gained much mention in the literature. The paradigm seems to be taken as the mass-production industry, where it is important to keep activities going continuously. There are, however, many organisations for which this is a misleading parallel. The prime example is that of the armed forces who (it is to be hoped) are employed in their primary task of fighting at only rare intervals, and other duties that they carry out are basically filling in time. There are, however, many other organisations that function basically on an intermittant basis, such as a football club, the Fire Service, fish canneries, frozen vegetable suppliers, and so on. Many businesses are markedly seasonal (toys, publishing, Christmas cards, etc.) and are closer to an intermittant than a continuous operation. It is reasonable to suspect that the organisational requirements for the two extremes may be different; certainly the problems will be different.

The fifth and final proposed variable is the degree to which the environment is stable. It must be remembered here that the "environment" is a function of the organisation; each organisation finds itself in its own environment, and it is the stability of this that is important. Even two firms in nominally the same business may find themselves in markedly different environments - for example, the circumstances attached to British Leyland are quite different to those surrounding Rolls-Royce. The latter has secured an exclusive niche in the market, relatively stable demand, with little direct competition. The same is not true of British Leyland, (though at one time it may have been). The stability or otherwise of an environment could be expected to have consequences for organisation structure. At one extreme, with a rapidly changing and unpredictable environment (the two conditions are not tautologous) the emphasis should be on rapid response. Here again the military situation is the paradigm. In a stable environment, the emphasis needs to shift to considered action and the long-term view, and the paradigm is perhaps the Civil Service or a basic industry such as coal or steel. The demands for information processing and decision procedures at these two extremes are distinct, and may well be reflected in organisation structure.

There is one omission from this list of variables that may cause some surprise, the variable of size of organisation. This has been omitted because it does not appear to be of such fundamental importance as the issues that have been raised. The basic form of organisation, it can be argued, should be derived from considerations such as those listed above; the size of an organisation may well require the basic form to be replicated at different levels, and greater specialisations within this form. Nevertheless, the basic structure is not a function of size.

There are no known studies of organisation using the variables set out above, and further research is needed to investigate their usefulness as classifications of organisation types. There are two major difficulties in the way of such research. Firstly, there is only one major model of organisation available, that of hierarchy, and it may be that different concepts are needed. Secondly, organisations change in the course of time (re-organisation is a favoured pastime of senior managers), frequently on the basis of pet theories rather than external circumstance (See for example, Ryder (date?)

In conclusion, it can be seen that the basic form of organisation today is that of a hierarchy, involving the concepts of line of command, authority, responsibility, and delegation, and this can be traced back to the original military tradition. Modern thinking is beginning to question some of these ideas, but any cybernetic description of management must be capable of including the concept of hierarchy, as well as possible alternative forms. It is, of course, desirable that a cybernetic model will account for the phenomenon of hierarchy in more fundamental terms, as well as point the way to other structures.

The position is well summarised by Woodward (op. cit.) "The danger lies in the tendency to teach the principles of administration as though they were scientific laws, when they are really little more than administrative expedients found to work well in certain circumstances but never tested in any systematic way".

2. (2) THE FUNCTIONING OF ORGANISATIONS

Given that organisations are hierarchical structures of people and equipment, what do they actually do ? What are their activities, what roles do people play in them ? These are questions of function rather than structure, although the two aspects are closely related.

Clearly, each individual organisation is unique in this respect if considered at a sufficiently detailed level. However, it has been found that there are sufficient similarities between organisation to enable useful classifications of activities to be made.

The pioneer in this field was again Fayol (op.cit). He produced the following list of activities, which he suggested were present in all industrial undertakings:-

(i) Technical activies (production, manufacture, adaptation)

(ii) Commercial activities (buying, selling, exchanging)

(iii) Financial activities (search for, and optimum use of, capital)

(iv) Security activities (protection of property and persons)

(v) Accounting activities (stocktaking, balance sheet, costs, statistics)

(vi) Managerial activities (planning, organisation, command, co-ordination, control)

It must be remembered that Fayol was referring to industrial concerns; there are organisations which do not undertake all these activities, but specialise in one or two of them - retailers and finance houses, for example.

A point of special interest is that Fayol specifically includes management activity as a distinct classification. It is worth remembering that his original work was published in 1916, based on experience gained during the late 1800's, when industry was only just beginning to move out of the era of the individual entrepreneur into the era of the corporate enterprise. It says much for Fayol's acute perception that his concepts have withstood the passage of time and still remain valid today.

Furthermore, he was not content to identify management as an activity and leave it at that. He spelt out quite specifically what he saw as the functions of management. Those were:-

(a) To forecast and to plan, which means to examine the future and draw up plans of action.

(b) To organise, which means to build up the structure, both material and human, of the undertaking.

(c) To command, which means to maintain activity among the personnel.

(d) To co-ordinate, which means to bind together, unify, and harmonise all activity and effort.

(e) To control, which means to see that everying happens in conformity with established rule and expressed command.

This analysis still remains as the basis of modern thinking on management theory. It has been extended and modified, but never seriously challenged. It is remarkable that Fayol's analysis of management, which is the first known attempt at a theory of management, has survived largely unscathed. He even provides a definition of good management - "to get the optimum return from all employees of his unit in the interest of the whole concern" - which is still relevant today.

Many other writers have contributed observations on the functioning of organisations. The divergence of views available is difficult to summarise adequately, but some of the main themes can be seen in the works of Barnard (1948 i and ii), Brown (1960,1962,1971) and Bakke (1950,1953,1959).

Barnard's view of the nature of organisation (" a system of consciously co-ordinated activities or forces of two or more persons") has already been mentioned. His view of the functioning of organisations centres around the concepts of purpose, communication, and commitment, which can be related to Fayol's notions of planning, co-ordinating and commanding. His view of purpose is interesting in that he sees the purpose of an organisation not in abstract terms such as "survival" or "profit" but as the production of a specific item or service, and as such is an extremely pragmatic approach.

Given that co-ordination of activities is required, it follows, Barnard argues, that acts of communication are necessary so that purpose can be translated into action. He views communication in a very broad sense, not restricted to verbal or written media, and this leads him on to consider the "informal organisation", - the network of communication that supplements the manifest organisational structure. Furthermore, Barnard recognises that the degree to which an invidual will accept the organisational purpose will vary from person to person and from time to time, and he sees an important part of the functioning of an organisation as to secure sufficient commitment to its purposes from its personnel. He takes a somewhat pessimistic view of the nature of this process, and seems to feel that this commitment is hard to obtain in modern societies.

Basically, Barnard seems to expand on Fayol's principles, and introduce some of the complexities of these principles in practice. In particular, he emphasises that psychological and sociological forces have their part to play in the functioning of organisations, and acts as a precursor to more modern investigations in industrial psychology and the like.

Brown, writing on the basis of his own experience of management, takes an interesting and individual approach, complementary to Fayol rather than directly derived from him. He sees the functioning of an organisation in terms of social systems, of which he identifies three, namely:-

1. The Executive System
2. The Representative System
3. The Legislative System

The Executive System is meant to comprehend the structure of roles usually referred to as the organisation chart or hierarchy, and Brown maintains that this exists irrespective of people; people may come and go, but the roles do not disappear. (Interestingly, here he is at variance with Barnard, who is prepared to concede that organisation may be tailored to the individuals available). He also points out that the design of this Executive System may have conflict built in to it, and that friction between individuals can arise because of this, friction which is all too easy to put down to "a clash of personalities". He does not seem to agree that such conflict can be beneficial to an organisation in the long term, by providing a source for change and development.

At root, Brown's concept of the Executive System is in accord with the views of Fayol and Weber, that of an ordered hierarchy, but he examines it in considerable detail, introducing variables of Personnel aspects (organisation and personnel) a Technical aspect (production techniques) and a Programming aspect (balancing, timing and quantification of operations). He is particularly concerned with the role of specialists in these aspects and their relation to the actual work process, and elaborates on what he feels to be a suitable structure to accomodate these needs.

However, rather more interesting is his identification of the Representative system which, he maintains, will always exist alongside an Executive system and acts to convey the feelings of subordinates upwards to superiors, in contrast to normal channels which convey information from superior to subordinate. Brown points out that this system may not be explicitly recognised, but he maintains that it always exists.

Commonly, these days, such a structure is given formal recognition (as a Staff Council or some such body, or a Trade Union). The point of interest, however, is the contention that such a system is an integral part of the functioning of any organisation, and (although Brown does not directly say so) is quite distinct from Barnard's informal organisation.

On top of this complication of the view of organisation, Brown adds a further system, the Legislative system. This he envisages as an interaction between shareholders, directors, customers, the Executive system and the Representative system. He maintains that the joint power of these systems, and the interaction between them puts limits on what a company can do - in effect, legislates for the company, and hence the title given to this system.

It can be argued that this last analysis is not wholly convincing. For instance, Brown's other two systems consist of a set of structural roles, whereas his Legislative system is a process of interaction, and is thus different in kind. At a more mundane level, it is rare for shareholders to exert any direct influence over the actions of a company, and virtually impossible for customers to do so. Nevertheless, a company does need to bear in mind the attitudes of shareholders and customers alike, even if it does not negotiate directly with them. It is certainly a valid point that organisations do not exist in a vacuum, and are subject to powerful influences from outside which severely circumscribe its freedom of action. It is not necessary to limit these influences to just simply shareholders and customers; government and competitors, for example, play just as significant a role.

A different approach to the functioning of organisations is typified in the work of Bakke. His is a somewhat more academic approach, and his aim is more to provide a theoretical framework of analysis, applicable to all types of organisation, not necessarily just business and commercial activities. He approaches this task by considering the basic resources which any organisation needs, a rather different line of attack from many other analysts. These he identifies as:-

Human Resources

Material Resources (including plant and equipment)

Financial Resources

Natural Resources (i.e. not processed by human activity)

Ideational Resources (including the language used to communicate these ideas)

It is possible to question whether all these resources are essential to every organisation (for example, does a bank need natural resources, does a Ramblers' Association need financial resources) but these are rather forced examples. Of more interest is the inclusion of "Ideational Resources". Where these originate if not from the human resources is not clear, but the main aspect of interest is the implicit acknowledgement of the importance of information processing to the functioning of an organisation. This is a distinctly different thread, not found in many other schemes of analysis, yet its importance should not be allowed to pass unmentioned.

Bakke introduces the concept of the Operational Field of an organisation, which can be considered closely analagous to what many others term "the market", which he also appears to consider to be a resource of the organisation.

He then goes on to consider that the functioning of an organisation can be regarded as the operation of Activities on these resources and further that these activities can be classified under five headings, namely:-

(1) Perpetuation
(2) Workflow
(3) Control
(4) Identification
(5) Homeostasis

Perpetuation activities are those acts designed to ensure that the organisation continues to have access to the necessary resources. Examples include recruitment of new personnel, or the issuing of more shares. Workflow activities include all those acts which are necessary to create and distribute the output of an organisation, be it goods or services; Examples include assembly operations, driving vehicles, and sales activities. Control activities are specified as designed to co-ordinate and unify, and are further sub-divided into:-

(a) Directive activies, which initiate action, such as deciding what work will be done and to what standards.

(b) Motivation activities, rewarding or penalising behaviour.

(c) Evaluation activities, such as reviewing and appraising performance, or comparing alternative courses of action.

(c) Communication activities, providing people with the premises and data needed to perform the job.

Identification activities are what might be termed image-building, presenting an image of the organisation both to its members and the environment, with the aim of promoting the character, or "Charter" as Bakke terms it, of the organisation.

Homeostatic activities are those which are designed to preserve the dynamic equilibrium of the organisation, arranging and regulating the other four types of activity so that the organisation is maintained in existance. Again, further sub-divisions of this type of activity are introduced as follows:-

(1) the Fusion Process

(2) the Problem-solving process

(3) the Leadership process

(4) the Legitimisation process

In postulating a Fusion process, Bakke accepts Barnard's premise that there will be conflict between the aims of individuals and the aims of an organisation. The Fusion process is the name he gives to the way in which these differences are reconciled, enabling people to co-operate. He takes this concept further, and applies it to the relationships between the organisation and other outside bodies. Rather than a series of specific acts, Bakke seems to regard this Fusion process as a useful framework for categorising and understanding some otherwise inexplicable activities.

The Problem-solving process is the term applied to the continual solving of non-routine problems, and an attempt is made to provide a sequence of steps used in logical problem-solving. This is a particularly interesting aspect of Bakke's analysis, in that it recognises problem-solving as an activity that occurs within organisation as a necessary part of their activities.

Finally, the Legitimisation process aims to justify and get accepted both the purposes of the organisation and the means adopted to pursue them. This can range from the registering of Articles of Association at one end of the scale to Alfred Sloane's reported dictum of "What's good for General Motors is good for the U.S.A.", at the other. It is an expression of the idea that ultimately an organisation cannot survive without acceptance by society at large.

It is evident that there is some overlap in Bakke's categorisation - for example the precise boundary between Perpetuation and Legitimisation is not altogether clear, nor are the boundaries between Control and Homeostasis precisely defined. Nevertheless, the concepts do provide a framework for surveying the functioning of organisations.

The foregoing authors are not an exhaustive list of people who have contributed to the study of organisations, but it can be maintained that they are reasonably representative of the main strands of thought. Taken as a whole, it can be seen that the basis was laid by Fayol, and others have followed his lead. Most of the concepts and categories introduced by other workers can be related to Fayols, with re-arrangements to suit the differing points of view of other writers, combined with elaborations and further elucidations on particular points. Barnard, for example, contributes the concept of purpose, and conflict of purpose, together with the notion of the informal organisation. Brown elaborates on the variety of role-systems and structures within an organisation, and the importance of psychological and social systems within organisations, as well as introducing the concept of an organisation being regulated at least in part by its environment. Bakke elaborates to some extent on this relationship between organisation and environment, in particular bringing out the point that organisations attempt to influence the environment as well as vice versa. His other major contribution, in the present context, is the introduction to the idea of information processing and problem-solving as an essential part of organisational activity.

Viewed as a basis for a theory of organisation, these works would appear to suffer from a serious limitation. They are all based on reported experience, and represent attempts to classify that experience into general categories. What is lacking are any underlying concepts at a more atomic level of detail that would in the first place suggest a more fundamental scheme of classification and in the second place enable a testable model to be constructed.

Nevertheless, taken together, these writers present a useful picture of the functioning of organisation, and of some of the complexities that need to be accounted for in a theory of organisation.

2. (3) THE MANAGEMENT OF ORGANISATION

In the previous section, "management" was mentioned as one of the functions of organisation, and its tasks set out under broad headings. This particular function has been of great interest, and many people have been concerned to write on various aspects of the managerial process, either to report on the reality of managerial life or to offer more or less comprehensive theories of management.

One of the early pioneers in this field was Taylor (1903, 1911, 1947), who founded the movement known as Scientific Management, an attempt to subject the process of management to the scrutiny of objective, scientific, study. He was moved to this approach by his observations of inefficiency of production and antagonism between workers and management, which seemed completely at odds with his conception of an organisation as a co-operative enterprise. For him, there was no conflict between high wages and high profits. As he wrote (opcit, 1911) "The principal object of management should be to secure the maximum prosperity for the employer, coupled with the maximum prosperity of each employee", which of course, in todays terminology, implies high productivity.

He identified three obstacles to this goal:-

(i) belief by workers that any increase in output would lead to unemployment, a belief which Taylor thought fallacious.

(ii) Defective systems of management, which made it necessary for workers to restrict their output to protect their own interests.

(iii) Inefficient, rule-of-thumb, effort-wasting methods of work.

To overcome these, Taylor proposed use of "Scientific Management", by which he meant firstly a systematic study of work to discover the most efficient way of performing a job, and then a systematic study of management, to discover the most efficient methods of controlling the workers.

To achieve this, Taylor proposed his four underlying principles of management, which were

(i) The development of a true science of work. This revolved around establishing "a fair day's work", acceptable to both workers and management, and for which the worker would be highly paid. This high pay, made possible by high productivity, was an essential element in Taylor's thinking, the due reward for accepting scientific management.

(ii) The scientific selection and progressive development of the workman. In order to ensure that the worker could achieve high output, Taylor believed that it was first of all necessary to select people with the physical and mental qualities required by the job, and then to train them systematically to become "a first-class man". It is of interest that Taylor thought that this training should be a continuous process, to develop the worker to the highest level of which he was capable.

(iii) To bring together the science of work and the scientifically selected and trained men. This Taylor saw as a revolutionary change of attitude, particularly for management. He found little resistance among workers to learning to do a good job for good pay.

(iv) The constant and intimate co-operation of management and men. Taylor's concept here was that management took over all the work for which they were better fitted than the men, (There is an interesting parallel here with the views of Plato (op. cit) on the organisation of the city state). The tasks which he had in mind were those such as specification and verification of methods, and quality, and continuous control of the worker. He maintained that with this close personal contact, opportunities for conflict would be almost eliminated, since the operation of authority would not be arbitrary. The manager would be continually showing that his decisions were subject to the same discipline as the workforce, i.e. the scientific study of work.

Taylor's thinking was developed by a number of people, notably Gantt, Gilbreth, and Bedaux, and led eventually to the group of techniques known as Work Study and/or Industrial Engineering. It can hardly be claimed that they have done justice to his ideas. They have concentrated almost exclusively upon one limited aspect of his work, that of establishing norms for output using improved methods, and almost totally ignored his other principles. Taylor's own contribution was much broader than this, and many of his ideas are still extremely relevant today. He still stands as the pioneer of the application of the scientific spirit of enquiry to the problems of management.

A different approach to management, or perhaps an examination of a different aspect of the subject, is exemplified in the work of Follett (1920, 1924; collected papers 1941, Edited Metcalf and Urwick). Her approach was centred much more on the human interactions within organisations, and especially the attempt to analyse the fundamental motives involved in human relationships. Her aim in this was to answer two questions:-

(i) What do you want men to do ?

(ii) How do you scientifically guide and control men's conduct in work and social relations ?

This work led her to an appreciation of the value of psychology, then a new discipline, and she was a pioneer in applying this tool to the analysis of organisational and managerial problems. The central problems for her were those arising from the need to reconcile individuals and social groups, and to weld these groups together into a cohesive whole. She too formulated four principles,

(i) Co-ordination by direct contact. Follett maintained that the responsible people must be in direct contact, regardless of their position in the organisation. This she applied to horizontal communication across an hierarchy as well as vertical communication.

(ii) Co-ordination in the early stages. In order to increase motivations and morale, people who will be affected by decisions should be brought into the decision-making process at an early stage - before decisions are formulated, not afterwards.

(iii) Co-ordination was the "reciprocal relating" of all factors in a situation. All factors have to be related to one another, and these inter-relationships must themselves be taken into account.

(iv) Co-ordination as a continuing process. The making of management decisions is a continuing process, not a series of isolated events. Many individuals contribute to the making of a decision, and the concept of final responsibility is an illusion. Authority and responsibility should derive from the actual function to be performed rather than from position in an hierarchy.

As can be seen, Follett's main concern was with the integrative aspect of management, with arranging a situation so that people co-operate of their own accord. She laid great stress on her concept of "The law of the situation"; she maintained that conflict could be avoided by the joint study of facts, from which the law of the situation would emerge. This in turn would lead to an agreed course of action.

It is possible to criticise Follett's views as being largely restricted to one aspect of management, and based on a somewhat idealistic view of human nature. Nevertheless, her contribution of the concept of partnership, the joint rational approach to problems, brought a new element into thinking about the management process. In particular, her attention to the importance of psychology initiated a major thread in the understanding of organisations.

A complete contrast to Follett's approach can be found in the work of Simon (1958, 1960, 1960). To Simon, the complete essence of management lies in the taking of decisions, and he has devoted a great deal of attention to the way in which decisions are taken, and the effectiveness of these processes. In outline, he identifies three main stages in reaching a decision.

(i) Finding a problem that requires a decision - an investigative activity

(ii) Inventing, developing and analysing possible courses of action - a design activity

(iii) Selecting a particular course of action from those available - a choice activity

In practice, the process may be much more complex than this, involving iterative loops and many levels of analysis, but the same three stages can still be discerned. Likewise, the implementing of a decision that has been made can be regarded as a further set of problems and decisions.

Over and above this, Simon is concerned to attack the view that managerial decisions were taken on the basis of arriving at a rational evaluation of the maximisation of economic return. To allow for the element of emotional and unconscious factors in human decisions, he introduced the concept of "satisficing" - of a decision being "good enough". This allows a gross simplification of the decision-making process, and reduces the number of factors that have to be considered.

He furthermore distinguishes two types of decision lying at the ends of a continuum. These are programmed and non-programmed decisions. Programmed decisions are routine and repetitive, and frequently there is a definite procedure for dealing with them (an algorithm). On the other hand non-programmed decisions are new and unstructured, with no definite method to resolve them, (heuristic decisions). He foresees that modern developments in mathematics and computing will make it possible for an ever-increasing proportion of unprogrammed decisions to be made on computers, until eventually all aspects of organisation will be automated.

It is possible to disagree with this conclusion on a number of grounds including the difficulties encountered in heuristic programming, and the probable psychological reaction against a computer running a business. Nevertheless, Simon provides important insights into the executive decision process.

It is impossible to discuss the management of organisations adequately without mentioning the work of Urwick and Brech (1947, 1950, 1957, 1963). Their contribution was not so much any specific innovation as in their collation of the work of many others, covering an extremely wide range of topics, and bringing a degree of coherence to the subject. Additionally, they were extremely active in promoting the practical application of the growing body of management theory. Their work has surveyed the field of management much more comprehensively than has been possible here and has provided the foundation for much further work.

2. (4) PEOPLE IN ORGANISATIONS

It has been mentioned several times already that people are an essential element of organisations. An important area of study has been the way that people actually behave within organisations, and the consequences of this behaviour.

This area of interest can be traced to the work of Mayo (1933, 1949), who carried out the well-known Hawthorne studies. In these experiments, a series of changes were introduced into a work situation, and the effect on output noted. The result was that output was increased, but this could not be attributed to the changes - for example, one "change" was to revert to the original, pre-experiment, conditions, which resulted in increased output. Eventually (though not originally) Mayo came to the conclusion that the rise in output resulted from a change of attitude amongst employees, a change brought about by their participation and involvement in the experiments. Coupled with other investigations on attitudes, motivation, and morale, this led to the concept of the informal working group (a different notion to the informal organisation), and a recognition that the group exerted considerable pressure on individuals within it to conform to expected behaviour. Mayo also identified different logics in the attitudes of workers and management; the former was a logic of sentiment, the latter a logic of cost and efficiency. In such a situation, it is all too easy for conflict to arise.

Mayo devoted much time to trying to find ways in which this conflict could be resolved. Although he was unsuccessful in this aim, the true measure of his success is in founding what can be termed the Human Relations school of thought, and the use of the social sciences as a tool of investigation in organisations. He threw great light on the influence of the "human factor" in the work situation.

A different aspect of problems of people and organisation can be found in the work of Jaques (1951, 1956, 1961). He worked at Glacier Metals, and much of it was in association with Brown (op.cit) on the topic of organisation structure. However, his distinctive contribution was in his approach to the analysis of work and responsibility. He divided work into two elements, a "prescribed content" and a "discretionary content". The prescribed content was exactly specified, leaving no need for judgement on the part of the worker. The discretionary content was more loosely specified, and required a degree of judgement from the worker. It was Jaques contention that all jobs had some element of discretionary content, but the proportion of this varied widely from job to job. Furthermore, the discretionary content varies in the length of time that needs to elapse before the effectiveness of an act of judgement can be effectively reviewed. From this, Jaques developed the concept of "time-span of discretion", and the use of this concept to evaluate the importance of a job. He found that time-span of discretion increased as level in the organisational hierarchy increased. In later work, he applied these results to the calculation of wages and salaries, and particularly to the problem of equitable differentials in pay at different levels of the organisational hierarchy.

Although his work has received little follow-up - perhaps because it was seen as just another payment scheme - it deserves attention as a pioneering effort in the application of science to management. It is an attempt to produce a rational basis for the quantification of managerial work.

Mention also needs to be made of Argyris (1957,1960,1962). He examined the role of an individual in an organisation in terms of the conflict between the needs of the two. He maintained that such a conflict was unavoidable, and the result was mutual adaptation, together with the development of informal groups.

The conflict he saw was rooted in the development of an individual from infancy to adulthood, maturity and independence. A mature individual will strive to set his own goals, and will allow others to do the same. Additionally, having set his goals, he will strive to achieve them - and in doing so, will adapt to his environment - a process Argyris terms "self-actualisation". Against this, the basic characteristic of a formal organisation is rationality. Ends and means are expressly given, goals and activities are imposed. The results of this for the individual are that his job requires only a few, shallow, abilities, he becomes dependant upon his leader (i.e. passive and subordinate), his time-perspective is shortened, and, perhaps most important, his goals are defined and controlled for him. Together, these create the conditions for psychological failure.

To adapt to this situation, the individual can adopt one of four courses. He can leave the organisation; he can rise in the organisation; he can use psychological defence mechanisms; or he can become apathetic and disinterested. These adaptive responses are re-inforced by informal groups. Commonly, the observable result is lack of interest and restriction of output. This in turn can set up a vicious circle as management becomes more autocratic and authoritarian.

Argyris suggests some possible means of alleviating this conflict. These include "job enlargement", allowing the worker to use more of his abilities, a more democratic approach by management, and particularly a more skilled and sensitive approach to human relations by managers. (It is interesting to note the parallels between these views and those of Taylor (op. cit)). To this end, he proposed special training for managers in human relations.

In his own way, Argyris has made an important contribution to the understanding of the interaction between people and organisations. His work is separated from that of Mayo by his comparative emphasis on the psychology of the individual, as contrasted to Mayo's emphasis on the importance of group processes.

A feature of the views of people in organisations put forward by Mayo and Argyris is that it basically relates to the viewpoint of a subordinate, particularly of a worker. "Management" appears in their works as a nebulous, and somewhat forbidding, entity, almost a "deus ex machina". There is little acknowledgement of the fact that "management" consists of people too, and little effort to examine the psychological factors that drive the behaviour of managers and executives. Attention to this aspect of organisation can be found in the writing of McGregor (1960) and Likert (1961).

The basis of McGregor's work was an examination of the underlying assumptions about human behaviour that appear to govern managerial behaviour, particularly the type of managerial behaviour prescribed by traditional management theory as expounded by Fayol, Brech, and others referred to above. He summarised these assumptions, under the heading of "Theory X", as follows:-

(i) The average human being has an inherent dislike of work and will avoid it if he can.

(ii) Because of this human characteristic of dislike of work, most people must be coerced, controlled, directed, threatened with punishment to get them to put forth adequate effort toward the achievement of organisational objectives.

(iii) The average human being prefers to be directed, wishes to avoid responsibility, has relatively little ambition, wants security above all.

Theory X has persisted for a long while - indeed, the work of Mayo suggests that it is a self-fulfulling prophecy, in that organisations based on Theory X will produce behaviour in line with its assumptions. However, McGregor felt that Theory X was not necessarily true, a view supported by observation. He proposed an alternative view, which he called Theory Y, in which the basic assumptions about human behaviour were:-

(i) The expenditure of physical and mental effort in work is as natural as play or rest.

(ii) Man will exercise self-direction and self-control in the service of objectives to which he is committed.

(iii) The most significant reward that can be offered to obtain commitment is the satisfaction of the individuals self-actualising needs. This can be a direct product of effort directed towards organisational objectives.

(iv) The average human being learns, under proper conditions, not only to accept but to seek responsibility.

(v) Many more people are able to contribute creatively to the solution of organisational problems than do so.

(vi) At present, the potentialities of the average person are not being fully used.

He went on to examine how the adoption of this theory would affect the running of organisations, particularly in such areas as performance appraisal, salaries, promotions and the like. Not surprisingly, since Theory X and Theory Y are diametrically opposed, he found that many changes could be called for, which goes some way to explaining why his views have not been widely implemented, although lip-service is often paid to them.

A very similar view was put forward by Likert, though in contrast to McGregor his work was based on research findings. These findings showed that low-efficiency groups tended to be in the charge of supervisors who were "job-centred", i.e. supervisors who concentrated on keeping their subordinates busily engaged in going through a specified work cycle in a specified way. (This is an attitude clearly derived from Taylor (op.cit)). Whilst there were some highly productive groups led in this style, they were exceptions, and were not without problems. Generally, the effective groups were supervised by managers who concentrated more on the human aspects of their subordinates problems, and on building effective working groups. They were more concerned with getting high targets accepted than with the details of the work. In particular, these supervisors were interested in their subordinates as individual people, rather than as work-producers.

A common theme in the work of both McGregor and Likert was the view that essential role of management was to provide the support and assistance required by individuals to enable them to function. Between them, they cast light on the psychological processes of managers, complementary to the work of Mayo, and Argyris on the psychology of employees. The work of Jaques forms a distinctively different thread, which to some extent forms a bridge between the others.

2.(5) THE ENVIRONMENT OF THE ORGANISATION

An essential fact about organisations is that their functioning cannot be fully understood by regarding them in isolation. They exist in, interact with, and are a part of, a much wider culture and society.

Several writers have been concerned with this complex relationship, from differening points of view. The political aspect of this relationship is expressed in the work of Burnham (1941). Although not an original view (as he himself says) he analysed the relation between organisations (specifically, business organisations) in Marxist-capitalist terms. The conclusion he came to was not that capitalism was giving way to socialism but that a new class was emerging in society, the managerial class, who were in the process of becoming the dominant social group. Increasingly the wealth of society was being produced by organisations, and organisations were controlled by managers; the role of shareholders, financiers, and the boards of companies were becoming less and less influential, and as a result power and influence were being concentrated in the hands of managers. Increasingly management was taking on the trappings of power, and influencing the political and legal process.

Burnham saw this as a continuing trend, which would have important repercussions on society. There would be a move away from the individualistic ideology of capitalism towards the concept of the state, with increased emphasis on planning, security, duty and order rather than freedom, jobs and individual rights. This trend he named "The Managerial Revolution". Although it cannot be claimed that all his predictions have been realised - perhaps because of the rise of Trade Union power - his analysis is an example of the powerful forces involved in the relation between organisations and society.

A somewhat similar approach to the relation between society and organisation can be seen in the early work of Drucker (1939, 1943, 1946). He took as the archetype of modern organisation the large corporation embodying a mass-production plant. He saw the central dilemma of such organisations as being that although economics was the driving force behind such institutions, economic activity for its own sake makes no sense; account must be taken of wider social, ethical and moral considerations, or the whole structure would wither and die.

To overcome this dilemma, Drucker maintained that a "Functioning Society" was required, which would involve three things. Firstly, the individual must have a definate social function, which would largely be defined in terms of his occupation. Secondly, he must have a recognised social status. Thirdly, and most importantly, these two must be shown to be accepted, by legitimising the distribution of social power.

He contended that, for power to be wielded legitimately, it must be justified in terms of the basic value structure of society, and further that this was no longer true in Western society as a whole. The original basis for managerial authority was derived from individual property rights, but with the rise of large corporations this was no longer true. Managerial power, in practice, was not controlled or limited by shareholders, for various reasons. Thus management power was unfounded, unjustified, uncontrolled and irresponsible, since it was not based on a principle which was accepted by society as legitimate. Hence, management must be legitimised.

To achieve this, it was Drucker's view that organisations needed to pay heed to ethical factors as well as economic factors, and fulfil their social obligations in addition to pursuing profit. The key ethical considerations were, for him, equality of opportunity and individual dignity. The alternative to this type of solution was the disintegration of society as it existed, and its replacement by a totalitarian state.

Although this analysis parallels that of Burnham in many respects, the important element it brings in is the relevance of ethical and moral considerations to the running of a business. This theme is taken up and amplified by Whyte (1956), from the point of view of the individual. In a work which has become apocryphal, Whyte examines the conflict between the Protestant ethic of thrift, hard work and independence, and the demands of the large organisation, which are expressed in what Whyte terms the Social Ethic. This Social Ethic emphasises the values of group identity, group belongingness and group achievement, together with a belief in science as a means of controlling human relationships. He examines at length the pressures upon the individual to conform to group behaviour, and the conflict between these values and the values necessary for attaining higher levels within the management hierarchy. It is Whyte's contention that such influence of the organisation over the individual is against the accepted moral ethic of society, and the individual must struggle to resist it.

In addition to influences such as these, the organisation, particularly a business organisation, must cope with external factors of economics. Economics is an area of study in its own right, which it is not intended to pursue here. An introduction can be found in Tustin (1953) or Leontief (1941). The study of the economy is not directly germane to the issues to be discussed here, it is sufficient to identify it as a source of disturbance external to the organisation.

2.(6) SUMMARY

The foregoing has been intended as a survey of the main threads of what may be termed the received view of organisations, to identify their main characteristics. Organisations consist of a group of people who use resources to accomplish a comman task (or set of tasks). These tasks can be regarded as consisting of several separate identifiable functions, which interact with each other, and within which people are assigned to specific roles. A function of particular interest here is that of management, whose role is broadly to plan, co-ordinate and control, (It is of interest to note that there is little attempt to justify the existence of management within organisations; it is more or less accepted, and its nature described). Management also involves communication, problem-solving, decision-making and motivating. Particular problems arise within an organisation in reconciling the different interests of the people who constitute it.

These then are the general features of organisation. They suggest a complex system, involving equally complex goal-setting and control procedures, and as such merit serious cybernetic consideration. The managerial function is obviously of special cybernetic interest, and is the topic examined in the main part of this thesis.

Before moving on, mention should be made of further work that has been done in the area discussed above. There has been a great deal published which it is not practical to discuss in detail. Much of it, however, develops the main themes set out above.

Firstly, there is much of what can be considered as reportage of management practice, usually admixed with some degree of didactic advice culled from experience, represented for example in the works of Stewart (1963), Townsend (1970), and Parkinson (1958).

Secondly, the topic of organisation structure has been elaborated, by writers such as Newman (1968, 1973), Pfiffner (1960) and Barnes (1970).

Management techniques have received much attention. Amongst the major innovations can be counted the work of Humble (1970) in attempting to rationalise and structure objectives; the rationalisation of decision procedures via game theory and decision trees (see, for example, Williams (1966) or Kaufman (1968)) or through applied logic as presented by Kepnor and Tregoe (1965); and the use of simulation, particularly in "management games". (See, for example, Eilou (1963)).

Similarly, problems of human relations in industry have been examined by workers such as Herzberg (1966) and Marlow (1965, 1970). A development of particular interest has been the work of Blake (1969) in the analysis of managerial style and effectiveness.

3. THE CYBERNETIC VIEW OF ORGANISATIONS

Part I of this thesis discussed the general nature of organisations and set out the general classes of observable phenomena which it is desirable should be accountable for within a cybernetic view of organisation. This section of the thesis sets out to examine existing cybernetic approaches to the problem. In doing so, the decision has been taken to take a fairly broad definition of cybernetics, to confine discussion of a spectrum of approaches to one heading. In some cases, the dividing line between a cybernetic view and a more traditional approach, as outlined in Part I is somewhat hazy, and a matter of personal choice.

Three main themes can be discerned under this heading, the Operational Research approach, the General Systems Theory approach, and what may be termed for convenience the "pure" cybernetic approach - though again the dividing lines are hazy.

The Operational Research approach grew out of the success of applying scientific method to operational problems during World War II. Since then it has developed a philosophy of investigating situations through explicit modelling, usually using mathematical models, and manipulating the model to produce answers to specific problems. Several standard models have been developed to deal with common problems, such as stock control packages, linear programming techniques, network analysis, and queuing theory, as well as a large variety of more specialised models. An introduction to such work can be found in Duckworth (1962), Ackoff and Sasieni (1968) or Rivett (1968). A common feature of this area of study is that it is not so much concerned with problems of organisation as to provide decision procedures to solve particular problems facing particular managers at a particular time. A specially interesting study in this field is that of Ansoff (1965), who developed an analytical model for decision procedures at a very high level of management dealing with problems of major investment in diversification of business.

The roots of General System Theory can be traced to von Bertalanffy (1956) and Sommerhoff (1950), working in the field of biology, who introduced the concept of the open system. At about the same time, Shannon and Weaver (1949) were developing information theory, a tool widely used in the analysis of systems. These concepts were soon applied to business organisations, in various ways. At one level, the general notion of a system as a complex interaction of functions and information flows was taken up by writers on business and applied at a descriptive level to the workings of business. A typical example can be found in the work of Hart (1964). A different approach can be found in what is usually termed systems engineering, as exemplified in Goode and Machol (1957) and Gague (1962). Systems engineering is concerned with the detailed analysis (usually mathematical) of operational, on-line systems, and particularly with the initial design of such systems. Rarely, however, does it deal with matters of organisation and management. The closest approach to these problems is perhaps to be found in the work of Forrester (1961, 1968, 1969, 1971). He is concerned with the effects of time-lags on the dynamics system, the instabilities that can arise because of them, and strategies to reduce their worst effects.

A more managerially oriented application of the systems approach can be found in the work of Miller and Rice (1963, 1967), Emery and Trist (1960, 1965) and Cutcliffe and Strank (1968). These writers used a systems approach to various aspects of the managerial process, as distinct from concentrating on purely production operations.

As far as organisation and management are concerned, the destinctive contribution of cybernetics can be said to be the concepts of feedback and goals. These two ideas have found ready acceptance (though little critical evaluation) in managerial writing, to the point where it is rare to find a recent management text where they are not mentioned. The work of Humble (op. cit) can be seen as a specific application of the concept of "goal" or "objective" in the organisational situation (whether or not it is a successful application is open to debate). Similarly, the work of Donald (1967) shows how these concepts are starting to be applied in the field of accountancy.

However, serious "pure" cybernetic attention to the nature and problems of organisations is comparatively rare. Even Wiener (1948) in his definition of cybernetics as "the science of communication and control in the animal and the machine" makes no reference to organisations, though his later book (1950) does make it clear that he was concerned about many of the problems that occur in organisations. Pask (1961) dismisses the whole subject in four pages, and appears to feel that all that is required is the application of a little elementary cybernetics to solve all problems. Thus he says (p. 110) "Cybernetics offers a scientific approach to the curseduers of organisations, suggests how their behaviours can be catalysed, and the mystique and rule of thumb banished", and proposes that management be replaced with an "evolutionary network" (i.e. a type of adaptive computer). He does acknowledge some of the possible problems, and concludes "On this test, I shall accept the network if and only if it sometimes laughs outright, which, in conclusion, is not impossible". Unfortunately, he gives no specification for the network, nor does he discuss the problem of how the organisation will survive while the network is learning its job. Certainly, he does not appear to feel that there is any important distinction in principle between an organisation and a biological organism.

Ashby (1956, 1960) nowhere makes specific reference to organisations or management, though it is apparent that the concept of ultra-stability is of relevance.

Much of the published cybernetic work which refers to organisation is basically concerned with the application of principles to solve particular managerial problems (and is analagous in this sense to much O.R. work, as discussed above). Some examples of this can be found in Dewan (1969). Much of the work of Simon (1960, 1958) falls into this category, since he is concerned with the decision-making process, which is only one facet of management. Some of his work, however, (1959, 1964) is concerned particularly with goals, and the complex goal structures found in organisations. Thus he says (1964) "First, we discover that it is doubtful whether decisions are generally directed towards achieving a goal. It is easier and clearer to view decisions as being concerned with discovering courses of action that satisfy whole sets of constraints. It is this set, and not any one of its members, that is most accurately viewed as the goal of the action". Whilst there appears to be an element of semantic confusion in this view (i.e. how in such a situation is a line to be drawn between goal and constraint?) it does reflect an important aspect of organisational behaviour, which it is intended to explore further later.

Another writer of the cyberneticsof organisations is George (1970, 1974). He is one of the few people who it can be maintained has commented in depth on organisations from the standpoint of a profound knowledge of cybernetics. His main interest is, however, once again the solution of particular managerial problems through the application of cybernetic insight. Although he covers a wide field, from automation on the factory floor to major investment decisions such as diversification and acquisition, he pays little attention to the structure of organisations. The nearest approach to this general topic is when he discusses Executive Information Systems (1974, pp 100 - 113), and then it appears he takes the roles and structures of management largely for granted. Thus, his introduction to the topic of information systems is as follows:

"This chapter describes executive information systems, which are, generally speaking, a computerised version of data which is basic to decision making and planning.

It is quite vital to the success of such an information system that it be usable by senior management and easy for anyone to handle".

Perhaps the most relevant contribution to the particular aspects of cybernetics in relation to organisations of interest here is the work of Jankowicz (1973). He discusses management in terms of control and goal achievement. He identifies three types of control activity. The first of these is what may be termed "classical feed back", measuring deviation of output against goal and taking corrective action. The second is where control action is initiated on the basis of information of incoming disturbances reaching the manager via an input mechanism. This distinction is perhaps made clearer in diagrammatic form, as below (reproduced from Jankowicz).

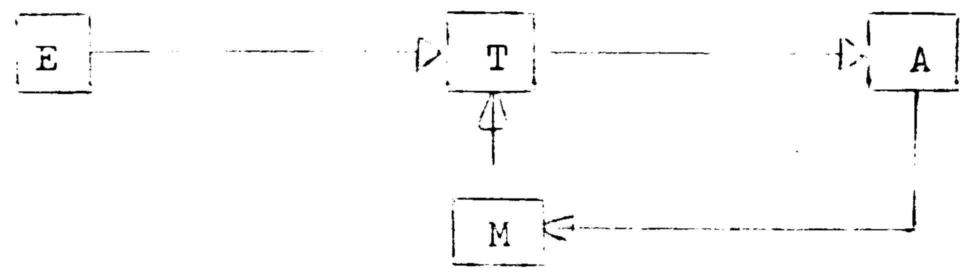


FIG. 1

Figure 1 (Jankowicz's figure 3) illustrates the "classical feedback" form. E is the environment, T is a transformation table, A is the manager's area of responsibility, and M is the manager.

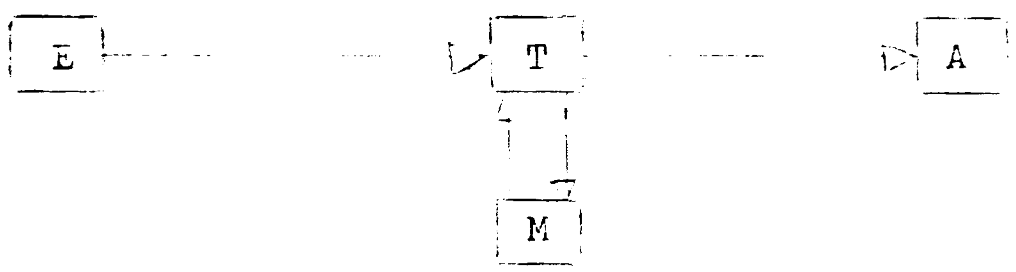


FIG. 2

Figure 2 (also Jankowicz's figure 2) shows the alternative form of feedback proposed by Jankowicz, where the manager is fed information direct from the input.

He then goes on to analyse the time delays inherent in such a system and points out that inevitably decisions will be delayed relative to the disturbances that they are designed to counteract, and some disturbance will be transmitted to A, and perfect control is not possible. - - " . . . . the manager can only achieve control to the extent that environmental disturbances are not critical (. . . .) at every instant at which they occur; the same comment applies more generally to all feedback control systems".

Jankowicz apparently feels that this limitation on control is of serious consequence for an organisation, and proposes a type of control, "strategic control", to overcome the problem. The basic intention of strategic control is to reduce the time-lag in information reaching the manager (M), and is achieved as shown below

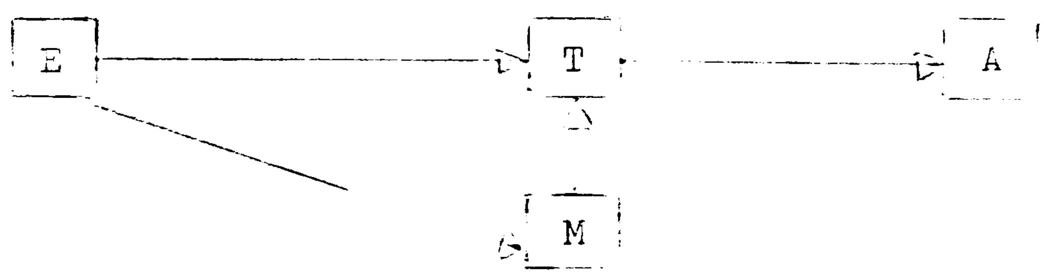


FIG. 3

by incorporating a channel direct from E to M.

What this channel consists of is not specified. However, unless it is assumed that the manager has "direct awareness" of the environment (whatever that may mean) some form of encoding/decoding mechanism must be assumed in the channel $E \rightarrow M$, and it is difficult to see how this channel can then function faster than $E \rightarrow T \rightarrow M$ (for any principle that can be applied to $E \rightarrow M$ can also be applied to $E \rightarrow T \rightarrow M$).

However, this point is not essential to Jankowicz's main line of argument; if one considers the difference between "classical feedback" in fig. 1 (Jankowicz's fig 3) and the alternative form in fig 2, then this latter can be considered to contain the essential elements of "strategic control".

As conceived by Jankowicz, the nature of strategic control appears to be essentially predictive. Disturbances in the environment E are to be classified into two disjoint subsets, those which will be critical to the organisation and those which will not. The former subset, once identified, cause M to change its mode of operation. As Jankowicz himself puts it, the characteristics of strategic control are

" a) It acts as a parameter to individual control operations in T. Thus if we were to see M together with T as a finite automation, the parameter change involved in the $(E_1 - E_2)$ stage results in M + T taking on new responses, coping with new disturbances, indeed becoming a different finite automation by changes in its transformations. The $M + T + (E_1 - E_2)$ stages thus constitute a finite function machine, rather than the "push-pull" finite automation $M + T$ whosefunctions (transformations) do not change over time."

" b) As a parameter, it is at a higher level of discourse (acts within a higher universe of phenomena) than individual control operations."

" c) It must impose some delay on the environmental disturbance".

Whilst the present author is in agreement with the fundamental concept of strategic (or predictive) control as a function of management, the formulation given above requires some comment.

In the first place, there is no detailed mechanism described which will enable the environmental disturbances to be partitioned into "critical" and "non-critical" subsets. This is assigned to the (somewhat mysterious) powers of senior management. In practice, such a distinction is by no means easy to discern. (For example, the appearance of Japanese-manufactured mopeds was not immediately obvious as a threat to the U.K. motorcycle industry, though it has turned out to be merely the thin end of a very long wedge). Equally important, there is no mechanism suggested for selective attention to specific features of the environment ('perception' to use a psychological analogy), yet this is surely essential.

A further area where comment is required is the mechanism by which a parameter change is induced. This is apparently envisaged as a new version of T, where T is an Ashbean-type input/response/outcome table. Jankowicz does not suggest how a new table may be constructed, yet it must be assumed that a new table is required or a parameter-change would not be needed. Nor can it be assumed that there is a store of T-tables available, ready for use. If this were the case, the situation would have occurred previously, and thus would be known not to be critical. Furthermore, if a store of T-tables were available, it would only put the question one stage back as to where they originated.

This leads on to the basic philosophical position behind Jankowicz's approach. He appears to see organisations as finite-function machines, i.e. as deterministic systems. This in turn enables him to construct tables (T) of required responses to produce a required output. It is doubtful whether, in practice, such a philosophy is applicable to real managers in real organisations. Outcomes of courses of action are difficult to predict with any confidence.

As a final point, Jankowicz asserts that strategic control "must impose some delay on the environmental disturbance". It is difficult to envisage how this may be achieved.

However, these difficulties with the proposed model should not obscure the fundamental point that is being made (- indeed Jankowicz himself seems aware of some of the difficulties, though he does not include them in his formal model). This point is, to put it at its simplest, that organisations need to look to the future and act in anticipation of events, rather than just react to them.

Jankowicz also goes on to discuss the topic of self-organisation in relation to organisation, and models this in terms of information theory. Here he seems on less certain ground. He states that " . . . for any system to increase its level of organisation over time, the rate of change of redundancy of its states should increase over time. Taking redundancy as

$$R = 1 - (H/H\ max)$$

where H max represents the entropy of the total possible states of the organism, H the entropy of its states at any one time, we can derive the rate-of change inequality

$$(1/Hmax)\frac{d\ Hmax}{dt} > \frac{1}{H} \cdot \frac{dH}{dt}$$

Presumably this last equation is derived as follows ;

$$\frac{dR}{dt} = \frac{d}{dt}\left(1 - \frac{H}{Hmax}\right)$$

$$= -\left(\frac{1}{Hmax} \cdot \frac{dH}{dt} + H\frac{d}{dt}\left(\frac{1}{Hmax}\right)\right)$$

$$= -\left(\frac{1}{Hmax} \cdot \frac{dH}{dt} - \frac{H}{(Hmax)^2} \cdot \frac{d\ Hmax}{dt}\right)$$

and then saying

$$\frac{dR}{dt} > 0$$

whence $$\frac{H}{(Hmax)^2} \cdot \frac{d\ Hmax}{dt} - \frac{1}{Hmax} \cdot \frac{dH}{dt} > 0$$

and $$(1/Hmax)\frac{d\ Hmax}{dt} > \frac{1}{H} \cdot \frac{dH}{dt}$$

However, this version of the inequality will not ensure that the rate of change of redundancy will increase over time. What is required is that $\frac{d^2R}{dt^2} > 0$, which leads to a much more complex expression which it is not intended to examine here.

(It is also worth noting that the above treatment assumes that H max is variable with time. This would appear to be an arguable assumption - it could equally be assumed that H max is fixed for a given system. This leads immediately to the much simpler inequality $\frac{d^2H}{dt^2} < 0$).

Jancowicz then goes on to map H max onto the total variety in the T-table (the product set of environmental disturbances and reactions from M) and H onto the subset of T that satisfies the organisational goal-set, G. No justification for this mapping is given, and it is not intuitively obvious that it is correct. For example, it is not obvious why the total possible states of a system should be a function of the disturbances in the input to the system, yet this is what the mapping implies. Equally, the mapping ignores Ashby's concept of equifinality, that a given result may arise from more than one state of a system. Additionally, no consideration is given to the possibility that G may itself vary over time.

In summary although his conclusions are open to considerable doubt, Jankowicz has pioneered a cybernetic approach to the nature of organisation structure. It is a topic which is well worth further exploration.

No discussion of the cybernetics of organisations would be complete without reference to the work of Beer (1959, 1962, 1966, 1967). Perhaps more than anyone else, he has developed the application of cybernetic ideas within organisations.

Beer's approach is derived basically from the discipline of Operational Research, and he sees cybernetics as one of a collection of scientific tools available for solving problems, rather than as the discipline best suited to the examination of the whole complex nature of organisations. This can be seen, for example, in 'Decision and Control' (1966) where only one part of the book (Part III, chapters 11-15) is devoted to cybernetics. Furthermore, Beer too is largely concerned with solving specific operational problems facing an organisation (how to control this machine shop, where should a new factory be located) rather than examining the more general problem of how organisations function and how they should be designed.

Where he may be considered to be different from other writers is in his derivation of particular solutions from broad scientific principles. Thus 'Cybernetics and Management' is at least as much concerned with expounding scientific philosophy and its relevance to management as it is with detail application and results.

Beer's most detailed and explicit examination of the cybernetic aspects of management is to be found in "Towards the Cybernetic Factory" (1962) which consequently merits close attention. In passing, it is perhaps worth commenting that the use of the word 'factory' indicates a rather limited view of organisations, even of business organisations, taking no cognisance of equally important activities such as finance, selling, marketing, and so on. Beer's expressed view of management (i.e. " . . stock control, stores control, financial control, cost control and other functions of management . . . "(p.28-29) gives a rather limited range of activities, centred round mechanistic control procedures, and does not cover the totality of the job outlined in Part I of this thesis. It is perhaps also of relevance that Beer admits that the theory he presents was developed to account for a successful technique, rather than being the pre-cursor of that technique (See 'Decision and Control' ch. 13, p. 338. "As a matter of historical fact, the stimulus for the creation of the prototype system of this kind was found in production control. The methods described were devised in 1949 and 1950 for the solution of a practical problem; the full and more generalised account of the underlying theory . . . . was not achieved until later").

Beer's cybernetic account of a factory is in set-theoretic terms, and uses the analogy of a brain - "The cybernetic study . . . went on to construct a model of the company organism and its environment and to detect the brain-like aspects of its control". Much of the paper is concerned with developing a set-theoretic model of brain functioning, and it is a matter of some concern that the question of how this model maps onto the real-life firm is not examined. It is assumed, but not demonstrated, that such a mapping can be performed.

At a broad level, the brain model consists of a sensory mechanism (the T-machine) a decision-taker (the U-machine) an output mechanism (the V-machine) and a reward-mechanism (the R-machine, or 'algedonic loop'), which seems to be similar in many ways to a positive feedback loop. At this level of description, the model is unexceptionable. However, there are a number of unresolved problems when the more detailed model is examined.

Beer's initial model is of the T-machine, which analyses the input set G (Due to typographical problems, the notation here does not always follow the original exactly; Greek has been rendered into Roman equivalents). It would appear that T, which is a form of neural net, initially analyses the input elements Si (Si $\in$ G) into "sensory configurations" via some kind of perception - like association process. Thus, section 1.2.4. " - the formal cortical networks generated by G, for which the i^{th} elemental sensory input is either activated or not". This kind of model has been used for the brain elsewhere (See for example, Stewart (1967) George (1961) McCulloch 1965)) and is again unexceptionable. The problem is that in parallel with this cortical network, Beer uses the concept of quantification of the inputs - "each input Si is assumed to be assigned a value Xi" but omits to discuss how the values Xi may be generated, stored, or processed. Furthermore, no evidence is presented that real brains work on analogue values of this kind. Yet, later in his discussion of the T-machine the use of such values (via a measure - Set Xn) is critical to the model. Complex transformations of the measure-set Xn are called for - eg. p.43 "1.5.1. The assumption is now made that the brain artefact will find some degree of statistical homogeneity convenient in its treatment of these numbers.

To achieve this a succession of statistical transformations will be necessary. 1.5.11. There are various transforms (for example $\varphi = \sin^{-1}\sqrt{p}$) that will tend to return a skewed distribution based on ratios to normal . . . ". Presumably, it must also be assumed that knowledge of such transforms, and the ability to use them, is inborn into the brain (it is difficult to see how they could be learnt, if the use of them is necessary to brain functioning), which argues for an extremely high genetic inheritance of structure, and again no evidence is presented for this. Nor is there any discussion of the neural networks required for such transformations.

There is a similar lack of discussion of another important aspect of the T-machine, or sensory cortex. In 3.251, p.59, it is stated " . . . the sensory cortex, (with its learnt patterns and ability to forecast) . . . ". Nowhere in the formal description of the T-machine is there mentioned any ability to forecast, or how this may be achieved. Yet, this feature is crucial in the operation of the brain.

There are other difficulties with the model, associated with the amount of computation required. One example of this may suffice. This in 3.2622, p.61, it is stated that " . . . Therefore, the maximum structural variety . . . which converges on the U-machine is $2(2^{2n})$" and

Beer seems to consider that n of the order of 30 is possible in practice - e.g. (p.66) - " . . . . further experimental exemplifications have already brought the number of sensations considered in this work up to 36 . . . ".

Beer himself appears to be aware of this difficulty. For example, he says in 3.2623 " . . . The expression for the channel capacity required for output is elusive . . . " Or again, in 3.2624, " . . . attempted calculations suggest, for example, that the transfinite cardinal must in practice be reduced to a cardinal of 4 or 5 . . . " But in 3.2621, the value of this cardinal is given as 2^{21G1}, where G is the set of sensory inputs. Putting these two statements together yields

$$2^{21G1} = 4$$

and hence $1G1 \simeq 1$ - a very limited set. This apparent conflict is not resolved in the paper.

A further point of interest is Beer's description of his U-machine as "an Ashbean homeostat" which is densely interconnected both internally and externally. He does not examine the problem of how long this machine would take to reach stability - or indeed, whether such stability is desirable.

However, in a sense, problems of the detailed functioning of the brain-model are not directly relevant to problems of management, particularly since, as noted above, the mapping from the model to the factory is not well specified. It is thus, in a sense, quite separate from problems of managerial cybernetics.

Beer goes on to discuss an exemplification of his theories in a practical situation (although, as has been pointed out, in fact the exemplification preceded the theory). On examination, this exemplification appears to be chiefly, if not exclusively, concerned with the T-machine aspect of his brain-model, i.e. with statistical transformations of input data. This work would appear to be a highly successful and original appraach to the design of a management information system. By using a series of transformations Beer succeeded in producing a highly relevant homomorphic mapping of input onto a set of predictive measures. Furthermore, he succeeded in making the mechanism of the mapping adaptive, to reflect changes in operating conditions, an advance whose significance is perhaps not generally recognised. It does not seem to have been followed up elsewhere.

Going on from this point, Beer's other work (1959, 1966, 1967) shows a great deal of concern with problems of variety and regulation (in the Ashbean sense). He asserts that organisations exist in an environment of extremely high variety, and is interested in cybernetics as a means of assisting organisations to cope with high variety. In particular, he is concerned with the concept of a "black box" inserted into control procedures to provide sufficient variety in the control loop to cope with the input variety, and with the relation between (thermodynamic) entropy and measures of information.

This approach is arguable as to its correctness. In the first place, if it is true that organisations need to cope with extremely high variety, then it is equally true that they do so successfully - organisations are extremely viable entities. It would seem more appropriate scientifically to attempt to establish what mechanisms are employed to cope with variety than to import mechanisms into organisations to achieve this end.

Furthermore, his more detailed approach to variety and requisite channel capacity seems confused. Thus, in "Decision and Control", p.252, he illustrates his point with a hypothetical set of 7 binary elements, in which all possible interconnections are allowed, which yields a variety of 2^{42} distinguishable states. Mapping this set onto a machine-shop with seven machines, he says "The manager has to handle a system of great complexity, it was said; just how great is the variety that must be handled is now beginning to emerge as a measured quantity". Later (p.282) he relates this variety to the manager's task via Ashby's Law of Requisite Variety, e.g. he says " . . . the capacity to proliferate variety within the control box must be as great or greater than the capacity of the situation box to proliferate variety".

This view seems erroneous (or at least incomplete) on two counts. In the first place, Beer has omitted the important variable of time. Thus, in his hypothetical example, the variety generated is 42 bits; for control purposes, it is important to know over what span of time this total variety may occur. If it takes one minute for the system to permute over all its possible states, then the rate of information transmission is $42/60 \simeq .75$ bits/second - which is by no means an impossible channel capacity for a manager to achieve. (In practice, one would assume that it would take much longer than a minute for a machine shop to pass through all possible states).

In the second place, Beer appears to misinterpret Ashby's law. The Law of Requisite Variety establishes an upper limit to the amount of regulation or control that may be achieved; it does not state that control channel capacity must equal or exceed situational rate of variety for any control to be achieved. In fact, the maximum amount of control that can be achieved is expressed by the difference between the two; if control capacity is less than situational capacity, there will be residual variety left in the output. From the organisational point of view, such a situation may be perfectly acceptable; production output may vary by ± 10% per day, but the situation is not critical provided there is sufficient storage capacity in the system and there is no long-term trend in the daily average.

There are two further points that are relevant here, concerned with the actual amount of variety generated in the environment. The first is that there are causal laws operating in the environment; knowledge of (or discovery or invention of) such laws will serve to reduce considerably the variety input to an organisation. The second is that variety is a measure imposed by an observer on a system, rather than an intrinsic property of the real system. Thus (to take an example from Beer), if the input to a system is billets of steel, the input variety is a function of the measures applied to such billets. If the measures are weight in milligrams, length in micrometers, chemical composition to · 001%, then the input variety is likely to be high. If the measures are simply the number of lumps of mild steel weighing about 5 tons and between 18 and 22 ft. long, the input variety will be correspondingly low. Following on from this, it can be seen that in fact organisations will themselves take measures to restrict the input variety to an amount with which they can cope; if it truly is necessary for the input billets to be accurate in length, weight and composition, the organisation will seek suppliers who can meet these specifications.

Thus when Beer discusses the need to introduce sufficient variety into the control system via a "black box" (see, for example, "Decision and Control, ch. 13. pp 229-334), it is possible to question the logical basis for such a requirement. This is particularly so when it is realised that, on close examination, the effect of his "black box" is to effect a reduction in transmitted variety, not an increase.

Beer also discusses at length the relation between thermodynamic entropy of a system and information-content of a system. His starting point is the similarity between the equations

$$S = k \log g \qquad \text{(entropy)}$$

and

$$I = -\sum_i pi \log pi \qquad \text{(information)}$$

This is a dubious base, unless some closer connections can be found between pi and g. To illustrate this, consider the equations

$$r^2 = x^2 + y^2 \qquad \text{(a circle)}$$

$$a^2 = b^2 + c^2 \qquad \text{(Pythagoras)}$$

$$= \sigma^2 = \sigma_1^2 + \sigma_2^2$$

Does this imply that a circle is the same thing as a right triangle, and that both of these are an experimental variance? Such a conclusion is not logical. Or further, consider the equation for intensity in dB,

$$dB = 20 \log (P1/PO)$$

$$= -K \log P1$$

Does this infer by analogy that the information content of a message is equivalent to its intensity? Again, such a conclusion appears peculiar.

On closer examination, the alleged equivalence between information and entropy appears to rest on a misinterpretation of the meaning of the variable g. Beer states it meaning (p.356) as "If the innumberable ways, of which there are, (say) g, are all equally likely to occur, then the entropy moves as the logarithm of g". - in other words, g is the number of possible states of the system. On the other hand, Boltzmann's derivation of the entropy equation (as given in Allen and Maxwell (1952) pp 815-816) assigns to g (given as W in the text) the probability of the most likely state of the system. These two meanings of g are substantially different, and the physicists interpretation must be accorded precedence. It is perhaps also worth noting that Boltzmann's derivation has been the subject of criticism, and that alternative expressions for entropy are available not involving the notion of 'number of states of the system' but based on physical dimensions such as energy and temperature. Furthermore, it may be of relevance that entropy as a concept is usually applied to closed systems, information to open systems.

Overall, it would seem safest to say that, although there may be a relation between entropy and information, such a relation has not as yet been satisfactorily demonstrated.

Until it has been so demonstrated, there must be considerable doubt as to the reliability of any conclusions drawn from such a supposed relationship.[1]

A further point raised by Beer is the application of Ashby's concept of homeostasis as a description of the interactions both between internal departments of an organisation and between an organisation and its environment. (See, for example, 1966, p.257, or 1967 pp 156-162). The organisation is modelled as attempting to come to equilibrium via a progression through unstable states until a stable set of interactions is reached, in a similar fashion to Ashby's Homeostat (See Ashby, 1960, ch.8). Although this parallel is in some ways attractive - it certainly reflects the constantly changing patterns of activity within an organisation - it is open to doubt whether or not it is an accurate account of organisational philosophy. It could equally well be argued that much of the functioning of organisations is designed, conciously or unconciously, specifically to avoid any permanent homeostatic equilibrium. Companies pursue a constant policy of innovation and change, in what can be interpreted as an attempt to veto any possible state of equilibrium. Indeed, it is probable that a company that achieved a policy of homeostatic equilibrium would be regarded as stagnating.

1. A paper by Brillouin (1951) shows that in at least one set of circumstances, there can be identity between entropy and information. However, this is not a generalised result.

It is perhaps true that, in the short term, the combined effect of a large number of organisations interacting with the market produces a kind of apparent equilibruim, in which variables such as market share, and profitability remain reasonably constant, but history suggests that these are comparatively short-term stabilities, as illustrated by the rise of new technology bringing obsolescence to many industries.

It is in fact arguable whether such a state of homeostatic equilibrium as is proposed by Beer is in fact desirable. It would seem that the most obvious exemplification of the results of such an approach can be seen in the early civilisation of Egypt. Certainly, equilibrium was established in that society - it lasted for millennia - but the result was complete stagnation, and eventually a slow decline. Progress and equilibrium can thus be argued to be opposed to each other, unless the equilibrium that is being discussed is of some highly abstracted variable.

However, the argument is now straying well away from the topic of the cybernetics of organisation. In summary, it can be said that the cybernetic study of organisation has been the subject of comparatively little attention. Most of the work that has been done has been concerned with solving particular operational problems, rather than examining the nature of organisations and their management. What work has been done in this latter field appears open to a variety of questions.

4. THE CYBERNETICS OF MANAGEMENT

What follows now is an attempt at an in-depth account of organisations, and particularly the management of organisations, from a cybernetic viewpoint. It falls into four main parts. Firstly, a detailed model is developed, based on cybernetic concepts. Secondly, the model is compared with the reported nature of organisations, to see how it accounts for known aspects of organisational behaviour, and to validate it as a model. Thirdly, a practical application of the model to real-life situations is reported. Fourthly, the theoretical properties of the model are developed, to provide further insights into the needs of management.

4.1 A MODEL OF ORGANISATION AND MANAGEMENT

A convenient starting point for building a model is with a systems engineering approach to the operational activities of the organisation. At a very broad level of detail, these can be mapped onto a system diagram such as that given in fig. 4.

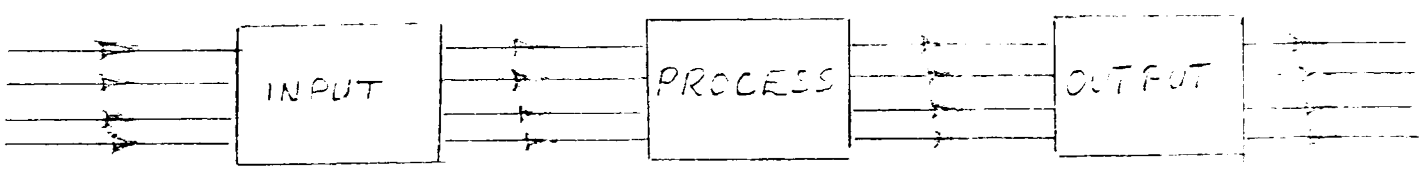


fig. 4.

Block diagrams such as these can be expanded to much greater levels of detail, showing specific functions and information flows. Examples of detailed analysis

Forrester (1961, 1968), Goode and Machol (1957) and several others. Such models, when appropriately quantified, have been found to be extremely useful tools for the analysis and design of operational systems. Generally, however, these models are not extended to include management operations as part of the analysis; at best, they indicate points at which decisions are required by (presumably) management, without examining the way such decisions may be arrived at.

Such diagrams can be extended, however, to give some indication of management activity. The justification for this extension lies in the fact of perturbation. In real life, the operations of an organisation will be disturbed by a variety of influences. Some will arise from within the organisation (e.g. machines will wear out or fail, employees will make errors) and some will arise outside the organisation (e.g. supply and prices of inputs will vary - c.f. Beer's envioamental variety). In order for the organisations operations to continue to run, a degree of regulation will be required, which it is apparent, can be divided initially into two categories, internal and external.

Internal regulation as a term is intended to cover these activities which an organisation undertakes to adjust its internal operations to cope with perturbation, and can itself be subdivided into two categories, according to whether the disturbance originates as an internal malfunction or as input variety. These two sub-divisions can be equated to Jankowicz's concepts of feedback control and strategic control, or (somewhat less precisely) to the managerial concepts of planning and administration.

External control as a term is intended to include those activities which an organisation may opt to undertake to achieve some degree of regulation over its environment. This is an area which has received little attention in the literature, but is a common form of organisational activity, and which can be broadly divided into three sub-categories, the input environment, the output environment and the social environment. Organisations frequently take steps to regulate their input by applying a degree of control to their suppliers - for example, contracts may give quite precise specifications, several suppliers may be used to ensure continuity of delivery, and so on. An extreme example is where an organisation will purchase an outside supplier outright, which can be interpreted as an attempt to regulate its input. A different example is the case where organisations attempt to influence educational and training institutions, to ensure a supply of suitably qualified employees.

Organisational attempts to regulate the output environment can be grouped under the general heading of sales promotion and advertising. The intention here is clear, to regulate the market in favour of using the organisation's product and is often regarded as a key business activity.

Organisations exist within societies, and are influenced by the society in which they find themselves. Society as a whole attempts to regulate the organisations within it (for example, it legislates on certain activities that companies must, or must not, undertake). Equally companies attempt to influence society, by asserting that their goods and activities are socially acceptable, and by forming pressure groups, to influence power centres within society - particularly government. This latter process is documented, for example, in the work of Gamson (1968), Olson (1965) Eckstein (1960) and Nettle (1965). Although they examine the process from differing viewpoints, they all agree that organisations bring influence to bear on governments to futher their own ends.

Obviously, the extent of such activity will depend, amongst other things, upon the size of an organisation and the threat or opportunity perceived at any given period. The main point though is that organisations are involved in this type of regulatory activity, and a full cybernetic account of organisations needs to allow for it.

To summarise at this point then, on the assumption that potentially disruptive perturbations will arrive both within and without an organisation, it has been established that there will be a need for control activities to ensure survival. Furthermore, there are two distinct categories of such activity, internal and external regulation, which can be futher sub-divided. Each of these merits detailed examination.

1. <u>Internal Regulation - Feedback or Administrative Control</u>

Feedback control can be illustrated on a block diagram as shown in fig.5., which is a modification of fig.4.

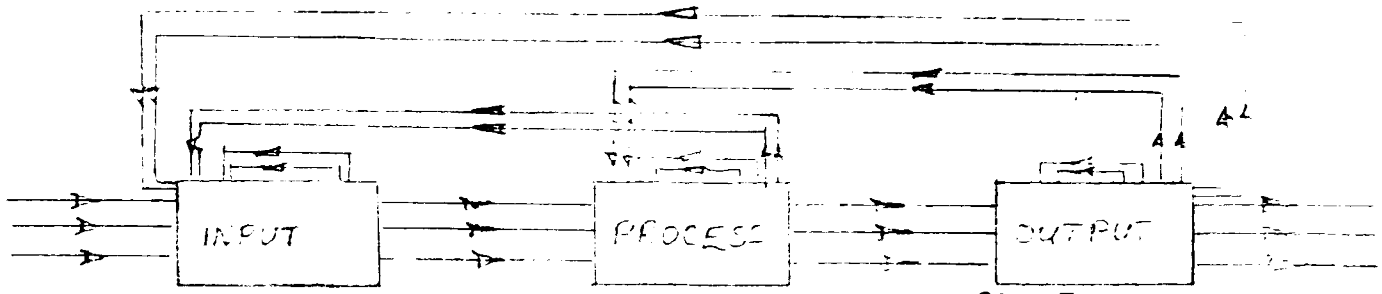


fig.5.

This shows schematically the feedback loops required to control the effects of internal malfunction and random disturbance in the input. Several loops are shown, to illustrate that many variables will need to be controlled, not just one. Two loops are shown associated directly with each major functional area, to illustrate that each of these will have a number of variables to be regulated locally. Two further loops are shown connecting adjacent major functions (e.g. between 'input'and 'process') to indicate the possible need for co-ordinated action by two functions. Finally, two further loops are shown, covering the whole organisation, to indicate the possible need for co-ordinated action by the whole enterprise.

It will be appreciated that fig. 5. is schematic in the extreme. In practice, the functional organisation of an enterprise is more complex than the three-box approximation given, and many more than these two variables require to be controlled. However, such elaborations involve no difficulty of principle. A point that does require some comment is the justification for the control linkages between major functions. It could be argued that local control of each function should be perfectly sufficient to enable proper performance to occur; each function would maintain its output within limits to allow other functions to perform properly.

This argument, however, depends upon the assumption that the overall organisation, and each constituent function, has been properly designed and specified to fit into the overall system, in full knowledge of all problems likely to occur. This cannot be assumed to be the case (many instances could be cited where it is not - see Forrester (1961) for example) and thus there emerges a requirement for functions to interact via feedback.

It is not asserted that this requirement is necessarily fulfilled in actual organisations; in fact, as others such as Pask (1961) and Beer (1967) have noted, the normal Hierarchical form of organisation structure puts great barriers in the way of such horizontal communication. It would seem possible to conclude on this basis that traditional management structure is based (consiously or unconsiously) on the premise that its systems are well designed. Clearly, if this were the case, and no horizontal communication was required, then the traditional management pyramid emerges as the proper organisational structure (at least in terms of internal feedback regulation).

To some extent, the argument is being anticipated here.

What has been demonstrated is a need for a multiplicity of feedback loops to control an organisation. These can be identified as the task of management, In particular, a group of such control tasks can be brought together and assigned to one man, a manager. (Note that this does not imply that a manager is necessarily solely concerned with regulation of the enterprise; indeed the title of 'manager' can be bestowed more as a mark of organisational status than any necessary connection with regulation and control. In what follows, the terms 'manager' and 'management' will be intended to refer to control activities as set out above and as implemented by organisational personnel) It is also worth pointing out that however desirable it may be from a theoretical viewpoint, in practice there need be no logical connection between the individual control loops that are grouped together to form a task. Nor is it unknown for what is essentially the same control loop to be allocated to more than one person; perhaps the most outstanding example of this practice is the use of inspectors to check on operatives work, but examples of the same thing can be found at higher levels in the organisational hierarchy.

As a final note of caution, it cannot be guaranteed in practice that all the control loops that are theoretically required will actually exist in any given organisation. For example, many companies have found themselves in difficulties because of failure to install adequate control of cash flow. The reverse situation is also possible, in that organisations may install control loops that are either irrelevent, redundant, or particularly harmful.

With these points in mind, it is appropriate now to start to build up a more detailed model of feedback control, starting, for convenience at the lowest organisational level, that of the operative. Operatives jobs can be described by a feedback model, as discussed by Walford (1968). The basic nature of the model is as shown in fig. 6.

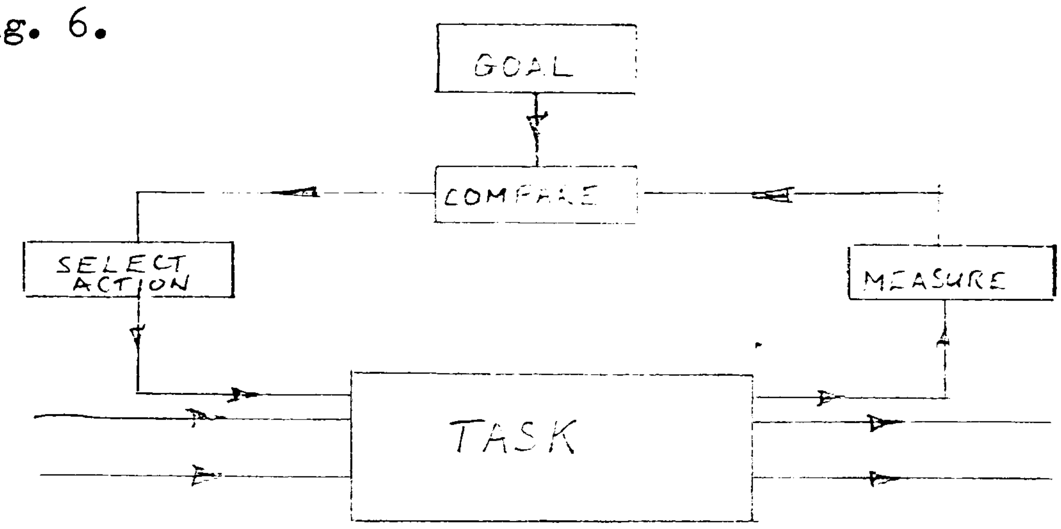


fig.6.

The operatives measure the progress of his task in some way (not necessarily via instrument readings) compares this with the goal of the operation, and selects an action designed to either correct any observed deviations or continue along the chosen path if there are no deviations. (This type of model is very common in a variety of contexts). It is however deficient in at lease one important aspect, in that it suggests that the operative has a single unitary goal. Even at operative level this is not the case, and a more representative diagram of the situation would be as shown in fig.7., where four goals are shown.

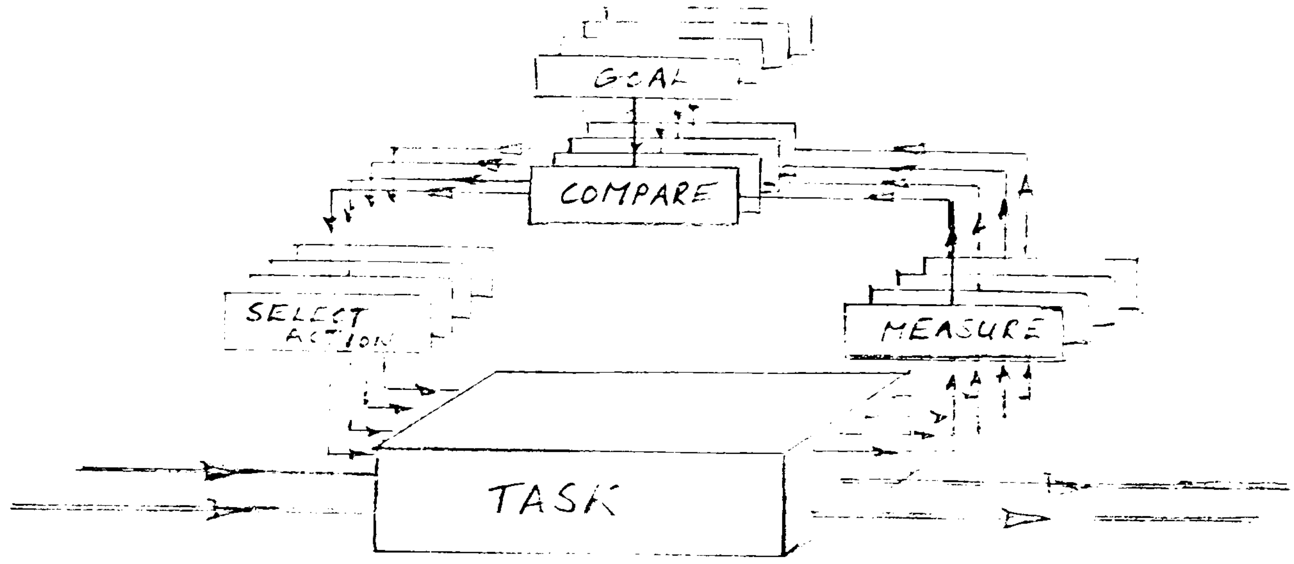


fig. 7.

This aspect of organisation has been discussed by Jankowicz (1973) where he introduces the concept of a goal-set, G where

$$G = (G_1, G_2, G_3, \ldots G_j \ldots G_m)$$

and furthermore where each G_j may set up a series of sub-goals,

$$G_j = (g_1, g_2, g_3 \ldots g_n)$$

which is in agreement with the formulation here.

It is perhaps worth re-emphasising that there is not necessarily any logical connection between any or all of the G_j. The common link may be only that they have all been allocated as the responsibility of a single person. Although it is rare to find a completely disjoint set for G, it is not uncommon to find that G can be sensibly partitioned into two or three distinct sub-sets - for example the job of telephonist/receptionist would break down in such a way. One consequence of this is that it can often be difficult to find a word or brief phrase that summarises the job adequetely. Thus statements about the total goal-vector G tend to be imprecise and nebulous, to the point where they become of extremely limited use as predictors of behaviour. Alternatively, as Pask (1969) has pointed out, the system can be regarded as possessing an underspecified goal.

It should also be pointed out that, due to imperfections in the design of the system, indivual elements within G may be incompatible one with another, e.g.

$$G_5 \rightarrow \sim G20$$

or perhaps in more complex forms such as

$$G_1 \cup G_7 \rightarrow \sim G_{19} \cup G_8$$

Incompatibles such as these are generally resolved by the fact that organisational goals are frequently in the form of ranges, (e.g. wages bill between £x + £y per week) or cut off points (e.g. return on capital not less than 12%) which gives sufficient room for maneouvre to approximate achievement of many goals. A further mechanism for the resolution of such conflicts is to assert that some elements of G are more important than others (this for example is a key assumption in the approach of Humble (1968)) and to concentrate on those. This approach may be considered as equivalant to attaching a weighting factor W_j, to each G_j, and the task then becomes one of maximising W, where

$$W = W_1\ G_1 + W_2\ G_2 + \ldots\ W_j\ G_j\ \ldots + W_m\ G_m$$

This is not necessarily a straightforward procedure if m is large and the elements of G interact, as suggested above. In practice, m may well be large; for example, a study of sales managers showed that each was responsible for 35 outlets, and had to control 15-20 quantifiable goals within each outlet, plus a number of qualitative goals, In this instance, m was therefore of the order of 1,000.

Another point of great relevance here is that the set G will contain the employee's own personal objectives as well as organisational goals. This is unadvoidable, since it is impossible to employ a fraction of a person (- which is perhaps the organisational equivalent of Plank's quantium theory?) Furthermore, Barnard (op.cit.) and Argyris (op.cit.) amongst others have agreed that some degree of conflict between indivual and organisational goals is inevitable. Since they are not identical this conclusion is, of course logical.

There seem to be two possible theoretical approaches to the resolution of such conflict. If G is partitioned into two sub-sets, organisational goals G_j^o and personal goals, G_ℓ^p, the first approach is to seek to maximise the intersection of these two sets, i.e. maximise P where

$$P = G_j^o \cap G_\ell^p$$

The second approach is to attach a very high weighting to one or two elements in G where a common interest exits, and use this to persuade the individual to subordinate his objectives to organisational goals. Common examples of such elements are continuity of employment, or wages. This is equivalent to maximising Q, where

$$Q = |W_j . G_j^o| - |W_r . G_\ell^p|$$

and Wj , Wr are the weighting factors. [1]

These approaches would appear to correspond to distinct managerial styles. The P-approach corresponds with the human-relations schools of management, as discussed by people

1. Mixed strategies are also possible.

such as Argyris (op.cit.) Mazlow (op.cit.) and others, allowing people to participate in the running of the organisation and aiming to create job satisfaction. The Q-approach would seem to correspond with the authoritanian school of management, whose outright preponents are not well represented in the liturature but are characterised by McGregor (g.v.) as upholding theory X.

It is of interest to explore the probable results of the two approaches to conflict-resolution. Using the P-approach can reasonably expected to lead to a greater degree of worker involvement with the job, greater loyalty and better job performance. It will also involve recognition, implicit or explicit, that employees will have an influence on the goals of the enterprise, which may well be psychologically unacceptable to senior management. Furthermore, the gaining of psychological acceptance of organisational goals as overlapping with personal goals involves what may be seen as an act of leadership. The need for leadership will be higher in organisations adopting a P-approach, with a consequent need for greater personal belief in commitment to organisational goals on the part of senior management. This element of personel belief will tend to make it harder to make radical changes to organisational policy if they are needed.

One type of organisation of especial interest from this point of view is a Trade Union. In theory at least - and to a considerable degree in practice - the goal setting process is a reversal of the usual process. The goals of Trade Union leadership are determined by the common goals of indivual members - and in this instance the goals will be personal rather than organisational. If the indiviuals personal goal-set is I^n, where

$$I^n = (I_1, I_2, I_3, \ldots\ I_1 \ldots\ I_z)$$

then the goals of a Trade Union, I, can be symbolised as the intersection of the individual I^u i.e.

$$I = I1 \cap I2 \cap I3 \ldots \cap Iu \cap \ldots \cap Ir$$

In practice, I will probably reduce to a very small set, representing the comparatively few interests held in common by members. This difference in goal-setting structure has a profound effect upon the nature of Trade Union activity, and particularly upon its leadership. This is frequently forgotten, because the organisational structure of such bodies is outwardly similar to company structure.

The Q-approach is substantially different from the P-approach. It is essentially a bargain struck between employer and employee, where the latter agrees to subordinate himself to the former in return for some form of consideration – usually financial, (it is worth noting that the value of such a bargain to the employee depends upon his having time available away from the organisation in order to enjoy such benefits). It is this type of approach that is likely to appeal to the entrepreneur stereotype, who conducts his affairs in this way. It can be expected to result in a great deal of concentration upon the heavily-weighted elements (usually wages) with the employee trying to maximise its value, the employer trying to minimise it. Hence, it can also be expected to encourage co-operative (or union) activities amongst employees. Furthermore it does nothing to encourage psychological acceptance of organisational goals by employees.

Although there are no firm data to support this analysis it corresponds to subjective impressions of different types of organisation. Furthermore, it facilitates cybernetic discussion of a range of problems reported in the literature (vide Argyris (1960), Mayo (1933), Jaques (1961), Bernard (1948)) that have not received cybernetic attention.

Two aspects of the multiple-goal situation are of interest from a cybernetic viewpoint. The first is that bringing about a stable situation where all goals are met is a difficult problem in itself. Ashby (1960, ch.20) has examined an analogous situation, and concluded that the probability of stability of a multi-variable system decreases as the number of variables increases - hypothesises that the probability falls off as $(\frac{1}{2})^n$ where n is the number of variables. Thus introducing a new variable into a situation, or changing one goal among many, can be expected to change the stability of the overall system dramatically. Furthermore even if a new stable region is discovered, its characteristics are likely to be markedly different from the previous situation. An intuitive appreciation of this may lie at the root of the phenomenon of resistance to change.

The second aspect, which is related to the first, calls into question the validity of attaching weighting factors to goals. Adopting such an approach may allow some variables to depart widely from desired values, which may in turn affect the overall stability of the total system. Such affects have been discussed at length by Ashby (1956), where he shows how a system may change abruptly from one field of behavior to another when its state-vector exceeds certain limits.

Overall the picture emerging of organisations up to this point is one of virtually total instability, of constant teetering on the edge of violent upheaval. To counteract this, it must be borne in mind that the day-to-day operation of most organisations contain inbuilt inertia - particularly so in the case of large scale manufactoring operations.

So far, the examination of organisations has not proceeded very far. It is still at the operator level. However, the problems discussed at this level apply equally at other levels, and it is worthwhile to point out that the application of cybernetic principles can be made at all levels of organisation.

As far as administrative or feedback management is concerned, an organisation can be regarded as a series of hierarchically arranged supervisory feedback loops. Bearing in mind that G is a vector, the basic arrangement is as shown in fig. 7.

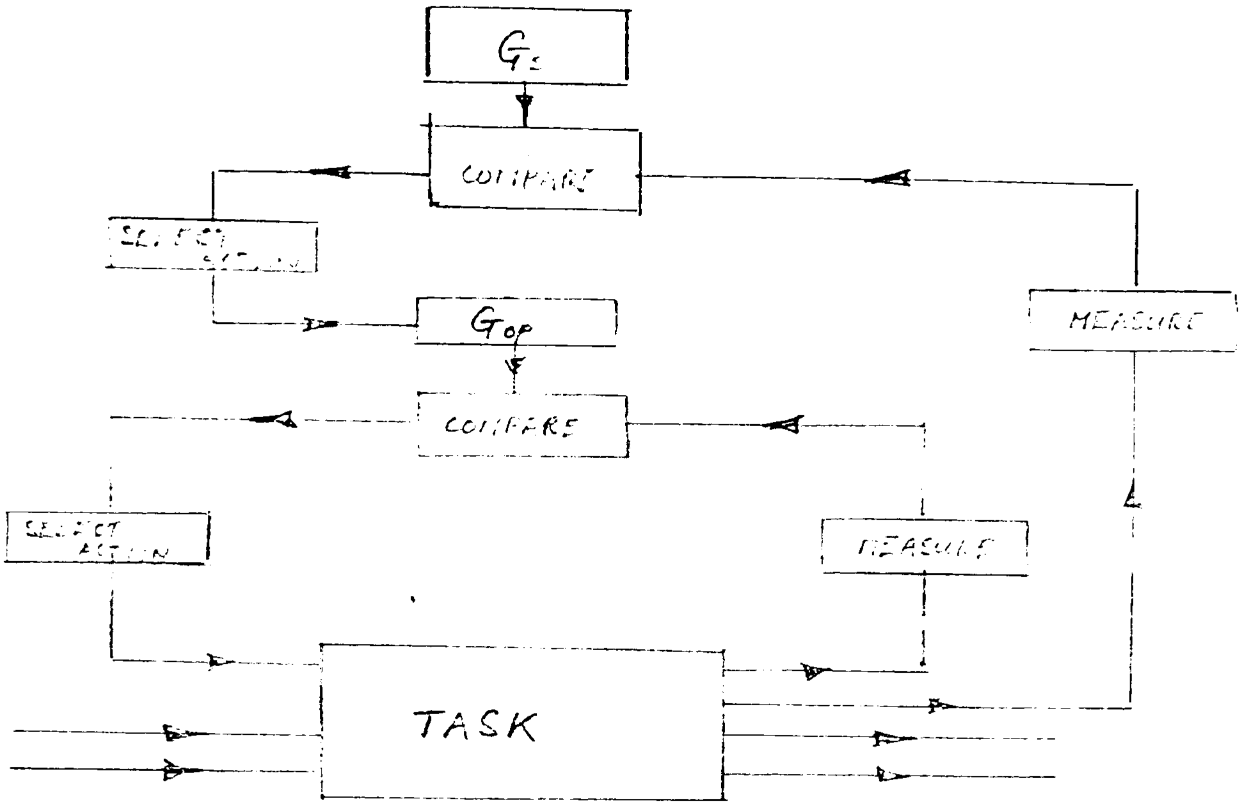


fig.7.

Where Gs is the supervisors goal-set, Gop the operators goal-set. The basic functioning of this supervisory loop is that the supervisor assess current performance against his own goals, and selects any corrective action required.

The most fundamental point about fig.7., is that corrective action is not applied directly to the task, but to the goal-set Gop (this is encapsulated in the definition of management as "Getting things done through people"). Furthermore, in the present context, this corrective action is not basically a servo-mechanism type designed to track a changing goal, but is more akin to a simple control loop.

The question then naturally arises as to whether there is any theoretical need for supervision of this type? Once the operator has accepted a set of goals, why should there be any need to check on his performance?

The answer to this comes in three parts. The first is that Gop is stored in human memory, it is therefore liable to decay and error; therefore, some reinforcement will be required. The second is that, as discussed above, Gop contains personal ambitions which will evolve with time. In turn, these evolving aims will, if unchecked, influence task performance. The third is that the organisational subset of Gop is derived as a subset of Gs. Thus if

$$Gs = (G1s.\ G2s,\ G3s\ \ldots\ Gjs\ \ldots\ Gms)$$

then

$$Gop = (Ges,\ Gfs,\ \ldots\ Gns)$$

and where each Gfs can be viewed as generating a series of sub-goals,

$$Gfs = (g1,\ g2,\ g3 \ldots gu)$$

(vide Jankowiz (1973), Pask (1969)) Now if, as is likely these goals and sub-goals have been set less than perfectly to bring about the desired results, then they will require to be reviewed and revised in the light of experience. This is a third function of the supervisory control loop, where overall purpose can thus be seen as to compensate for the inevitable shortcomings of real people in real situations.

Having accepted the need for supervision of this type, it should not be imagined that the cybernetics of the process are as straightforward and simple as might be inferred from fig.7. i.e. the straightforward issuing of an instruction which is promptly put into practice.

In the first place, remembering that the corrective action is applied to the set Gop, the superior will find it useful to know that this set consists of - or at least, what are some of the major components. He is thus involved with the general problem of establishing the goals of a working system. Pask (1969) has examined this general situation, and indentifies two different strategies, either to observe behaviour and infer goals from the relation between input and output or alternatively to enquire directly of the system what its goals are. Pask states this distinction as being between the system being regarded either as 'taciturn' or 'language-orientated', which distinction is basically a choice made by the observer rather than a characteristic of the system (Though there are some systems for which it is difficult to discover the appropriate language).

It is not proposed to pursue the point in great detail here. It should be noted, though, that either strategy can give rise to difficulties for the supervisor. Inferring goals from behaviour can lead to error, and equally asking the operator to state his goals can result in inaccurate or untruthful responses. Many supervisors in fact use both strategies together - and may spend much time trying to resolve the discrepancies between the answers from the two approaches.

A point of particular interest made by Pask is that "A taciturn system can neither be given new goals nor can it state its goals". (Although, as he also indicates, it is possible to change parameters of a given goal within a taciturn system). This is of relevance at a later stage in this model of organisation.

Another of the problems is that of language; instructions are issued and received via the medium of language. What is important here is not so much some of the deeper theoretical issues (as discussed for example by Chomsky (1957) or Morris (1946) but the more progmatic aspects of the subject as discussed by McGregor (1960), Mazlow (1965) and Drucker (1970). What seems to emerge from these writers is that it is necessary to set up and maintain a language that is meaningful to both parties - and furthermore that insufficient attention is paid to this problem by organisations. The results are commonly misunderstanding, misinterpreatations and mistrust. It would seem from this that many managers adopt what could be termed an 'information-theoretic' approach, rather than a 'communication-theoretic' approach. They ignore the fact that it is meaning that is passed on, not simply information, and this can only be done in the framework of a language that has a common significance to both sides of the conversation.

The setting up and maintaining of such languages involves a good deal of continuing effort, and involves both sides of the conversation. In conventional management terms, the 'upward' flow of the interaction is of equal importance to the 'downward' flow, as Drucker (1970) is at pains to emphasise. Furthermore, the setting up and maintaining of language is an essentially "off line" activity, which is facilitated by informal contact outside the working situation. It is of interest that many organisations activly discourage informal contact between different organisational levels. The basic result of such strategies is well discussed by Machiavelli (1961).

On the face of it, the foregoing line of argument is refuted by the military situation, where the paradigm is orders crisply issued and instantly obeyed. It is worthwhile, therefore, to examine the situation in more detail.

On closer examination it becomes apparent that, in fact military organisations do expend a great deal of effort to build up and maintain a language sufficient for their purposes. In this context, it is worth noting initially that the bulk of the time of armed forces is spend in "off line" activities - i.e. real (rather than simulated) combat is a relatively rare activity. Additionally, a code of dicipline is rigourously inculcated and maintained. Military forces will go to great lengths to maintain dicipline, up to and including execution by firing squad. (This latter is a sanction not normally available to industrial management).

The language used in military situations is highly codified, with exact terminology and usage; e.g. "Present arms" is an order uniformly and universally interpreted, as a result of intensive training and discipline. It is also a relatively simplified language, which is perhaps a result of the G-vector generally being simpler in structure. Thus, there are fewer conflicting G-elements (for example, questions of cost seldom figure largely in combat decisions) and priorities amongst the G-elements are much clearer.

The importance of such matters in a combat situation, where troops may suddenly come under the command of an unfamiliar officer, can be readily appreciated. That is not at issue here. What is less clear is whether the lessons learned by the armed forces can be readily transferred to the industrial situation.

Given these provisos, it is still interesting that many of the really great commanders apparently owed a large part of their success to their ability to communicate with their forces quite outside official channels, to establish a form of sempathy with their men. Montgomery was one such, as discussed by Horrocks (1965).

Thus far, communication (as distinct from information transfer) has been discussed and its importance to the functioning organisation established. Information transfer is, of course, also an important function, and is represented in the diagram of fig. 7 by the process of 'Gathering information', 'Compare' and 'Select action'. The distinction can be illustrated by the fact that the first two of these can be (and often are) automated to some extent, frequently with the use of computers. It should not however be concluded from this that managerial information systems can consist entirley of various types of statistical report, such as profit and loss accounts. More information than this is needed for successful management.

There are two aspects to this question. In the first place, many important aspects of an operation cannot readily be quantified (at least, in the present stage of technology, though it is feasible that some progress may be made). Examples of such variables are such things as motivation and morale. Fundamentally, the information required will be determined by the G-vector; in principle, each element of G will require a feedback path to control it. Whether the necessary information is readily quantifiable or not will depend upon the nature of each particular G.

The second aspect of the question is more fundamental. In order to control a system, a model of that system must be provided in the feedback loop (See Ashby and Conant (1970)) As far as simple feedback systems are concerned such modelling may be at a very primitive level (e.g. in a cistern, water level is modelled as the height of the float). Furthermore, as Ashby and Conant (op.cit.) point out, at this level of sophistication, "almost anything may serve as a model of almost anything else". Thus, if a manager takes decisions on the basis of "What would Uncle Fred do in a situation like this?", then Uncle Fred is serving as a model of the system under consideration. Nor, let is be stressed, is this necessarily a bad model in the circumstances being considered here. If 'Uncle Fred' as a model yields good decisions, then there is no need to seek further.

However, the point to be made here is that the control model used does not appear by some mysterious process out of thin air. It is obtained by study of the system under consideration. Ashby (1956, 1960) has discussed the general problem in cybernetic terms and Garner (1968) provides specific examples of the modelling of human performance. Though neither writer specifies it in these terms, what is essentially required is a metalanguage to describe the system, to propose hypthesised variables and parameters, which are then used to experiment with the system and see if the hypothesised model is adequate. Thus management information also needs to cater for this need to set up models of the organisation, and this precedes any flow of information about values of particular variables (The distinction is akin to the distinction made by Mackay (1950) between metron and logon content of information). In practice, these extra sources of management information may be obtained by a variety of means, such as written reports or actual visits and physical inspection of the system.

It should not be imaginged that the flow of such types of information is simply a once-off affair. Many managers are constantly updating their model of the organisation -

indeed, the desk-bound manager concerned only with 'the figures' is an archetypal whipping-horse in management training. He rapidly becomes divorced from reality - i.e. his model becomes inappropriate. The managerial model is vital to the interpretation of statistical information, without it, all the figures in the world are meaningless. In passing, it should be noted that the managerial model will contain a model of human behaviour, i.e. the system modelled contains a human element.

It should also be noted that these flows of modelling information are as liable as any other channel to noise and distortion. In practice, these factors may be deliberately introduced by the system under study; the consequent problems for management need no elaboration.

Thus it can be seen that the process 'Gather Information' is not necessarily as straightforward in organisations as might appear from fig.7. The extra considerations can be shown schematically as in fig. 8.

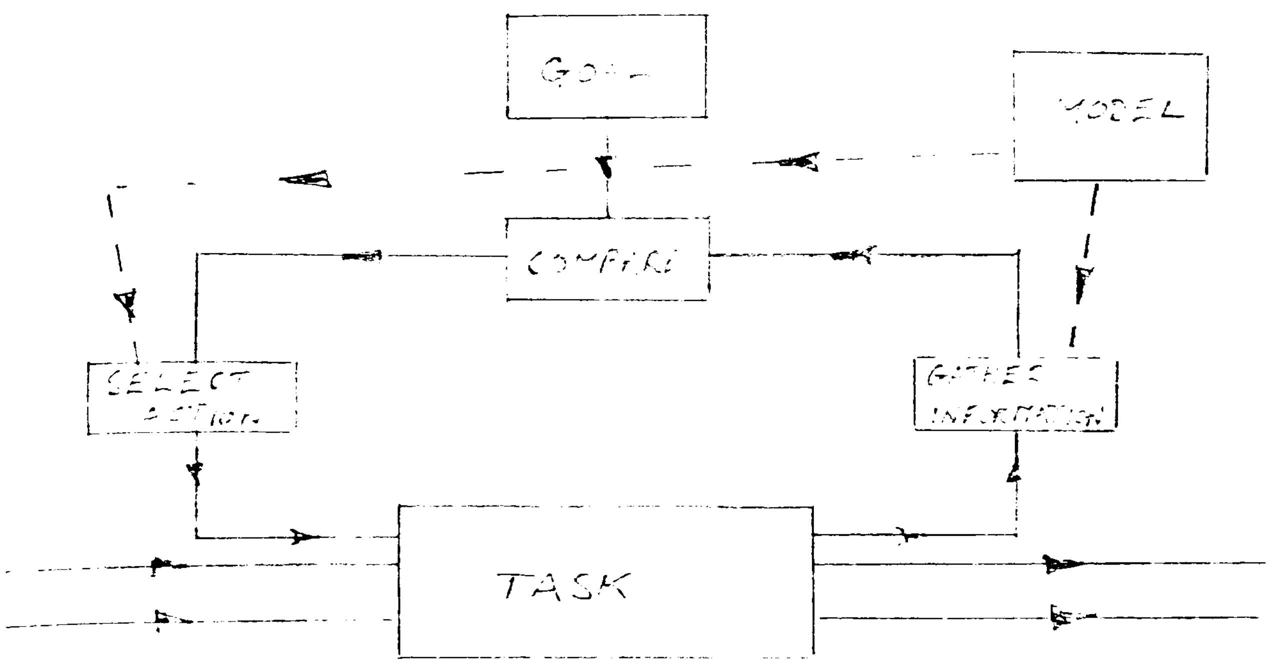


Fig. 8.

This indicates that the gathering of information may be viewed as a filtering process, selecting only those items which are relevant to the G-vector in question. The model provides the setting of the filter, and changes in the model can thus influence the data gathered. It is perhaps worth mentioning that a major type of model frequently encountered in organisations is the accounting or financial model, which is generally assumed to be constructed to reflect the working of the business. This is not necessarily the case, and it is not unknown for organisations to be re-constructed to fit a particular accounting model especially when accountants gain considerable authority in an organisation.

It is also worth mentioning that, although the actual gathering of data may be a reasonably continous process, the issuing of reports and statistics is generally done at discrete intervals (a week, a month, a year). Thus a supervisory control loop is basically an intermittent rather than a continuous process.

After information has been gathered the next stage in the process is comparison with the goal. This again is not altogether a straightforward process. The difficulty arises when as is frequently the case, the G-vector is not well specified (see, for example, Humble (1968)).

Three particular types of difficulty can be identified. In the first place, it can happen that a control variable is specified, but no value is attached. Statements such as "Manufacture item x at minimum cost" or "Deliver goods as quickly as possible" are examples of this. In instances such as these, the manager himself will supply a value believed to be appropriate - and the value chosen may well differ significantly from the value implicit in the mind of the manager's supervisor.

In the second place, although a value may be specified, no tolerance, or permissable range, is supplied. If for example, production costs are 2.4% above target, this information on its own is not sufficient to decide whether this is a minor inconvenience or a major disaster requiring a crash programme to rectify it. Here again, in the absence of other guidance, the individual manager will set his own tolerance limits. Variations on this theme are possible, such as a goal in terms of a limit function (e,g. labour turnover less than 10% p.a.) or a trend function (e.g. to reduce labour turnover).

In the third place, the appropriate weighting factors or priorities amongst the elements of G may not be set out specifically - at best, they will be ranked in order of priority for a small number of elements.

However, it is the final stage, that labelled 'Select Action' which is generally considered to be essentially a managerial function, usually under the title of decision-taking. (The term 'Select Action' is preferred here, in an attempt to emphasise the importance of actually doing something as the result of a decision). Other parts of the control loop can be (and often are) performed by others, it is the taking of decision that is the core of the managerial role.

Despite what has been written by others(e.g. Simon (1958, 1960), Kaufman (1968), Luce & Raiffa (1957)) it is the contention here that, <u>in the context of simple feedback management</u>, decision processes are, in principle, extremely straightforward, and do not need to involve complex evaluations often discussed. In principle, all that is required is a simple black-box model linking a deviation in the result of a task with the required adjustment to the input. There is no need to establish cause and effect, no need for complex evaluations of outcomes and payoffs. A simple black-box approach will serve equally well, if not better.

This does not of course, imply that managers necessarily use such a model for control - they may use considerably more complex approaches. It does though imply that they should seek to develop such black-box approaches. The writers observation does suggest that many managers do in fact adopt this type of stategy - which it is easy to misinterpret as a sign of a closed, single-track mind of low intelligence, whereas it is a cybernetically highly justified approach, within its own context. It can be regarded as a sign of acute perception - for it is by no means easy to develop a workable black-box analysis of a complex dynamic system.

Two complications of this basic contention deserves some discussion. The first is that, in the managerial situation, one option open when performance deviates from target is to change the goal. Since, as discussed above, goals are frequently not well specified, this often does not present much practical difficulty. It can be considered the organisational equivalent of the game-theoretic solution of 'leaving the field'.

The second is the complication introduced by the fact that G is a vector, and that the elements of G interact in the sense that an adjustment to return Gj to target may induce changes in the system that will disturb Gr. This is equivalent to saying that, when controlling Gi, the set G - Gi acts as a constraint on the permissable actions. Thus it can be seen as suggested by Simon (1959) that a given variable can act both as a goal and as a constraint - but not at the same time; which it is depends upon circumstances at the time.

Up to this point, the cybernetic aspects of the supervisor-single operative situation have been considered. This does not correspond with the reality of organisational relationships (except in a few anomalous instances). In practice a manager generally has several direct subordinates - typically 5 or 6, though the range is from 2 to 40 or more. The model can easily be extended to show this feature of organisation, as in fig. 9.

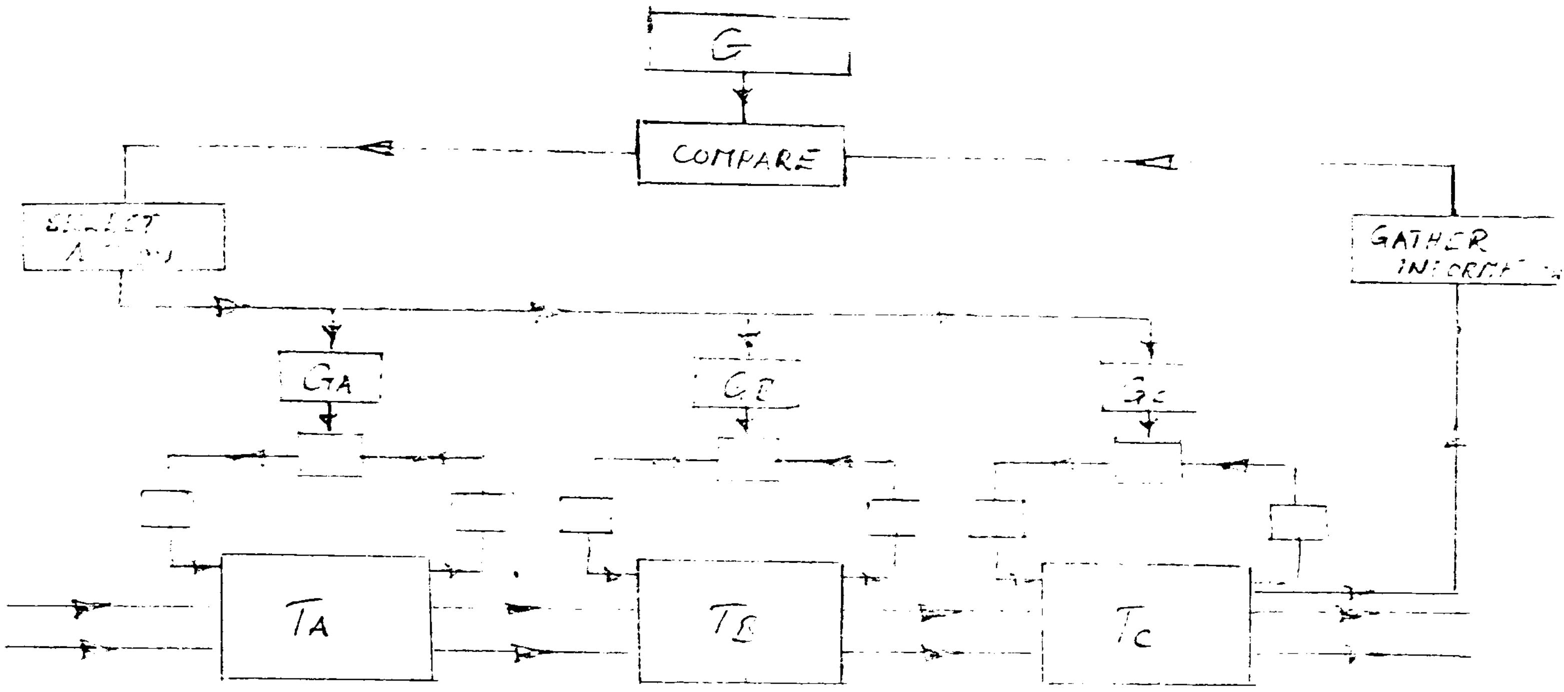


fig.9.

Here three subordinates are shown, though it can be seen that in principle the diagram could be extended to any number of subordinates. For the sake of clarity, the modelling information channels discussed above are not shown; for similar reasons, the supervisory control loop is shown as receiving all its information from the final output, though in reality information could be and frequently is derived from any intermediate point as well. The managers area of responsibility is defined by the points at which his information channels start and finish (c.f. Millar and Rice (1967) and the concept that "the executive functions at the boundaries of the organisation").

Fig. 9. shows a simple serial relationship between operation F1, F2, and F3, typical perhaps of a large-scale flow process. In practice, much more complex relationships may hold between operations, and modelling techniques have been developed for such cases (see Forrester (1961, 1968) or Beer (1967) for examples). A case that requires special mention is where the supervisor is in

charge of essentially parallel operations - such as a sales manager in charge of a team of salesmen, each with his own territory. This represents the opposite extreme to the series situation shown in fig.9. Mixed series/ parallel situations are possible. There is a fundamental distinction between these two forms which will be discussed below.

Over and above the problems of the supervisor/single subordinate situation, the introduction of several subordinates introduces extra feature of some interest.

One of the features is the complication added to the supervisors model of the situation. With a series operation as shown in fig.9., the model must encompass a greater degree of complexity, and thus input-output relationships may be more difficult to determine. With a parallel operation, although the same basic model may serve for all functions, it is desirable that it be given at least the same degree of 'fine tuning' to adjust it to the individual characteristics of each function, in effect, for n different functions, n different models will be required- or to be more precise, n different theories for the same model will be required. For either the series or the parallel case, different languages may be required for each operator.

The other features arise from the possibility of the operators or subordinates communicating among themselves.

Fig. 9 can be modified along the lines indicated in fig.10 to show some of the possibilities.

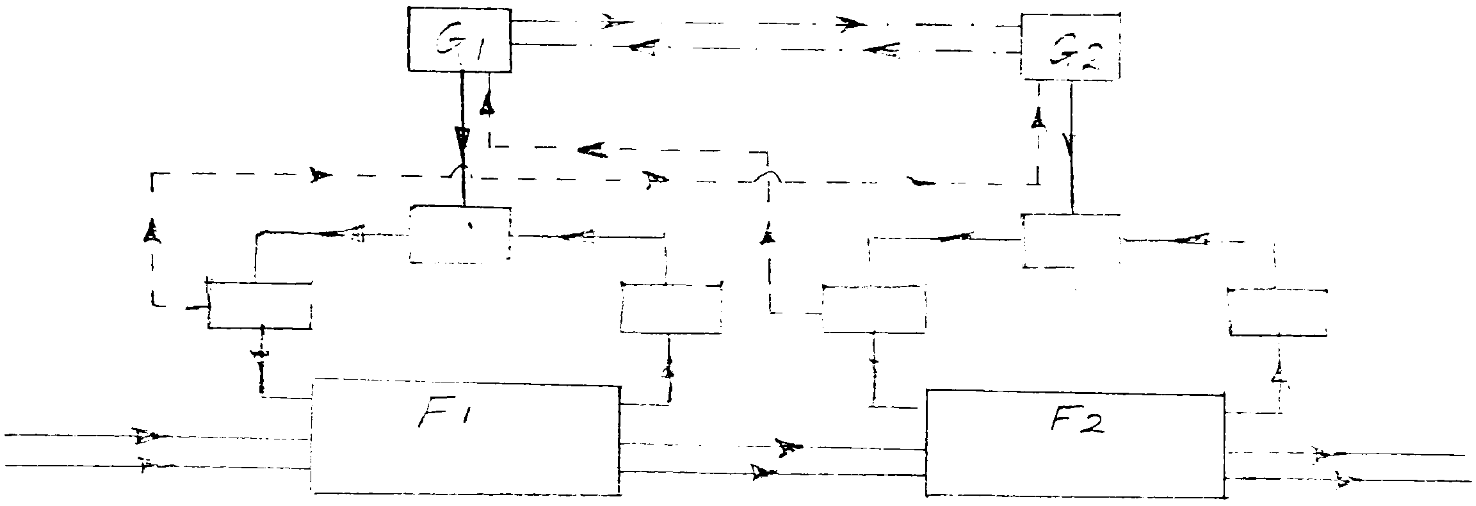


fig.10.

Two main types of communication are indicated. One is a channel from the 'select action' process of F2 (or F_1) to G_1 (or G_2). This represents the situation where one operative decides that the best way to cope with his difficulties is to modify the operation of some other function (e.g. "Slow down a bit Fred, and give us a chance") In organisational theory, such requests should go through the supervisory control loop; in practice they often do not. The other type of communication is a channel direct between the two G-vectors of the operatives. This represents the informal communication that will take place between colleagues, and will concern particularly, it can be presumed, those elements of the G-vectors that are personal rather than organisationally derived. Such communications may generate what are effectively new elements in the goal-set G_n^o (particularly when it is remembered that the personal component of G_n^o is subject to influences derived from outside the organisation).

This form of communication will obviously lead to the formation of working groups, this may result in mutually beneficial change - or equally lead to conflict and 'clashes of personality'. The effect is likely to be more pronounced in parallel-working organisations. The generation of new elements in the G-vector can also give rise to what can be termed with some justification 'organisational psycholgy', i.e. those aspects of behaviour arising specifically from the nature of organisations.

The arrangement shown in Fig. 10 is equivalent to Pask's (1971) concept of minimal structure required for a meaningful conversation, if the inputs from F_1 to F_2 are regarded as low level language. This in turn implies that the system has the capability of self-organisation. (Though the same does not necessarily apply if F_1, F_2 operate in parallel). This may or may not work to the advantage of the organisation, depending upon whether the self-organisation is centred upon organisational goals or personal goals. This in turn will be a feature of whether the organisation uses the P-approach or the Q-approach described above.

Mapping the P-approach onto the human relations centred school of management and the Q-approach onto the authoritarian school, thus leads to the hypothesis that a human-relations centred organisation will tend to be flexible and adaptive in behaviour with comparatively good industrial relations but comparatively lacking in 'business drive' (due to the fact that personal goals and organisational goals influence each other), whereas the authoritarian school will tend to be rigid and inflexible, have many disputes, particularly over wages, but will have a hard, aggressive approach to business, due to the dominance of organisational goals.

Data would be needed to confirm or deny this hypothesis, although it does appear to have some degree of face validity, at an intuitive level. Which form of organisation is superior is yet another question which would be of interest to answer(and indeed, remembering that organisations are fundamentally for fulfilling human needs, the criteria for 'superiority' are not self evident; simple measures of profitability are only part of the answer). The main point here, however, is that issues such as these can be seen to arise from cybernetic mechanisms and can be discussed in cybernetic terms.

It is also possible to attempt to quantify the likelyhood of significant Trade Union or similar activity. This can be posited to be a function of, amongst other things, size of group, time spent on intra-group communication, and time spent in communication with supervisor. Thus the probability of Trade Union activity Ptu can be expressed as

$$Ptu = f\ (n,\ t1,\ t2)$$

Where n = number of people in work group

t 1 = time spent with work as a cohesive unit

t 2 = time spent in direct communication with superior.

It is possible to speculate on the possible form of the function. Thus, it can be expected that the dependance of Pru upon n will not be linear, and may well be some form of power law, possibly quadratic. Since Pru is a pure number, t, and t_2 must appear as a ratio. Therfore, an initial approximation to Pru would take the form.

$$Pru \propto n^2 \ t_1/t_2$$

though experimental evidence would be required to verify this.

Even in such a crude form, the expression indicates that after factors being equal the probability of Trade Union activity is highest with a large workforce whose tasks interact and who therefore communicate often and where there is a low ratio of supervisors to operatives. This does not sound unrealistic as a reflection of the real world.

Another corollary of intra-group communication is that it enables subordinates to construct a far more comprehensive model of the supervisor, via shared experience, than the supervisor has of any individual subordinate. It is thus possible that, in appropriate circumstances, subordinates are better able to regulate some aspects of supervisory behaviour than the supervisor is able to regulate subordinate behaviour.

Thus far, the consequences of the possibilty of self-organisation for the supervisory control loop have not been pursued. One feature of importance is that the control model used in this loop should, in principle, be revised to conform to the altered system it is trying to regulate. As discussed previously, this implies more than can be achieved through reporting systems, the structure of the model needs to be changed, which can only be achieved via the flow of modelling information. In practice, it is not uncommon for managers to complain that they do not know what is actually going on in the organisation under their control. It is important to realise that this is not necessarily equivalent to a statement that they see their area of control as a 'black box'; it may imply that not only is it a 'black box', but a 'black box' whose input-output relationships are not static. It would appear that some managers find such a situation unmanageable and insist on standard procedures - ie actively inhibit self-organisation of their area of command. Others find it acceptable, and even encourage it. It may be that the root of this difference of attitude lies in the differences between the control model used by different managers (for nothing said up till now implies that there is any unique, or even optimal model for simple feedback regulation).

Using Blake's (1969) dimensions of managerial attitudes (i.e. broadly 'people-control' or 'task-control' it can be hypothesised that a 'people-control' manager uses models of his subordinates for control, a 'task control' manager uses models of the operation for control. The former will be less affected by self-organisation, and thus such a manager will be more flexible and still maintain control. Furthermore, the operation under his command is likely to be better adapted to provailing circumstances, and performance will be superior. Such a conclusion is supported by the work of Argyris (q.v).

A related issue here is that in the normal cause of events a manager may expect promotion and/or transfer his career. In theory, this would imply that his old models should be discarded and new ones built. At the other extreme, it may be that the manager retains his models, and attempts to re-shape his area of authority to conform with them. In practice, some middle course between the two is adopted. Again, it can be expected that a manager with 'people control' models could transfer more readily and painlessly than a more 'task-control' manager. Thus it is not unknown for a highly competant manager within a technical specialism to be unsuccessful outside his own specialist field.

The diagram of fig.9. shows a single level of management. It will be readily appreciated that the diagram could be extended vertically, to show a further contol loop spanning two or more supervisors, and so on, which would then correspond to the familiar hierarchical model of organisation.

Only a few extra features of significance arise from such a vertical expansion, and no great discussion is required.

In the first place, it should be re-emphasised that a diagram such as fig.9. is not intended to imply that all the (theoretically) necessary control loops are in fact present in any given organisation or, vice versa, that control loops found to be present in actual organisations are theoretically necessary, or indeed desirable.

An equally important feature that has not been mentioned previously is that it is not necessarily the case in practice that all the control loops pertinent to a particular function are channelled through a single individual. (A case in point is the personnel department in many organisations; it is often the practice for personnel to legislate over variables such as hours of work, payment, an so on, taking the control of such goals out of the hands of the individual manager). The general consequence of such practices, in theoretical terms, is that the control of a single function is mediated through two or more distinct models. These models may not necessarily be compatible one with another. The behaviour of this type of system does not appear to have been considered in the literature from a theoretical standpoint.

As a final point, it can be seen that expanding the diagram of fig.9. will allow much greater opportunity for inter-communication in an organisation, and consequently great opportunity for self-organisation. The degree to which this self-organisation can occur can be influenced greatly by the managerial level to which particular control loops are routed; if many control loops are channelled through senior management levels, then the possibilities for self-organisation at the lower levels are correspondingly reduced. As the responsibility for certain control loops is passed to lower managerial levels (i.e. as delegation occurs), so the opportunities for self-organisation increase,

Such a process is similar to what would be described as 'decentralisation' in traditional management terminology ('Centralisation' is obviously the reverse of this process). What is of interest here is not simply that such a concept can be modelled in cybernetic terms, but that some underlying rationale for it can be discerned. Thus, if an organisation is in a reasonably static environment, and is not contemplating any fundamental change in its own operation, then it may well make sense to allow the individual parts of the organisation to attain local equilibria through self-organisation, i.e. to de-centralise. Conversely, when co-ordinated action of the enterprise as a whole is required, to respond to either external threats or internal innovation, then it may be appropriate to centralise control.

It is not claimed that actual companies, do always centralise or de-centralise for this reason alone; it may be undertaken for a variety of other reasons, including the personal attitudes and predilection of a powerful member of top management. What is of interest here is the possible logical justification in cybernetic terms of a well-known feature of organisational behaviour.

However, mention of centralisation and de-centralisation brings up a key feature of the nature of organisations. This is that they have the capability (and frequently use it) to change themselves to meet new needs. This change can be at any level, and includes the ability to change management information systems and decision procedures - indeed, to completely re-structure any or all of the management of an organisation. There would seem to be no adequate analogy with this process within the natural world - it would be rather as if an organism could spontaneously generate a new type of input sense-organs and nerve structure for each environment in which it found itself. This is a feature of organisation that has not received much comment (apart from writers such as Burns and Stalker (op cit)) It is as though the approach to organisation has been based on the belief that there is one optimal form of organisation, and what is needed is research to identify it. However, in cybernetic terms, the ability to change organisation can bestow great benefits in a changing environment. Indeed, it may be this ability that enables organisations to survive in environments that are arguably of much higher variety than environments that one is used to considering - there are few natural redundancies (laws of nature) in the organisational environment. In fact, the environment of organisations can be regarded as made up almost entirely of other organisations.

This line of argument is leading on to topics that are more readily considered under the heading of strategic management. Before passing on this topic, it would be as well to summarise briefly what has been discussed up to now.

A feedback model of management has been proposed, and developed in detail. This has been found sufficient to explain many of the reported features of organisation, and offers the means of quantifying many of the problems occurring in organisations. It has been concerned basically with the problems of, line management, to use managerial jargon.

1.2 Internal Regulation - Feedforward or Strategic Control

In addition to the feedback mechanisms described previously, it seems necessary, for reasons which will become apparant, to hypothesise a further set of basically anticipatory (or what may be termed feedforward) control mechanisms. The basic reasons for postulating such mechanisms are cybernetic necessity on the one hand and observed management practice on the other.

The basic form of such a mechanism is well-known; it was proposed by Ashby (1956) as the basic model for regulation. As adapted for the purpose here, it can be shown as in fig.10.

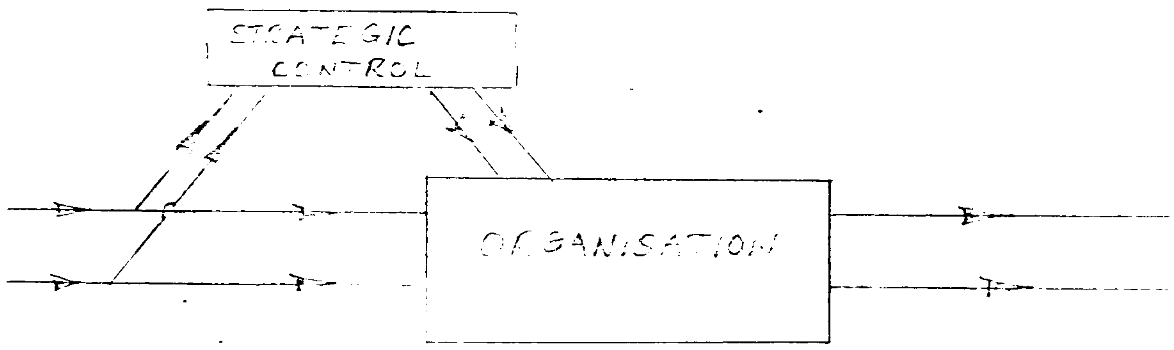


fig.10.

The basic principle illustrated is that, instead of using information about output behaviour, strategic control uses information derived from the input to adjust organisation performance. Ashby (1956) showed that this was canonically equivalent to the more normal feedback characterisation of control activity.

As has been discussed above, Jankowicz (1973) has used this model for the analysis of management, and indeed the term "strategic" has been taken from his work. He apparently saw the chief virtue of strategic control as reducing time-lags inherent in a feedback system. Thus he says "The second type of control, strategic control, attempts to regulate disturbances by reducing the time in which information reaches the manager". Furthermore, he sees this type of anticipatory action as the role of senior management, as setting parameter-values for the operation of lower-level managers.

These arguments do not seem to cover all the important aspects of the nature of strategic management or feedforward control. As far as speed of response is concerned, although the delay involved in feedback is widely recognised, in practical terms it is usually not of any great consequence, particularly if the delay is small compared to the rate of change in the environment. Furthermore, the feedback process itself, if suitably elaborated, can provide a sufficient framework for parameter changes within the system, as has been described.

Indeed, on closer examination, the idea that feed-forward control necessarily facilitates regulation by improving speed of response is not so simple as it at first appears. It is worth pursuing this point in some detail, since it leads on to clarification of important areas of management activity.

The diagram of fig, 10 can be expanded as in fig. 11 to show the nature of the feed-forward loop in greater depth.

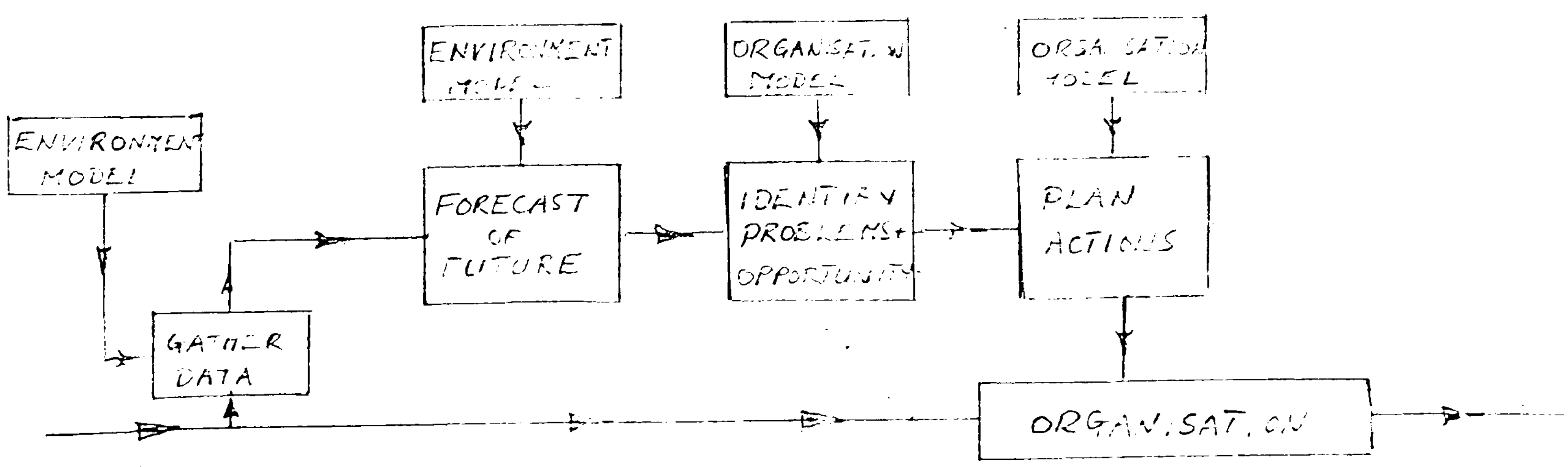


fig. 11

The process which fig. 11 illustrates are as follows. The first step, naturally enough, is to gather data about the state of affairs in the environment. Since the potential amount of information in the environment is infinite, there must be some form of selection or filtering process and this selection of information is mediated via a model of the environment, which specifies the parameters of interest (The situation is analagous to the one already discussed for the feedback situation). The processes by which this model is built up are not indicated in the diagram, but do not differ in principle from the methods used to build the models used in feedback control. It is worth pointing out that the model will be influenced to some extent in its selection of parameters by the goals of the organisation. Furthermore, in principle at least, these models can evolve in the course of time, to provide better approximations of outside reality.

Once the necessary (or believed to be necessary) data has been gathered, it is used to forecast the future state of affairs. This predictive act is a vital element; its purpose is to gain enough time to allow the remainder of the functions to take place and the end result to be co-ordinated with changes outside the organisation. Precise timing may or may not be important, depending upon the nature of the organisation. A fashion business for example, must time its changes to coincide almost exactly with changes in mood of its customers; suppliers of heavy capital plant, on the other hand, can take a matter of years to adopt a technological advance.

The diagram shows that the forecast of the future is derived by feeding the data with a model of the environment. There are some pertinent points here.

In the first place, the model used is shown as being separate from the one used to gather the data. This is to cater for practical possibilites rather than theoretical necessities; in practice, it may well be the case that two separate and different models are used for gathering information and for processing it. It is, of course, theoretically desirable that the two should be at least conformable one with another, if not isomorphic one with another. However, there is no a prori reason for assuming that such will be the case. If, as may happen, the models are not computer-based or not even explicitly stated but intuitive mental models held by two or more managers, then there may well be significant differences between them.

Secondly, there is once again no indication of the way in which the model is built up originally, or subsequently modified in the light of experience. The prime reason for this omission was to avoid complexity in the diagram of fig.9, but it must be admitted that it would be possible for a manager to attempt to operate without periodically updating his model (as distinct from updating his information). Taking the argument a little further, it can be seen that strategic control can easily reduce to what is effectively open-loop control; in principle, once the environmental model has been set running with the initial conditions specified by the input data, the model can continue to run without further reference to the external world. It is tempting to speculate how far organisations do actually function on these lines; although no hard evidence is available, some recent events suggest that planning procedures in some Government departments are close to an open-loop situation.

There would, of course, be nothing wrong with an open-loop situation if the model in use were sufficiently accurate to provide continuing correct forecasts. How far it is worth investing resources in improving the model is a question of some interest.

To attempt to provide a basis for answering this question, it is useful to start by hypothesising a fully determinate universe - i.e one in which there is no quantum limit to the possible accuracy of observation and modelling. (The quantum limit can be introduced into the argument at a later stage, if required). In order to provide a fully accurate and detailed forecast of the future it would be necessary to specify the position and momentum of every elementary particle in the universe at a given instant, together with the laws that govern their motion and interaction. This full specification is necessary if the model is to predict the exact course of future events, for events in distant galaxies have an effect on earth - and not necessarily an infinitesimal effect. Thus sources in general, and astronomy and navigation in particular, have been influenced by the study of the stars.

Once such a model had been set up, it would be necessary to find a medium on which to run it, and to supply the energy needed to drive it. At this level of detail, it becomes appropriate to talk not of a model but a replica, which puts the problem in its true perpective.

And such a replica would not necessarily be of any use for the purpose it was intended to serve. If it is to supply predictions of future states, then it must be able to compute these faster than reality achieves them. This would seem to imply that the modelling medium is capable of supporting communication at speeds greater than the speed of light.

All in all, the prospects for achieving such a model appear unpromising, to say the least. Since this is so, perhaps the tricky question of self-reference in such a model can be put to one side.

This line of argument indicates the difficulties likely to be encountered in pursuing predictive modelling to the ultimate. It does not lead to the conclusion that limited attempts at forecasting are of no use, if the requirement for full and absolute precision of forecasts is relaxed - or, from a slightly different point of view, if the requirement for absolute control is relaxed to one of adequate control. The problem then becomes to construct a model that will enable forecasts of acceptable accuracy to be made within a time-scale that enables use to be made of the forecast. The means by which these simpler models can be constructed lie in the redundancies and statistical properties of data gathered from the real world. Thus, to illustrate the point, it is possible in principle (except for quantum limitations) to calculate the paths and collisions of individual molecules of a gas held within a container. Amongst other things, there calculations would enable the instantaneous pressure on any part of the container to be calculated. It would be a fairly lengthy calculation - it would over 10^{20}-10^{30} particles each with 6 degrees of freedom, but it could be done. On the other hand, the simple equation

$$pu = mRT$$

(the ideal gas law) would in all probability serve to calculate the parameters of significance in a practical problem to a satisfactory degree of accuracy, and provide the answers much more rapidly.

In practical terms, in the context of organisation and strategic control, the problem is where to strike the balance between a fully detailed but cumbersome and slow model, and an approximate but rapid model. (There is a further problem, that of the reliability of, and validity of the model, but that is a different issue). It would appear that theoretically there is no absolute answer to this problem, but that the answer is contingent upon the nature of the organisation that is attempting to use the model. In particular, it is related to what might be termed the 'reaction time' of the organisation in question, ie the time which it takes for an undertaking to make significant changes to its product. The forecast needs to cover at least a sufficient period ahead to enable the organisation to adjust itself to predicted change. Thus, there is little point producing a forecast for the next six months if it takes five years for the organisation to change its operations. Equally, there is little point in a forecast extending ahead more than say 10 or so 'reaction times' ; it is an unnecessary use of resources to plan ahead much further than this, because the organisation will have ample time to adjust to changes beyond this time - scale. Furthermore, it is in the nature of forecasting that the further ahead the forecast is made for, the less precise and reliable it becomes.

As a consequence of this approach, it can be concluded thatthe need for, and nature of, strategic control will be a function of the nature of the organisation in question, with size of organisation being a very relevant variable. A small organisation which can adapt very rapidly to change in the environment will have a limited need fot this type of activity (indeed it may be possible for it to survive for an appreciable period without it.). A large organisation will require much more sophisticated forecasting techniques.

Another issue of relevance here is the degree to which the environment is stable. Obviously, if it is absolutely constant, or follows a simple cycle, there is no need for any elaborate forecasting procedure. (As an aside, it can be remarked that the activities of many organisations have been to a great extent responsible for the types of change in the environment that currently make it so hard to predict.)

However, once a forecast has been made, the next step is to evaluate the likely effect on the organisation, whether adverse or favourable. (In many ways, this is analagous to the process of comparing actual results with goals in a feedback loop). As shown in fig. 11, a necessary input at this stage is some form of organisation model, relating in particular to objectives and long-term plans. These are compared with the predicted future state of the environment, and discrepancies sought. Mismatches between the two indicate a need for the organisation to undertake some action. In principle, there is no reason why the organisation should not attempt to rectify a mismatch by changing the future course of the environment. However, such a course of action falls outside the scope of the present discussion, and falls more naturally into the category of external regulation. Discussion of such a course of action will therefore be postponed.

The basic process remaining is to adapt the organisation for the expected changes in input. There are two distinct aspects to such a process of adaptation. The first is what might be described as parameter - adjustment, i.e. setting new goals, more appropriate for the future as forseen. This is the type of process envisaged by Jankowicz, as has been discussed above. In principle it accomplishes nothing that could not be achieved through feedback, with the proviso that strategic control of this type allows a faster response - even an anticipatory response. In a competitive environment, factors of speed of response can be important.

The second aspect of strategic control is a modification to the fabric of the organisation to enable it to cope better with the foreseen environment. These modifications may be either to the productive base of the organisation (new products new plant, etc), to the managerial superstructure built on the base (a re-organisation) or a combination of both.

"Such modifications to an organisation (particularly modifications to the productive base) can only be achieved at a price. Resources need to be applied, and the amount of modification possible will be determined by the amount of resources available. In the case of a business, the amount of resources available is determined by the profitability of the enterprise. (Not necessarily directly, due to the fact that money can be borrowed, but the amount that can be borrowed bears a relationship to ability to repay, and hence to profitability). This need for modification to the business explains the need for profit, and also suggests that profit needs to higher in an uncertain environment. It also suggests that the profits that a firm requires can be calculated.

It is the capability of undertaking this type of activity that distinguishes organisations from entities in the natural kingdom. It is equivalent to growing extra limbs or re-shaping the neural pathways of the brain. The fact that such adaptations are possible increases the potential variety that organisations can cope with; the fact that such adaptations occur indicates that organisations function in an environment of a higher order of complexity than that of the physical universe that ordinary organisms exist in.

However, the laws of cybernetics still apply to this situation, in particular Ashby's Law of Requisite Variety. As has been pointed out, Ashby's law covers the basic mechanism of strategic control - indeed, it was first set out in that form, with feedback control as a subsidiary modification. Thus, the amount of regulation that can be achieved through strategic control is limited by the channel capacity of the control path.

Limitations on channel capacity are usually thought of as largely physical problems, associated with the rate at which information can be passed through a communication path. Whilst such factors can (and in many instances, undoubtedly do) limit the capacity of a particular channel, they are not the only possible source of limitations in channel capacity. The other source of restriction on channel capacity, which appears not to have been discussed in the literature, is what might be termed modelling capacity.

The fundamental concept that this term is intended to convey is that control over any situation is achieved by processing information through a model (see Ashby and Conant, 1970) and the limitation on channel capacity may well derive from the rate at which the model can process information rather than from the rate at which information can be transmitted to and from the model. (Indeed, it can be argued that the capacities required for information transmission should be calculated from the processing rate of the model).

This limitation on channel capacity arising from a model can be seen most readily in the case of a digital model. We are accustomed now to the idea that a given computation takes a certain amount of time. Thus, if the model we are using has three variables, x, y, z, then the time required to compute the outcome depends upon the functions used, i.e.

$$R = 3x + 3y + 3z$$

is quicker than

$$R = (\sin x + \cos^2 y + \tan z/2)(3x + 3y + 3z)$$

Thus (assuming that R is to the same accuracy in both cases) the rate at which R can be computed (i.e. the modelling capacity) depends upon the complexity of the model. It will also depend upon the number of inputs (and outputs) required, e.g.

$$R = \sum_{1}^{5} xn$$

is quicker than

$$R = \sum_{1}^{100} xn$$

The same limitation on processing capacity is also found in analogue models, though it is expressed in different ways, usually in terms such as transient response.

However, the most important point is that it is the model (or models) in use that form the essential limit upon channel capacity. The model in use will determine what input and output are required and to what accuracy. It will also determine the number and nature of calculations required to derive the output from the input. These factors, together with the speed of the computer used, will determine the maximum channel capacity available.

As shown in fig. 11, there are essentially at least two models present in the strategic control loop, one a model of the environment, used for prediction, the other a model of the organisation used to determine the changes required to meet the foreseen future. Apart from the fact that they are models of different things, there are important differences between the essential requirements for these two models.

The nature of the environment model is such that it is essentially variety - reducing, in that it seeks to predict the course of a limited number of key variables from information taken from a variety of sources. Furthermore, it can, in principle, be a black-box model; as long as it produces usable results, its internal workings are not necessarily of great relevance.

By way of contrast, the organisational model has the opposite characteristics. It is variety - generating, in that the input from the environment model is used to gernerate the required changes throughout the organisation. Furthermore, it cannot be a black-box model; in order to generate the required modifications to the organisation, the model must show some at least of the internal structure and connectivity of the organisation. The range of possible modification to an organisation is then the permutation of the internal inputs and outputs, coupled with the changes that can be wrought to each component function through investment, and the essence of the planning process is to extract the optimum from this range of possibilities. Naturally, the more detailed is the model used, (the more internal structure is shown) the more numerous are the possible courses of action.

The foregoing outlines the essential cybernetic requirements for the models used in strategic control. (It may of course be the case that in practice these requirements are exceeded). It does not necessarily follow that the functions are readily identified with the work of any particular individual or group of individuals. The models discussed are not necessarily embodied in computer programs - or indeed even set out formally at all. They may be distributed across the members of the organisation, particularly the management of the organisation. (Indeed, such informal models will always exist, even where formal computer models have been constructed). Nor is it at all likely that such informal, distributed, models will all be in total agreement one with another.

What is more, changes to an organisation rarely affect just one isolated section of it. Most changes affect considerable sections of an organisation, some involve all of it. Planning therefore generally involves large sections of management, acting horizontally across the hierarchy as it were. This may take the form of committee work, or the setting up of an informal network of communication (the 'informal organisation' of management literature) or a combination of these. It is a considerably different mode of organisational activity from the traditional bureaucratic hierarchy, which is not likely to be evident during periods of organisational change. This view is endorsed by the work of Burns and Stalker (1961), who observed that organisational innovation typically brought forth new bureaucratic forms of managerial behaviour. It would seem that the cybernetic explanation of this phenomenon is that innovation requires an interactive, unified, approach, across the whole organisation; it is likely, furthermore, that management will be heavily involved in re-structuring their models of the organisation during such a period of change.

A further consequence that can be anticipated to stem from strategic control is a cycle from (in management jargon) centralised to de-centralised and back to centralised forms of organisation. When the organisation is making major adjustments to fit a new environment, a relatively high degree of central co-ordination will be required, and hence a centralised form of management will be appropriate. As the organisation settles down in its new role, it is appropriate to allow the component parts of the organisation some freedom to 'fine-time' their operations (by a process of Ashbeam adaptation) and a more de-centralised form will be appropriate.

Thus there is at least some cybernetic justification for the well-known business phenomenon of a cycle from centralisation to de-centralisation. The explanation does not necessarily cover all instances of the phenomenon- firms may engage in the cycle for quite other reasons, more to do with personalities andpolitics; - but it does cover some instances.

Overall, the process of strategic control can be clearly differentiated from administrative management. The purpose of strategic control is to design (or re-design) the enterprise to provide the desired results. The purpose of administrative management is to operate the organisation to actually achieve the desired results. Although there are quite separate functions, this is frequently not recognised in organisation structure, and frequently both are carried out by the same individuals. The situation may be further complicated by the fact that the original design for the organisation may not have been totally correct, and operating management need to make some adjustments. However, although lines may be blurred in practice, the main features of both are clear.

2.1 External Regulation - Output Environment

As has been previously mentioned, organisations seek to influence the environment as well as well as their own internal affairs, and this influence can be divided into two broad categories. The first, which will be discussed here, is the category of influencing or controlling the output environment i.e. the market for the organisations goods and services.

This is not generally recognised as a specifically managerial activity, although it is widely acknowledged as a function of organisations, particularly of business organisations. (Its most obvious manifestation is in the form of advertising and kindred activities). The reason for including it here is that is is obviously a form of control activity undertaken by organisations, and therefore of cybernetic relevance.

Having established that, there is not a great deal more that requires to be said. The general methods used are well-known - advertising, pricing, public relations - based on a comparatively simple model of economic behaviour. The most interesting question surrounding these operations is to what extent they can hope to be effective - i.e. to what extent can an organisation control its market? Cybernetics would suggest that the answer is only to a very limited degree, an answer supported by experience.

2.2 External Regulation - Input Environment

As well as attempting to regulate their markets, organisations attempt to influence the society and culture within which they operate. This is at least in part because of the profound effect that attitudes, customs and laws have upon the operations of an organisation and the market for its products. For example, Factories Acts have effects upon methods of production, manning levels, shift work and the like; various Road Traffic Acts have a great influence on the design of motor vehicles; taxation can have more effect on price levels than any other factor, particularly for tobacco and alcohol products.

Given that such factors influence the operation of an organisation, it can be to the organisations advantage to have as much control as possible over them.

The basic functions needed have already been outlined in fig. 11 when discussing strategic control. A model of the environment is used to predict what is likely to happen, and the consequences for the organisation evaluated. However, instead of using the result to control the organisation, it is used to influence the environment.

However, in order to be able to do this, there is one important modification needed, which concerns the nature of the model of the environment. For strategic control, a simple black box model of the environment was all that was necessary; but to control the input environment, this will not suffice.

It is out of the question for the organisation to control the environment directly; one reason is the relative resources of each, and another is that the organisation does not have access to the inputs of the environment. Thus in order to exert some regulation on its environment, the organisation needs to be able to locate the centres of power in the environment and gain access to them.

It is a feature of a black box model that it does not identify the centres of power - or indeed anything beyond a simple input-output relationship. A model with more structure is needed - a 'grey box', as it were, with at least some of the internal models accessible.

Many organisations employ people whose major contribution to the enterprise can be construed as knowledge of how the environment is structured, and who can gain effective access to some at least of the power-centres. Such people are usually found at very senior levels within an organisation, and may often contribute little or nothing to the day-to-day operation of the enterprise. Yet, as can be seen, their contribution can be vital, even though it is not obvious.

In addition to this type of direct access to centres of influence, organisations often form into groups for the basically political purpose of forming a pressure group to represent their interests. Examples of such groups are easy to find, ranging from Guilds through Chambers of Commerce to the CBI for example.

III.2. SUMMARY

It is convenient to summarise what has been presented up to this point.

A model of organisation has been developed, based upon the cybernetic principles of feedback and feedforward control. The model follows the general principles used by other commentators such as George (1970, 1974) and Jankowicz (1973), but developed in greater detail. Additionally, it introduces extra concepts into the analysis, the chief ones being.

1) There need be no logical relation between elements in a managerial goal-vector.

2) Elements within the goal-vector may be incompatible one with another.

3) Not all elements in the goal-vector are organisationally derived.

4) Control is exercised through the use of models, these models being built up as a result of working in the organisation.

5) For some (though not all) purposes, the models used need to possess an internal structure.

It has been shown to be capable of accounting for many of the major reported features of organisational behaviour, including .

a) The basically hierarchical arrangement of most organisations

b) Widespread variation between different organisations

c) Change within organisations, and different structures during change.

d) The importance of the human element within organisations

e) The development of working groups

f) The development of informal organisations

g) The pressence of conflict between individual and organisational objectives

h) Imperfect management

i) Activities external to the organisation itself

It can therefore be claimed that the model gives a cybernetic account of the gamut of organisational behaviour. It succeeds in elucidating much of the detail that was formerly obscure, and this enables the reported facts about organisational behaviour to be placed in a rational and orderly framework.

Having developed a model that successfully accounts for a large proportion of the known facts, the next stage is to develop it and to test it by making predictions from it. A start on this is made in the next section.

4.2 AN APPLICATION OF THE MODEL

The analysis and experiment reported here arose from a practical requirement in a major British company. For commercial reasons, not all of the work undertaken can be reported here, particularly those aspects bearing on profitability.

The analysis formed part of a larger study of the work of Sales Managers, each of whom was totally responsible for the operation of a number of retail outlets. (Various support staff were available to assist in staff capacities, but the Sales Manager was the clear focus of responsibility). The chart in fig. 12 shows the organisation.

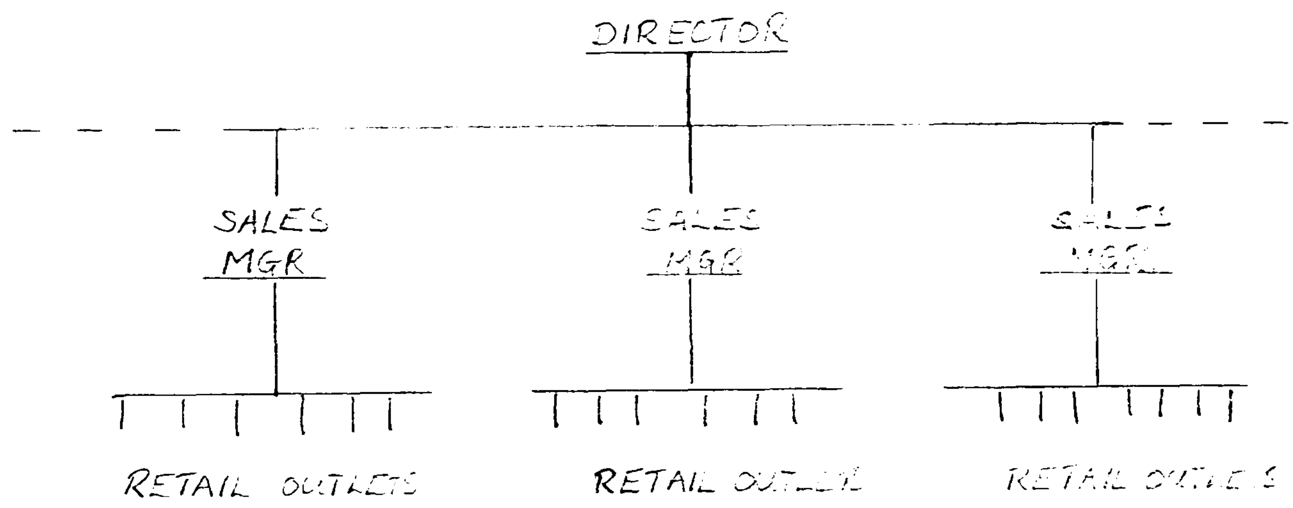
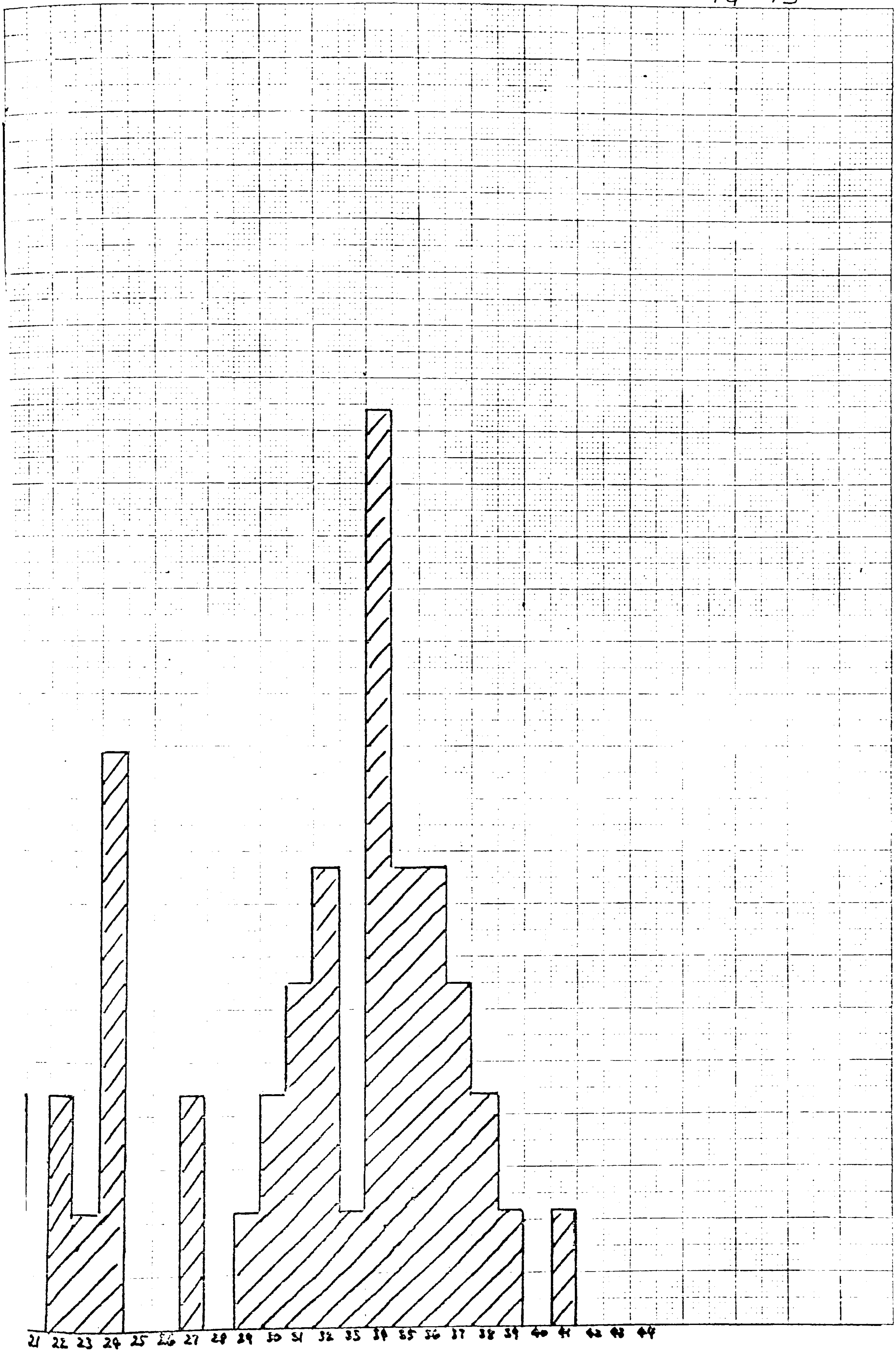


fig. 12.

Amongst other things, the larger study revealed that the number of outlets allocated to each Sales Manager varied widely, between approximate limits of 20 to 40 - i.e. a 2 - 1 ratio. Fig. 13 shows the actual distribution of outlet allocations. There appeared to be little if any scientific rationale behind these varying numbers, and the question arose as to what was

FIG 13


21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
Nº OF OUTLETS

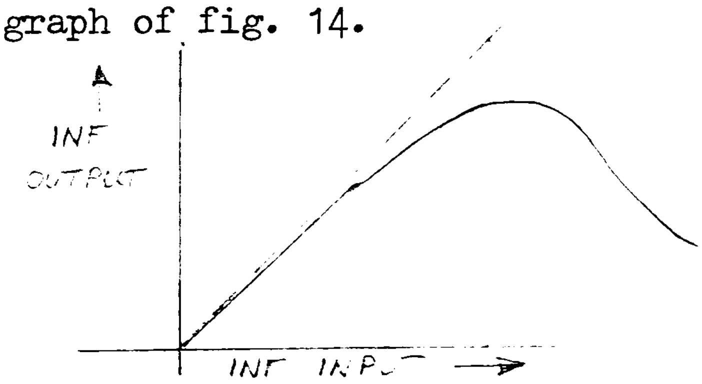
Fi. A1

the optimum number of outlets per Sales Manager.

Established methods of ascertaining work load were examined (i.e. variants of Time Study procedures) but none seemed appropriate to this type of work. However, the study had already established that approximately 95% of the Sales Manager's time was devoted to the 'administrative' or 'feedback' aspect of management, as defined previously. Therefore it was decided to investigate the use of the concept of channel capacity as a means of resolving the problem.

(In passing, it can be noted that the problem of how many outlets a Sales Manager can control can be answered from two different viewpoints, that of the Sales Manager - how many can he cope with in a working day? - and that of the Company - what is the best allocation for optimum profit, including the cost of Sales Managers? The two answers are not necessarily the same. The work reported here is concerned fundamentally with the former of the two approaches)

Channel capacity was applied to the problem as follows. Hick (1952) showed that the human operator can be regareded as a channel of limited capacity. Typical behaviour at various rates of information flow is shown in the graph of fig. 14.



Fig, 14

At low rates of input, the human operator functions as a virtually perfect information channel, information out equalling information in. At higher rates, performance falls off slightly and there is some loss of information.

This fall-off is approximately linear until the limiting channel - capacity is approached. This maximum channel capacity was of the order of 7 bits/second. However, this figure was not maintained as the input rate was increased; channel capacity fell off quite markedly as the input rate was increased beyond the point of maximum capacity.

Other work has confirmed this general shape of curve, and shown it to be a typical property of information - processing systems. A good summary of the evidence can be found in Miller (1962).

The Sales Manager can be considered as a control channel over his retail outlets. Furthermore, since each outlet is independent of the others (i.e. functions in parallel with them, not in series) the information input to the Sales Manager is a linear function of the number of outlets he controls. (This is true on average, if outlets are assigned at random from a statistically honogeneous population; the effects of such statistical variation are considered below). Furthermore, the required channel capacity to control them is also a linear function of number of outlets.

If the Sales Manager channel capacity follows the form of fig. 14, the control he exerts over his outlets can be expected to vary in the general way sketched in fig. 15 as the number of outlets varies.

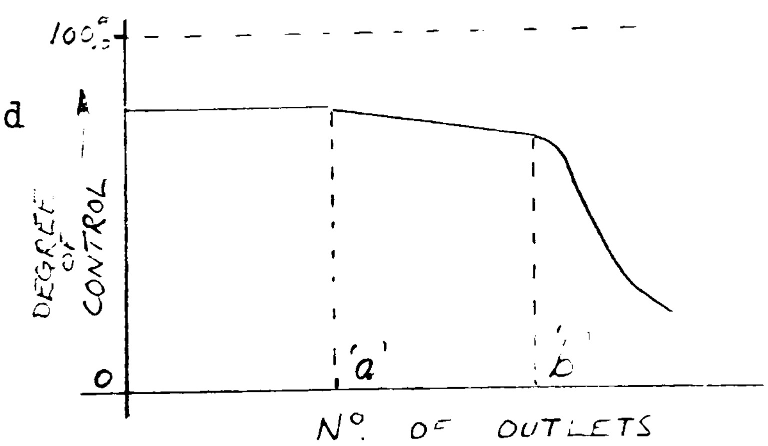


fig. 15

Even at a low workload, control would not be perfect (i.e. would be less than 100%) because the manager is operating in a feedback mode, which leads to residual error in the controlled output. Thus, the graph of figure 15 starts at less than 100% control. However, at a low workload, the Sales Manager can maintain control at this level as his number of outlets is increased. Eventually, however, at 'a' outlets on the graph, his channel capacity starts to fall below the capacity required, and overall control starts to decline. This decline will be progressive until, at about point 'b' on the graph his maximum channel capacity is reached. Thereafter, control declines rapidly, but probably not to zero.

Clearly, a graph such as fig. 15 would enable the optimum allocation of outlets to be determined, by determining where the points 'a' and 'b' fall. The optimum figure is a little beyond the point 'a', sufficient load to set a challenge, but not approaching point 'b', the point of overload. There is little point in operating outside this range; workloads lower than 'a' produce no benefits, and beyond point 'b' there is little point in having a Sales Manager, for he is to almost totally ineffective.

This was the basic theory which it was decided to use to attempt to answer the question as to how many outlets a manager should control. Clearly, such a simple theory could not be expected to account fully for all the factors likely to be encountered in practice. For example, the theory assumes that all outlets are identical, which is certainly not the case in practice. The average sample size (i.e. outlets per Sales Manager) was of the order of 35, which, while a reasonably reliable sample, was not guaranteed to even out all inconsistences. Some further variables not accounted for are as follows:

a) The ability and experience of the Sales Manager.

b) The overall geography of his ares (i.e. compact or dispersed)

c) Level of support staffing.

d) Quality of staff in the outlets themselves.

e) Local trading conditions.

Each of which could be expected to have some effect. Thus, it was to be expected that any results would show a considerable degree of scatter. Indeed, it was possible that the scatter would be sufficient to completely mask any effects due to workload.

The theory also left unresolved the question of how degree of control was to be measured. The basic definition of control can be taken (vide Ashby, 1956) as

$$C = (1 - Vo/V_1) \times 100\%$$

where

C = degree of control

Vo = range of controlled output

V_1 = range of input

The actual controlled output of an outlet is a vector with many components, including such items as staff morale, public relations, etc. The actual input is of similar complexity. However, it was decided that a satisfactory estimate of control could be obtained from examining the relationship between the takings of an outlet and its overall profitability. Quite apart from the fact that detailed data on these variables was apparent that they formed the key objective of most of the Sales Managers work.

The calculations used to arrive at Vo and V_1 for an individual outlet can be illustrated by the graph of fig. 16 Figures were available for the forecast and actual values of takings and profit, which typically showed the general pattern of fig. 16, with random flutuations imposed on a seasonal trend. In principle, Vo was the variability of the profit figure, whilst V_1 was the variability of the take. Certain corrections were applied to this basic scheme, arrived at as follows:-

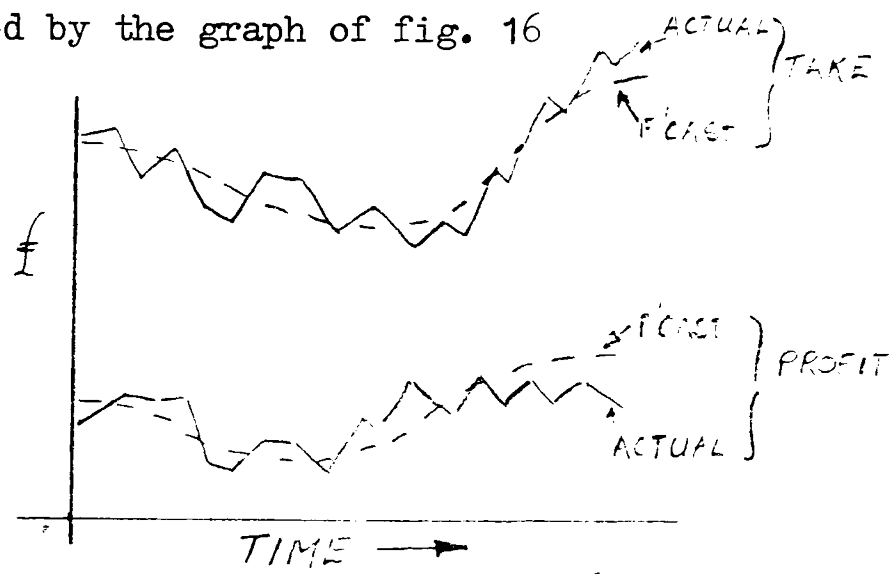


Fig. 16

if the takings were absolutely constant throughout the year, then the variability of the profit could be used as an index of control (periodic charges, e.g. rates, electricity, were spread evenly throughout the year by the accounting procedures in use). However, since the take is not constant, corrections need to be made.

Firstly, the forecast shows that the volume of trade is expected to vary through the year, and operating methods need to be adjusted to cope with this variation - e.g. extra staff need to be taken on, more stocks purchased, and so on. The greater the expected variation (i.e. the more markedly seasonal the trade) the greater these adjustements need to be, and the more critical is the timing of them. Individual outlets varied widely in the seasonality of their trade; for some it was no more than $\approx$ 5% of the annual average, whilst at the other extreme some outlets approached $\approx$ 100% of the annual average. The seasonality of the trade, as indicated by the forecast, was thus a factor that needed to be accounted for.

The other factor considered was the variability of the actual take against the forecast. If the actual takings differ by a constant ammount from the forecast throughout the year, then the difficulty of controlling the outlet does not increase. If the actual differs from the forecast by a variable amount, then the difficulty increases, in proportion to the variability of the difference.

Furthermore, the profit figure needs to be adjusted to take account of the variation in takings. To this end, actual profit was expressed as a percentage of actual take, and compared with the forecast percentage profit (obtained from forecast) in this way made allowance for the fact that expenses do not vary in strict proportion to trade, due to fixed expense elements. This method of correcting for the fixed element is not absolutely accurate, but is approximately true when working well above the break-even point, as was generally the case. What is more, any inaccuracies introduced apply consistently across all Sales Managers and thus should not affect the final result.

With these corrections, Vo and V_1 became as follows

Vo = standard deviation of (Pa - Pf) where

Pa = actual profit%

Pf = forecast profit %

and

V_1 = S x F

where S = standard deviation of the forecast, expressed as a percentage of the forecast average take

F = standard deviation of ((Ta - Tf)/Tf) x 100% where

Ta = actual takings

Tf = forecast takings

All measures were computed over one financial year for each outlet. It is worth noting that the measures used were all pure numbers, and that since variances rather than averages were used, any systematic errors in the forecast would be cancelled out and not affect the data.

Thus a control index could be calculated for each outlet over a year, using the formula

$$C = (1 - Vo/V_1) \times 100\%$$

To calculate the index for a Sales Manager, the mean value for all outlets under his control was calculated, with the proviso that the outlet must have been trading continuously under his control for at least 18 months. This proviso excluded outlets in the following categories.

a) Outlets transferred recently from another Sales Manager

b) New outlets recently acquired.

c) Outlets temporarily closed for major refurbishing, etc.

It was felt that such outlets should be excluded because the Sales Manager would not be fully familiar with its operation. However, outlets excluded on this basis were included back in when arriving at the number of outlets under his control. Only a small number of outlets - rarely more than 2 or 3 per Sales Manager - were excluded in this way.

The method thus developed was applied to a pilot sample of 8 Sales Managers. The sample was selected using the following criteria.

a) Sales Managers should be from the same geographical area, working under the same Director, to hold constant as many extraneous variables as possible.

b) the sample should include as wide a cross-section as possible of number of outlets per Sales Manager.

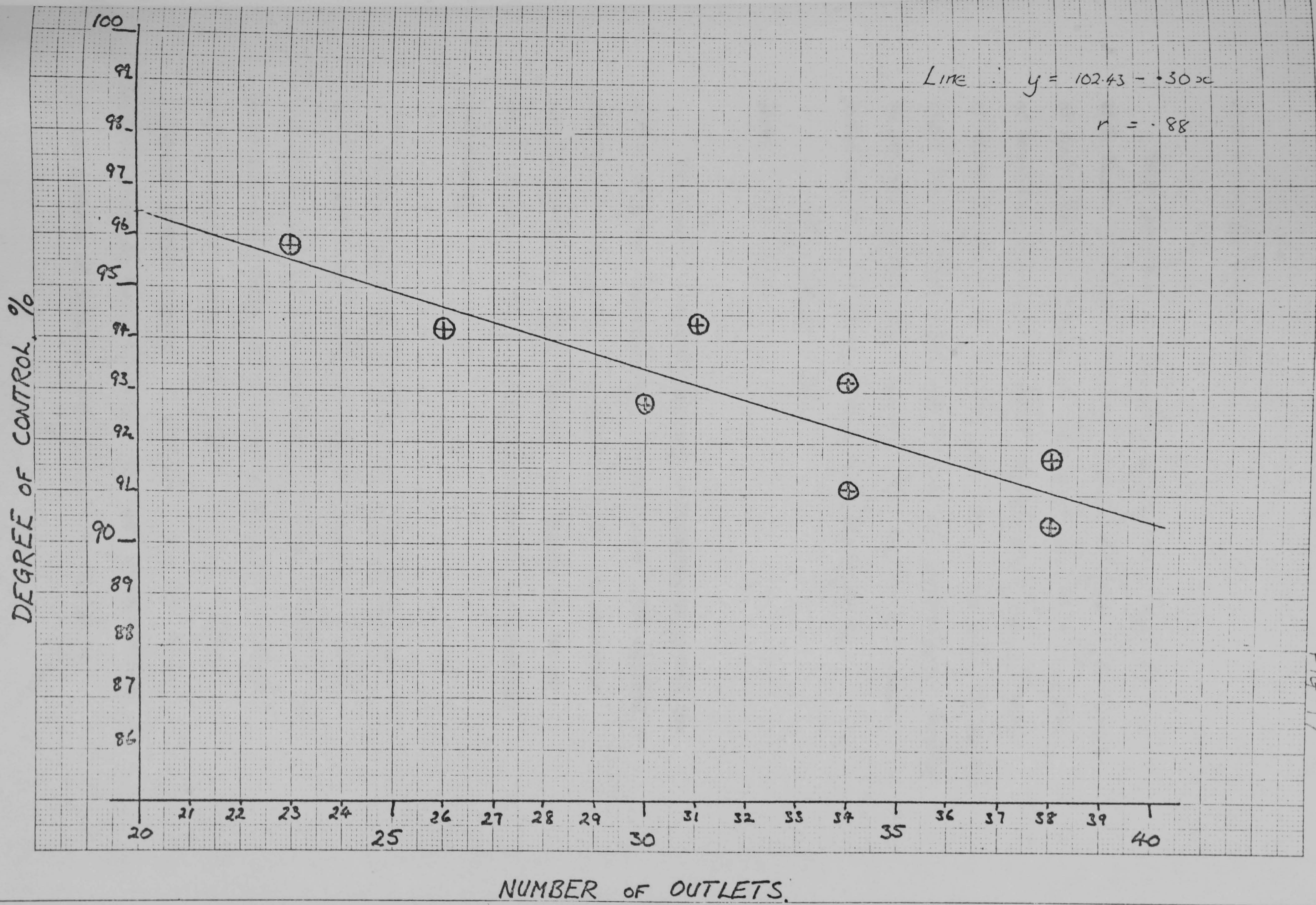
Data were obtained by manual extraction of figures from 4-weekly P + L accounts for each outlet, and processed with the aid of an HP65 programmable calculator. The results obtained were as follows.

Number of Outlets	Control Index
23	95.8%
26	94.2%
30	92.8%
31	94.3%
34	93.2%
34	91.1%
38	91.7%
38	90.4%

These results are shown graphically in fig. 17.

Fitting a straight line to the results yields the equation

$$y = 102.43 - .30x$$



Line : y = 102.43 - .30x
r = .88
DEGREE OF CONTROL %
100
99
98
97
96
95
94
93
92
91
90
89
88
87
86
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
NUMBER OF OUTLETS.

FIG 17

with a corrolation of 0.88

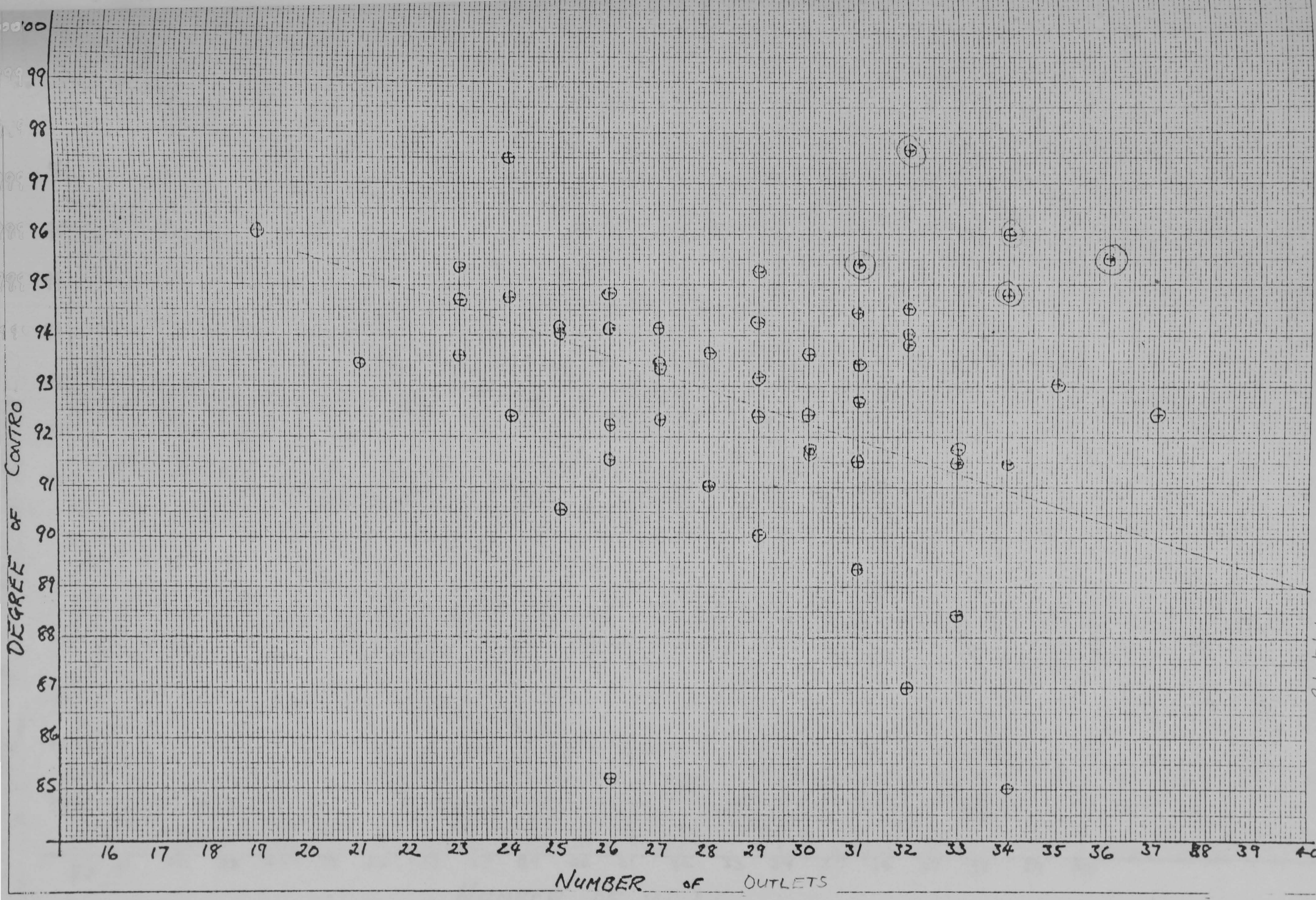
Thus the pilot sample confirmed the basic theory with a high degree of success, with all results falling in the region of declining performance but with no evidence that the point of breakdown was being reached. Nor was there any indication of where the point of overload (point 'a' on the graph of fig 15) might lie. A lower limit was found by extrapolating the results to cut the y = 100 line - since y 100, this gives a lower limit on 'a'. The value of this limit was given by

$$100 = 102.43 - .30x$$

Hence 'a' ≐ 8.1

The results were sufficiently encouraging to extend the method to a full-scale survey, covering some 2,500 outlets and 80 Sales Managers. The data extraction and analysis were performed by IBM370 computer, and thanks are due to Mr. C. Holmes and Mr. J. Perry who undertook the necessary programming.

These results are plotted in the graph of fig. 18. It is apparent that there is a greater degree of scatter than in the pilot study, which is to be expected due to the inclusion of variables which were minimised in the sample, such as trading conditions, support staffing, direction influence amongst others. Furthermore, there are some results which do not fall in with the main trend, notably at low numbers of outlets, and a group lying above the



DEGREE OF CONTRO
100
99
98
97
96
95
94
93
92
91
90
89
88
87
86
85
16
17
18
19
20
21
22
23
24
25
26
27
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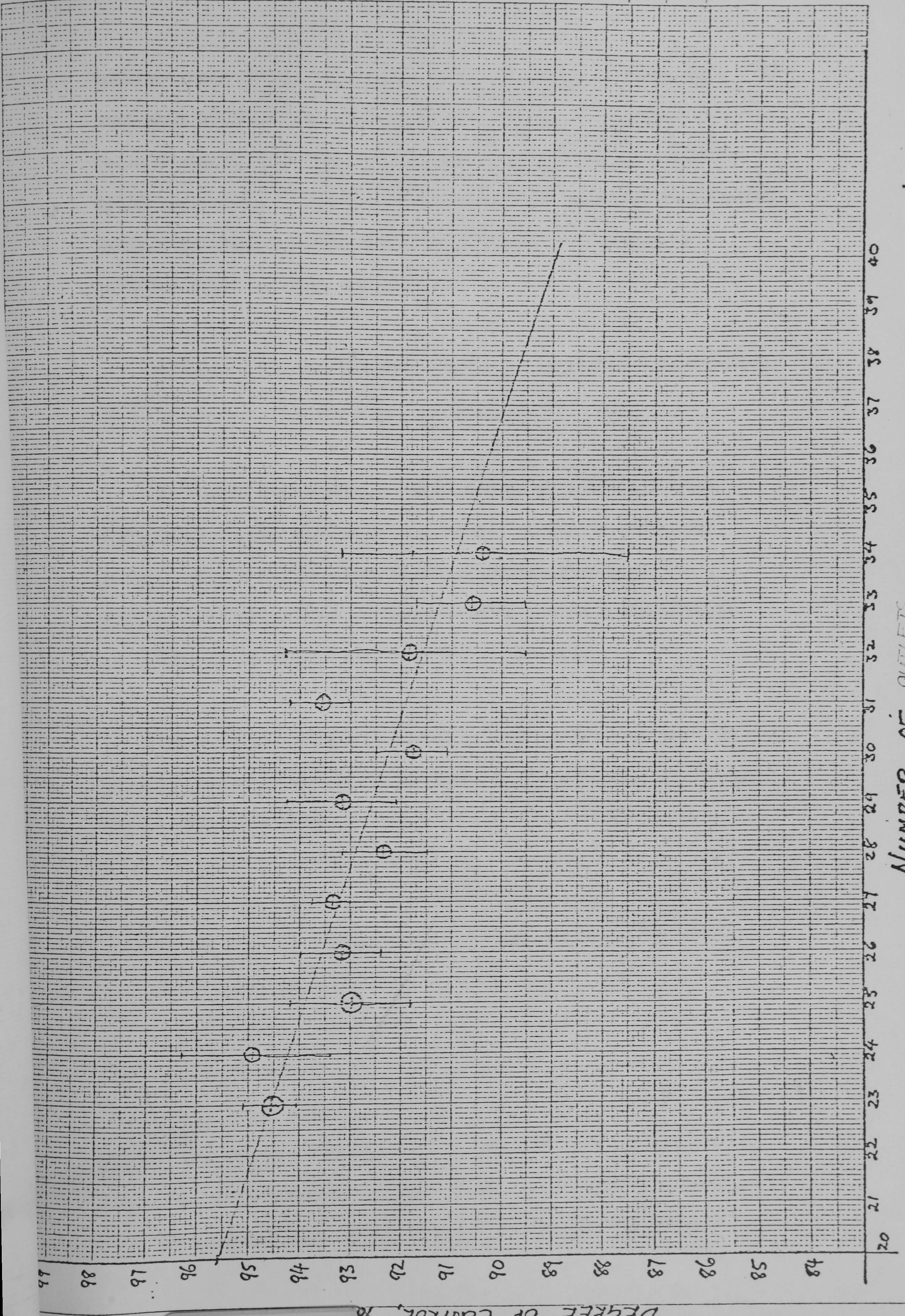
30
31
32
33
34
35
36
37
38
39
40
NUMBER OF OUTLETS

FIG 18

FIG 19



NUMBER OF OUTLETS
DEGREE OF CONTROL, %
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84

apparent main trend. Inspection of this latter group showed that they all came from one geographical region, and that all Sales Managers from that region fell into that group. Thus it could reasonably be inferred that there were special, unidentified factors in operation for that group which can therefore be excluded from the main analysis.

Fitting a line to the remaining results yields a correlation of 0.338, which is significant at the p = .01 level.

Averaging the results at each number of outlets - thus averaging out the effects of the random variables mentioned above - yields the results, shown graphically in fig. 19. Fitting a straight line to these results yields a correlation of 0.851, again significant at the p = .01 level.

These values of the correlation coefficient show that the data provide strong experimental support for the original proposition. From a practical point of view, the results as they stand do not answer the basic question with any precision, in that the location of point 'a' is still in some doubt. It is clearly outside the range of the main body of results, and the few results for low numbers of outlets are not sufficient to locate 'a' with any precision. Some extrapolation of the results is necessary, and this can most conveniently be done via a graph such as fig. 20. This graph is a reconstruction of the information input is conformation output graph of fig. 15. Each axis is plotted in terms of number of outlets, and the diagonal line at 45^{o} therefore represents perfect

FIG 20

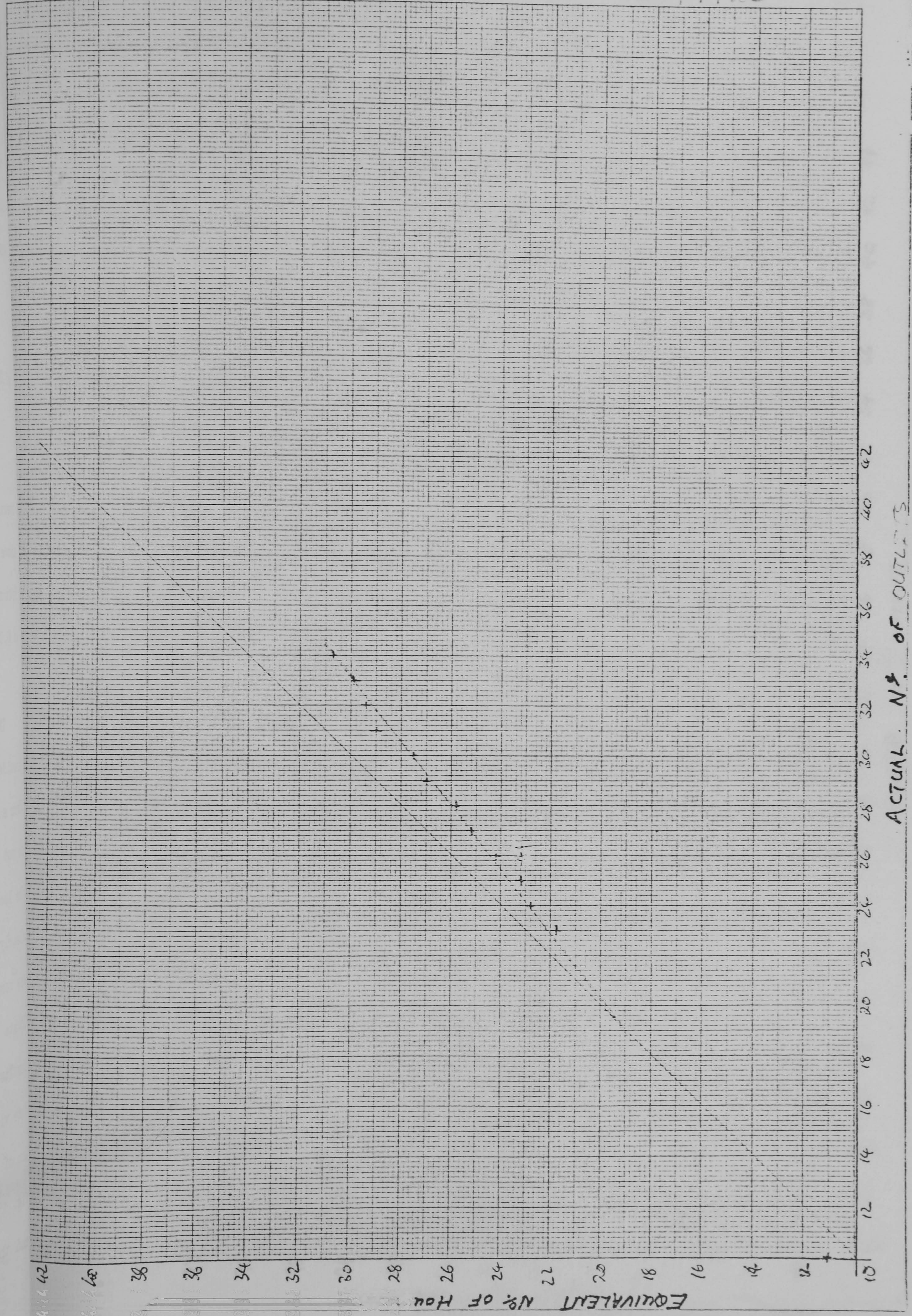
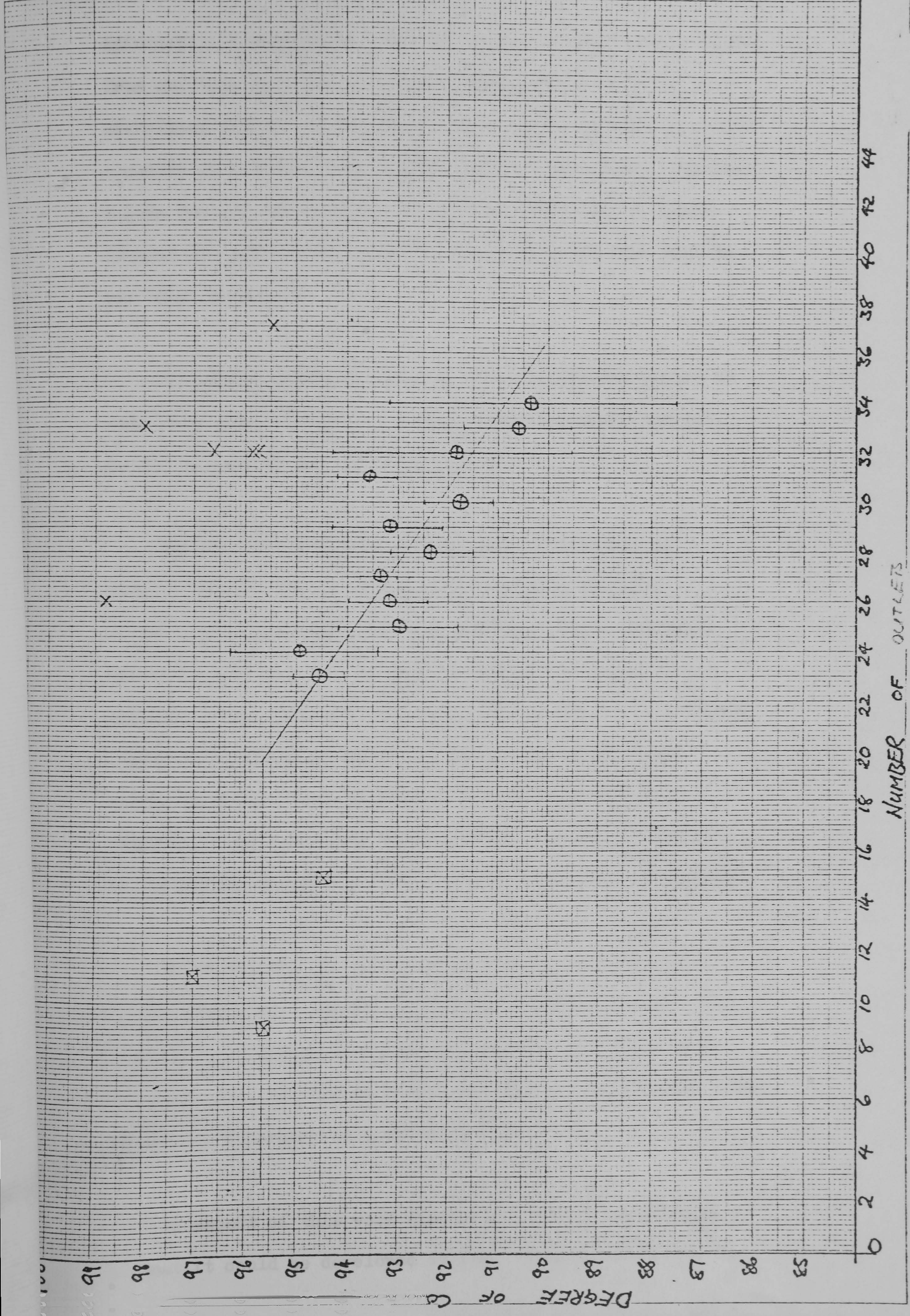

ACTUAL No OF
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
EQUIVALENT No OF HOU
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42

FIG21


NUMBER OF OUTLETS
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
DEGREE OF

information transmission. The points on the graph are obtained from the data by multiplying each number of outlets by its associated control index, which in turn is a measure of channel capacity as a fraction of channel capacity required. Drawing a line through these points to intersect with the diagonal locates the point 'c', which turns out to be at 19.6 outlets per Sales Manager.

This value also accords well with the limited amount of data available for fewer than 20 outlets per Sales Manager, as can be seen in the graph of fig. 21.

The results obtained are important at a number of levels. At the lowest level, they provide a definite answer to the original practical problem. This particular answer applies strictly to the environment in which it was obtained - the value for 'a' could well differ for a different organisation the same branch of retailing, would almost certainly differ for a different type of retail trade. However, it is clear that the method is sufficiently general to be applied to similar problems with every hope of success.

These similar problems need not be confined to retail sales management. The basic philosophy of the method could be applied to problems such as the optimum size of classes in schools, or the desirable manning level in the Police Force, as well as a variety of industrial situations.

An aspect of this work which should not be overlooked is that it could be developed to form a quantitative basis for the assessment of managerial performance (or at least the administrative aspect of performance). The results of an individual manager could be measured against the average value at any particular workload. Whilst this would provide only a comparative measure against his colleagues, rather than an absolute value, it would have the merit of avoiding entirely any subjective element in assessment.

At another level, the results provide confirmation of at least one aspect of the model of organisation that has been propounded. As far as can be ascertained, this is the first report of any direct evidence supporting the general feedback model for organisations.

At a final, and most important level, the results demonstrate that it is possible to undertake meaningful quantitative research in the field of organisation structure and design. Given the enormous and growing importance of organisations in everyday life, the ability to subject them to scientific scrutiny cannot be overstated. The work reported here forms a first step towards such an end.

4.3 SOME CONSEQUENCES OF THE MODEL

Having developed and tested a model for organisation, it is of interest to examine some of its features and the implied consequences. The features which it is proposed to examine here have as a common theme various aspects of the modelling process of which mention has been made. It is a process which appears to have been largely taken for granted in much of what cybernetic work has been applied to organisation, yet it is an issue of central concern. The particular aspects of it which will be discussed here are:-

1) The nature of managerial feedback controls.
2) Consistency of models among managers.
3) The nature of the modelling process.
4) Speed of Data Processing;

1 The Nature of Managerial Feedback Loops

Given that a significant part of management activity can be characterised as feedback control, it is of interest to examine the nature of this process in a little detail. It should be emphasised that what follows is a gross simplification of reality. In practice, managerial feedback is essentially a sampled - data system, controlling non-linear, even non - analytic systems with many interacting variables.

However, manager's ideas of feedback do not normally encompass this degree of complexity, and many management information systems are designed on the basis of an extremely simple notion of feedback. There is therefore some element of validity, as well as the merit of simplicity, in examining the simplest possible model of feedback.

As an initial example, consider a control system such as that shown in fig. 21.

Suppose the equations are ;-

1) $x_t = I_t - F_t$
2) $Q_t = 0.5\, x_t$
3) $F_t = Q_{t-1} - G_{t-1}$

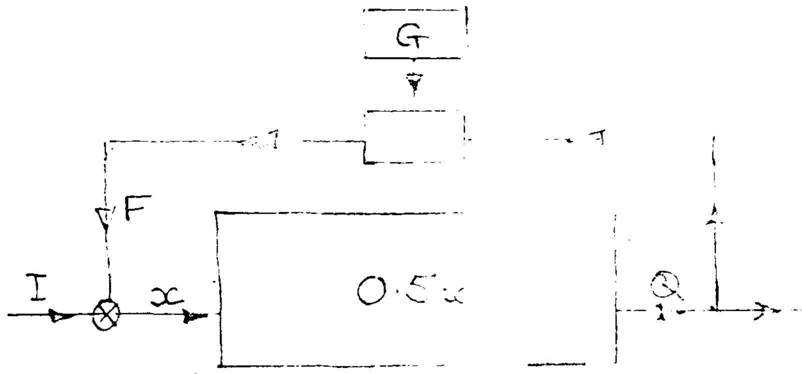


fig. 21

-i.e. a simple negative feedback situation. If I is set to 10, g to 5, and the system set off, then the trajectory shown in Table I results.

t	I	F.	x	Q	G.
0	10	-5	15	7.5	5
1	10	+2.5	7.5	3.75	5
2	10	- 1.25	1.25	5.62	5
3	10	+.62	9.38	4.69	5
4	10	-.31	10.31	5.16	5
5	10	+.16	9.84	4.92	5
6	10	-.08	10.08	5.04	5
7	10	+.04	9.96	4.98	5
8	10	-.02	10.02	5.0	5
9	10	+.01	9.99	4.99	5
10	10	-.01	10.01	5.00	5

(See also graph 1, p. 179a.)

The system finally stabilises to the goal (5), but only after a series of fluctuations. The 'uncontrolled' system would have reached the goal immediately. When the input varies, a trajectory such as Table I(a) following is obtained.

t	I	F	x	Q	G
11	10	0	10	5	5
12	11	0	11	5.5	5
13	12	+.5	11.5	5.75	5
14	13	.75	12.25	6.12	5
15	14	1.12	12.88	6.44	5
16	15	1.44	13.56	6.78	5
17	14	1.78	12.22	6.11	5
18	13	1.11	11.89	5.99	5
19	12	.99	11.01	5.50	5
20	11	.50	10.50	5.25	5
21	10	.25	9.75	4.87	5
22	10	-.13	10.13	5.06	5
23	10	.06	9.94	4.97	5
24	10	-.03	10.03	5.01	5
25	10	.01	9.99	5.00	5

(See also graph la, p. 179a.)

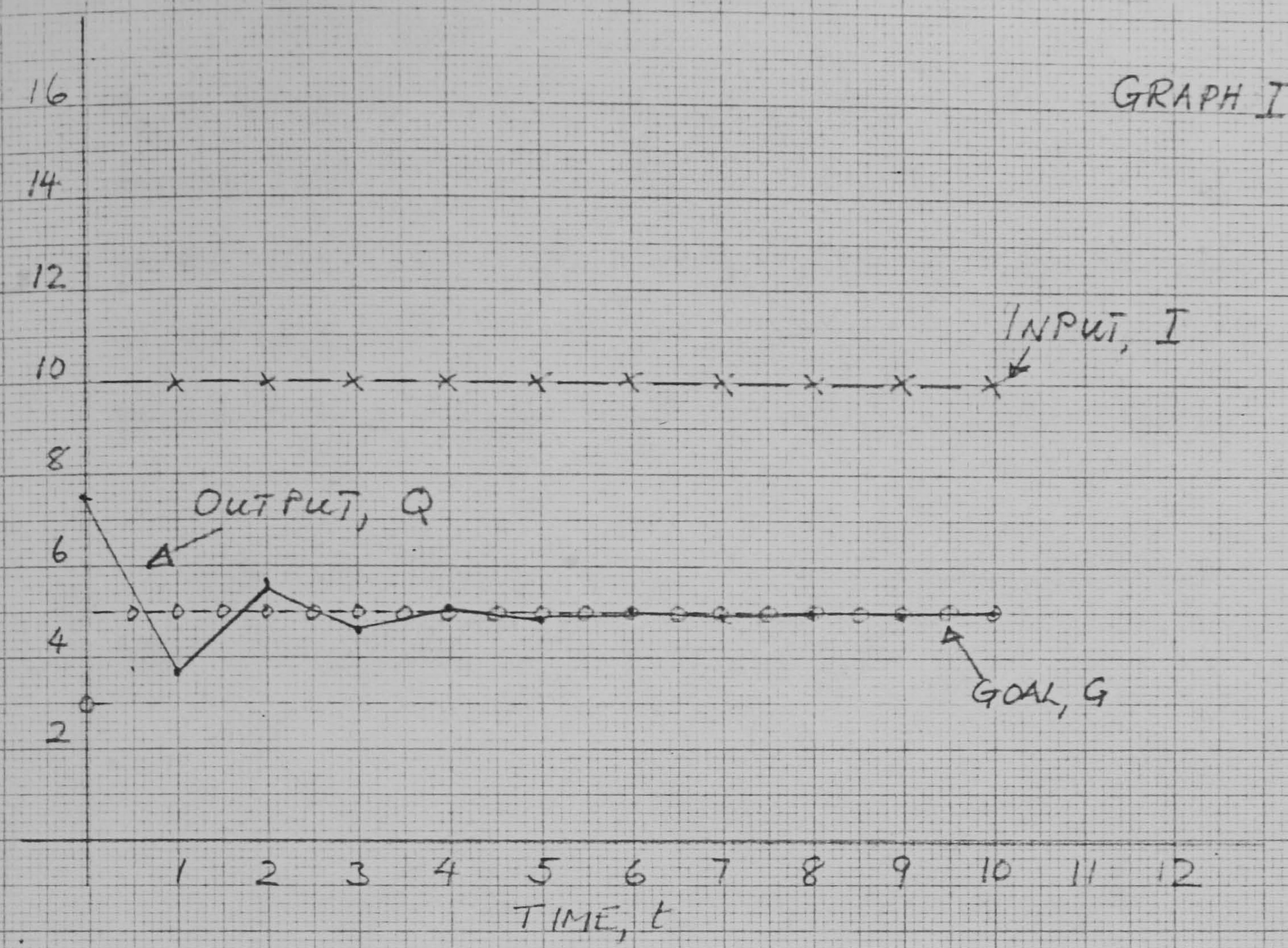
which is not a very impressive performance.

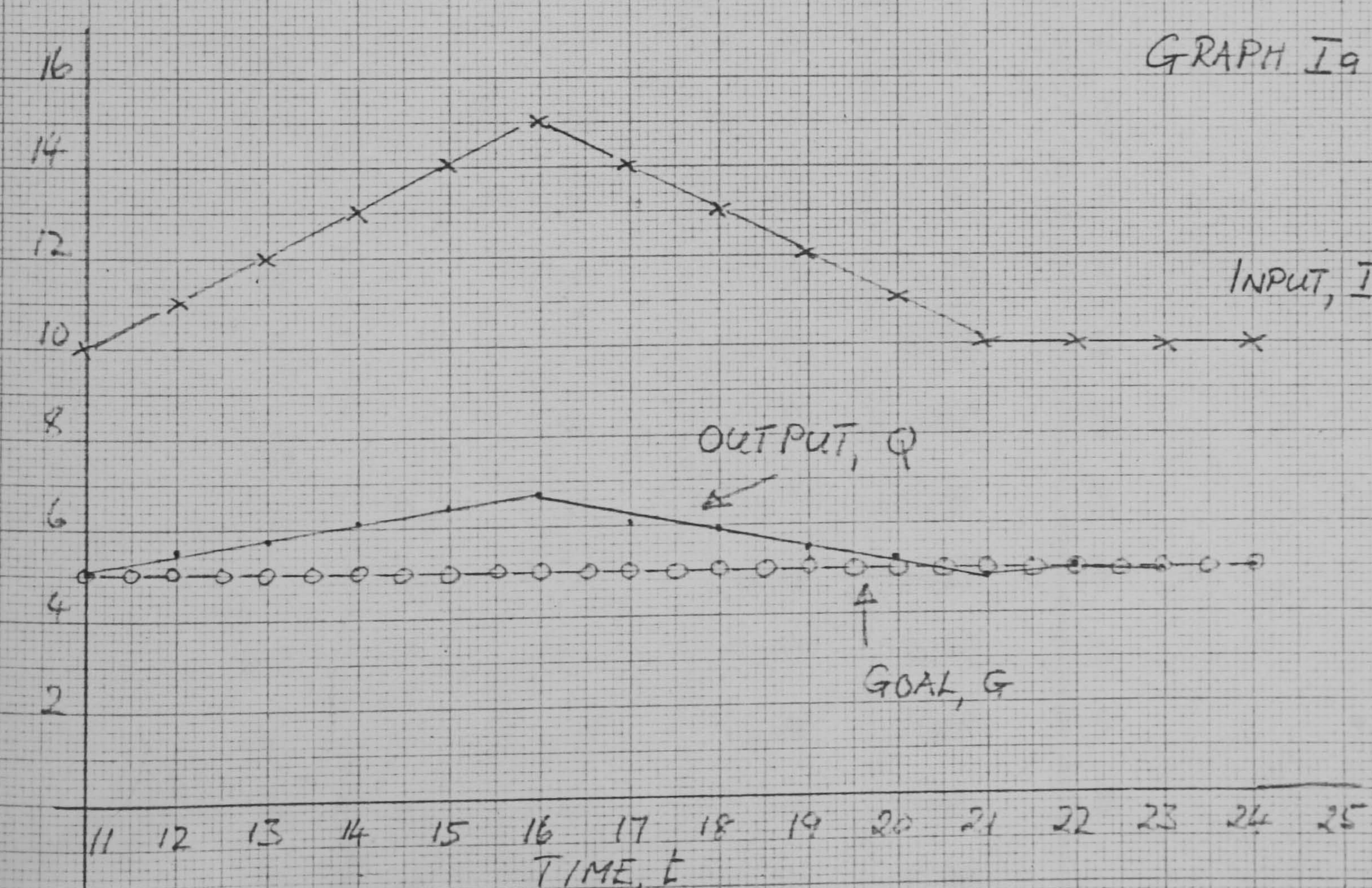
The control index

$$C = (1 - V_o/V_1) \times 100\%$$

is $C = (1 - (6.78 - 4.87)/2.50) \times 100\%$

$= 4.6\%$


GRAPH I
INPUT, I
OUTPUT, Q
GOAL, G
TIME, t


GRAPH Ia
INPUT, I
OUTPUT, Q
GOAL, G
TIME, t

obtained as follows.

V_o is the actual range in the controlled output, from a maximum value of 6.78 to a minimum of 4.87. V_1 is the range in the output that would have occured without the intervention of the control system, i.e. the range in the input multiplied by the forward transfer function, in this case (15-10)x0.5

A different form of input variation gives a different type of trajectory, as shown in Table II

TABLE II

t	I	F	x	Q	G
26	10	0	10	5	5
27	10	0	10	5	5
28	15	0	15	7.5	5
29	15	2.5	12.50	6.25	5
30	15	1.25	13.75	6.87	5
31	15	1.87	13.13	6.57	5
32	15	1.57	13.43	6.71	5
33	15	1.71	13.29	6.64	5
34	15	1.64	13.36	6.68	5
35	15	1.68	13.32	6.66	5
36	15	1.66	13.34	6.67	5
37	15	1.67	13.33	6.66	5
38	15	1.66	13.34	6.67	5
39	15	1.67	13.33	6.66	5
40	15	1.66	13.33	6.67	

(See also graph 11, p. 181a.)

A feature to note here, apart from the long settling time, is that the final equilibruim reached is not at the goal, but at a point intermediate between it and the new uncontrolled output level. The same effect can be observed if the goal is varied rather than the input, as shown below in Table III.

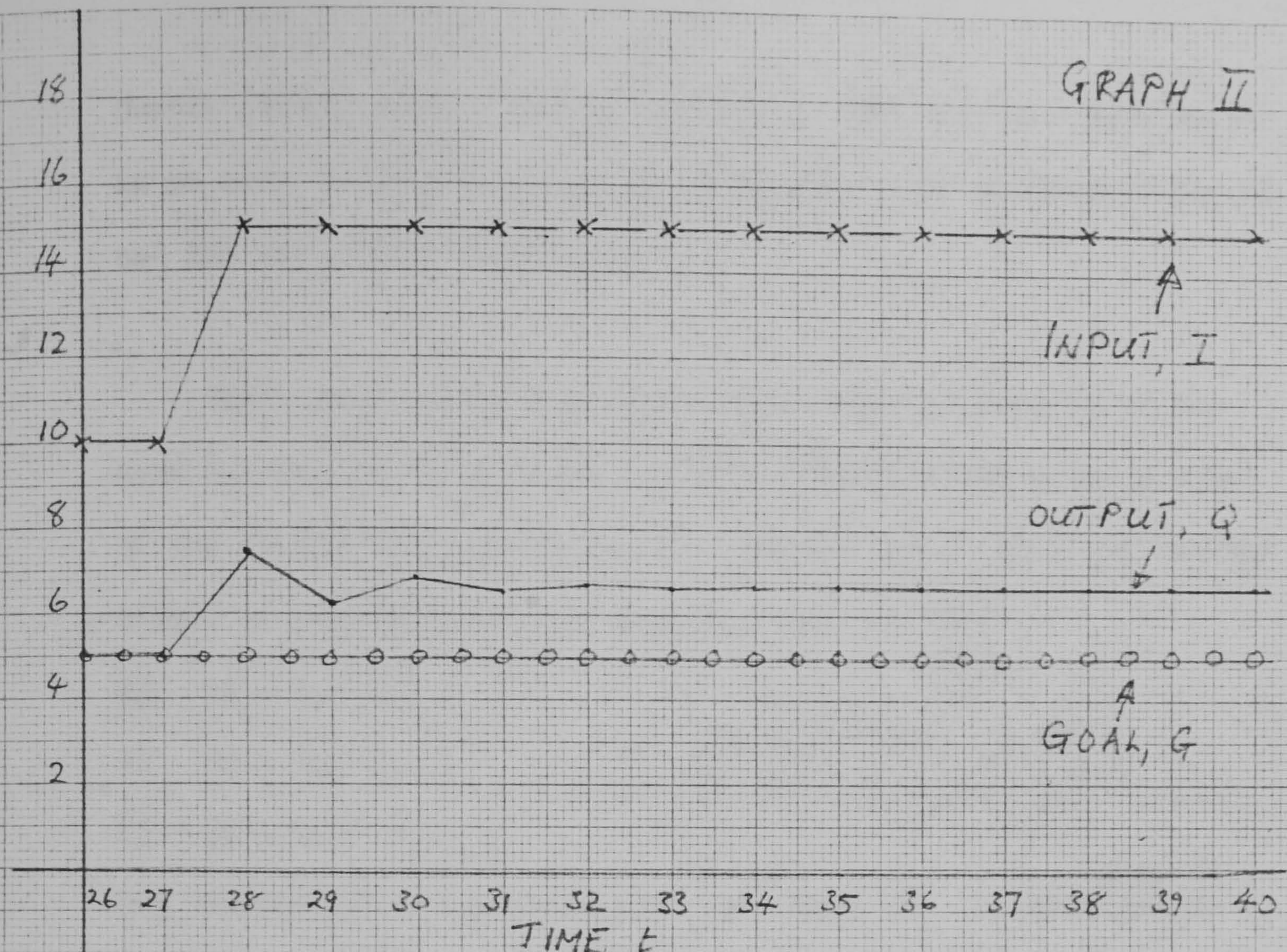
TABLE III

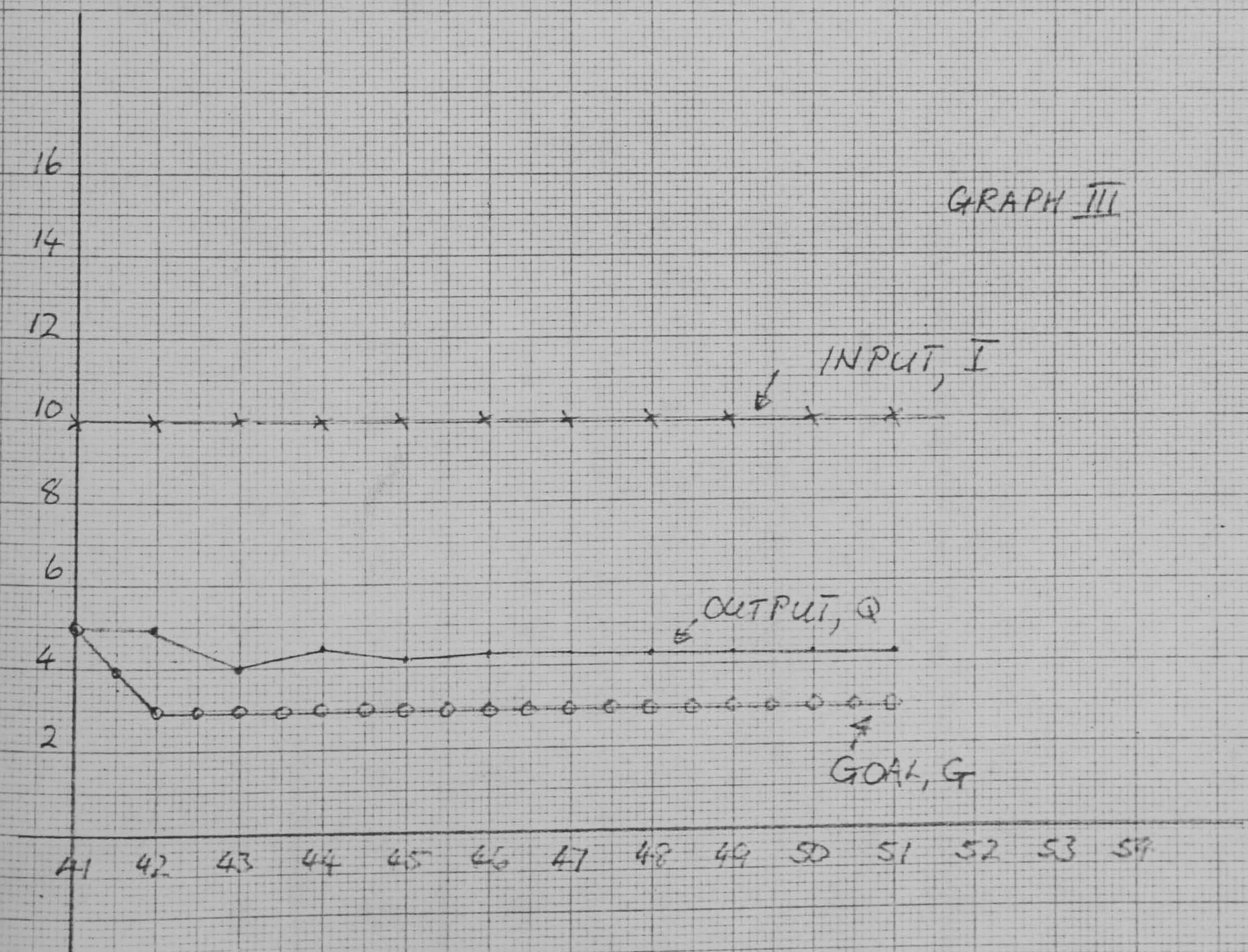
t	I	F	x	Q	G
41	10	0	10	5	5
42	10	0	10	5	3
43	10	2	8	4	3
44	10	1	9	4.5	3
45	10	1.5	8.5	4.25	3
46	10	1.25	8.75	4.37	3
47	10	1.37	8.63	4.31	3
48	10	1.31	8.69	4.34	3
49	10	1.34	8.66	4.33	3
50	10	1.33	8.67	4.33	3
51	10	1.33	8.67	4.33	3

(See also graph 111, p.181a)

Here again, there is a marked discrepancy between the goal of the system and its final equilibral value. (In passing, it can be pointed out that this serves to reinforce the arguments about the difficulty of inferring the goals of taciturn systems (Pask, 1969)

In total, the alleged feedback control system of fig. 21 does not perform too well. It is of interest chiefly because much of the literature about managerial feedback (e.g Brown (1971)


GRAPH II
INPUT, I
OUTPUT, Q
GOAL, G
TIME, t
18
16
14
12
10
8
6
4
2
26 27 28 29 30 31 32 33 34 35 36 37 38 39 40


GRAPH III
INPUT, I
OUTPUT, Q
GOAL, G
16
14
12
10
8
6
4
2
41 42 43 44 45 46 47 48 49 50 51 52 53 54

Humble (1968) Donald (1967)) appears to take the view that there is no more to feedback than is contained in the diagram of fig.21 and its associated equations.

There was much discussion in the foregoing section of the need for models for control. Let us therefore introduce a model of the controlled system into the control loop. This can be done simply by modifying one of the equations, so that

4) $x_t = I_t - 2F_t$

5) $Q_t = 0.5\ x_t$

6) $F_t = Q_{t-1} - G_{t-1}$

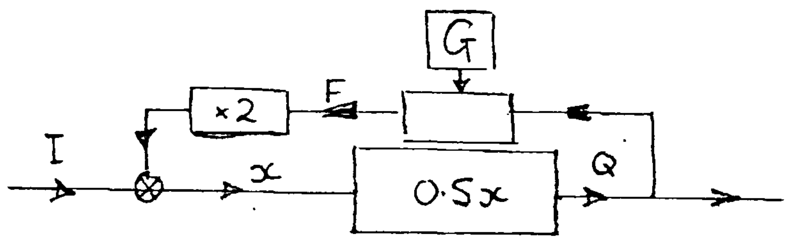


Fig. 22

The 'model' here corresponds to the factor $2F_t$ in equations 4- (2 = 1/Transfer function = 1/05). This modification does not greatly improve performance, as can be seen in the following trajectories in Table IV

TABLE IV

t	I	F	x	Q	G
0	10	0	10	5	5
1	10	0	10	5	5
2	10	0	10	5	5
3	11	0	11	5.5	5
4	12	.5	11	5.5	5
5	13	.5	12	6.0	5
6	14	1.0	12	6.0	5
7	15	1.0	13	6.5	5
8	14	1.5	11	5.5	5
9	13	.5	12	6.0	5
10	12	1.0	10	5.0	5
11	11	0	11	5.5	5

13	10	-.5	11	5.5	5
14	10	.5	9	4.5	

(See also graph lV, p. 184a)

For the same input function as before, the control index becomes

$$C = (1 - (6.5 - 4.5)/2.5)$$
$$= 20\%$$

Although it is a four-fold improvement on the previous situation, this must be balanced against the fact that the system has now gone into permanent oscillation. (Some readers may have noticed that originally the system could tend to oscillate in this way when switched on if the initial conditions were unfavourable)

This system is not much better at maintaining the goal when the input undergoes a step change, as is shown in table V below.

TABLE V

t	I	F	x	Q	G
15	10	0	10	5	5
16	10	0	10	5	5
17	15	0	15	7.5	5
18	15	2.5	10	5	5
19	15	0	15	7.5	5
20	15	2.5	10	5	5

(See also graph V, p.184a.)

The oscillatory behaviour is still present, and, a point of some importance, the mean of the oscillations is not at the goal. The same is true when the goal of the systems is changed, as is shown in the trajectory below in Table VI

TABLE VI

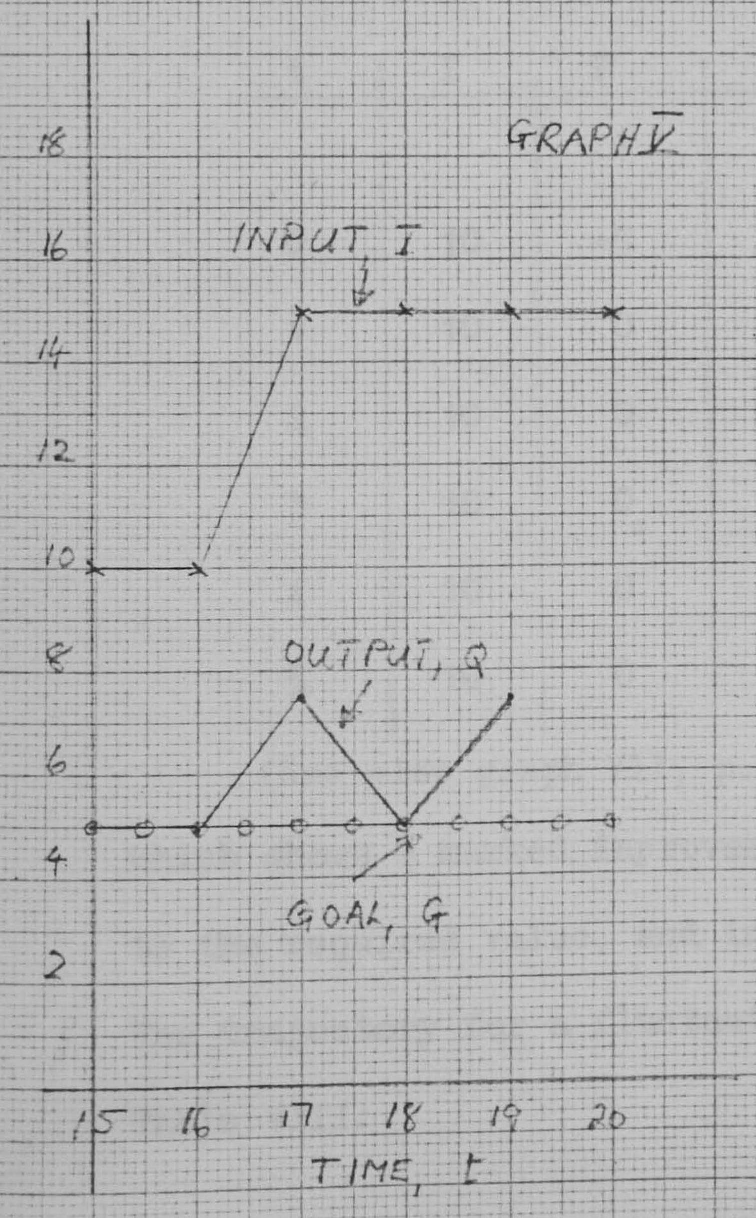
t	I	F	x	Q	G
21	10	0	10	5	5
22	10	0	10	5	5
23	10	0	10	5	3
24	10	2	6	3	3
25	10	0	10	5	3
26	10	2	6	3	3
27	10	0	10	5	3

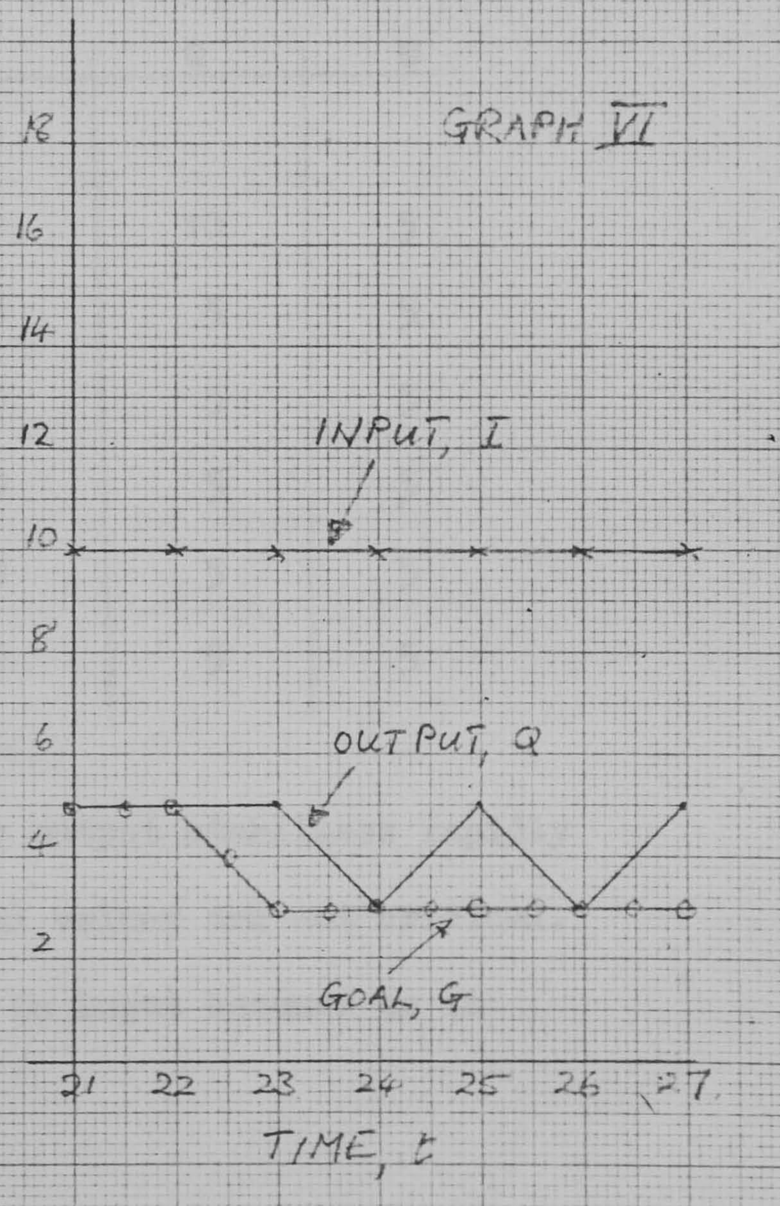
(See also graph Vl, p. 184a.)

The behaviour is still oscillatory, and the mean of the oscillations is still not at the goal. The control system is still not satisfactory, in spite of the fact that a perfect model has been built into it.

The initial response to the problem of oscillation is to include some damping in the control loop. However, as has been pointed out, the mean of the oscillations is not at the goal, and thus damping would not entirely rectify the fault. The root of the problem can be identified by examining column F; the feedback succeeds temporarily in correcting the output to the correct value, but the control loop contains no mechanism whereby the future of the input


GRAPH IV
INPUT, I
OUTPUT, Q
GOAL, G.
TIME, t
18
16
14
12
10
8
6
4
2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14


GRAPH V
INPUT, I
OUTPUT, Q
GOAL, G
TIME, t
18
16
14
12
10
8
6
4
2
15 16 17 18 19 20


GRAPH VI
INPUT, I
OUTPUT, Q
GOAL, G
TIME, t
18
16
14
12
10
8
6
4
2
21 22 23 24 25 26 27

can be estimated and therefore the control loop reverts to the inactive state once the desired output has been achieved, and the system oscillates. A means of fore-casting is required. The simplest forecast that can be made is that the input at t + 1 will be equal to the input at t, and this can be incorporated by modifying the equations to become.

7) $xt = It - 2Ft$

8) $Qt = 0.5xt$

9) $Ft = F_{t-1} + (Q_{t-1} - G_{t-1})$

The starting trajectory then becomes as in Table VII

TABLE VII

t	I	F	x	Q	G
0	10	-5	20	10	5
1	10	0	10	5	5
2	10	0	10	5	5
3	10	0	10	5	5
4	10	0	10	5	5
5	10	0	10	5	5

(See also graph V11, p. 186a.)

which shows a marked inprovement; output stabilises rapidly to the required value, and initial values are not critical. The trajectory for a fluctuation in input becomes as in Table VIII.

TABLE VIII

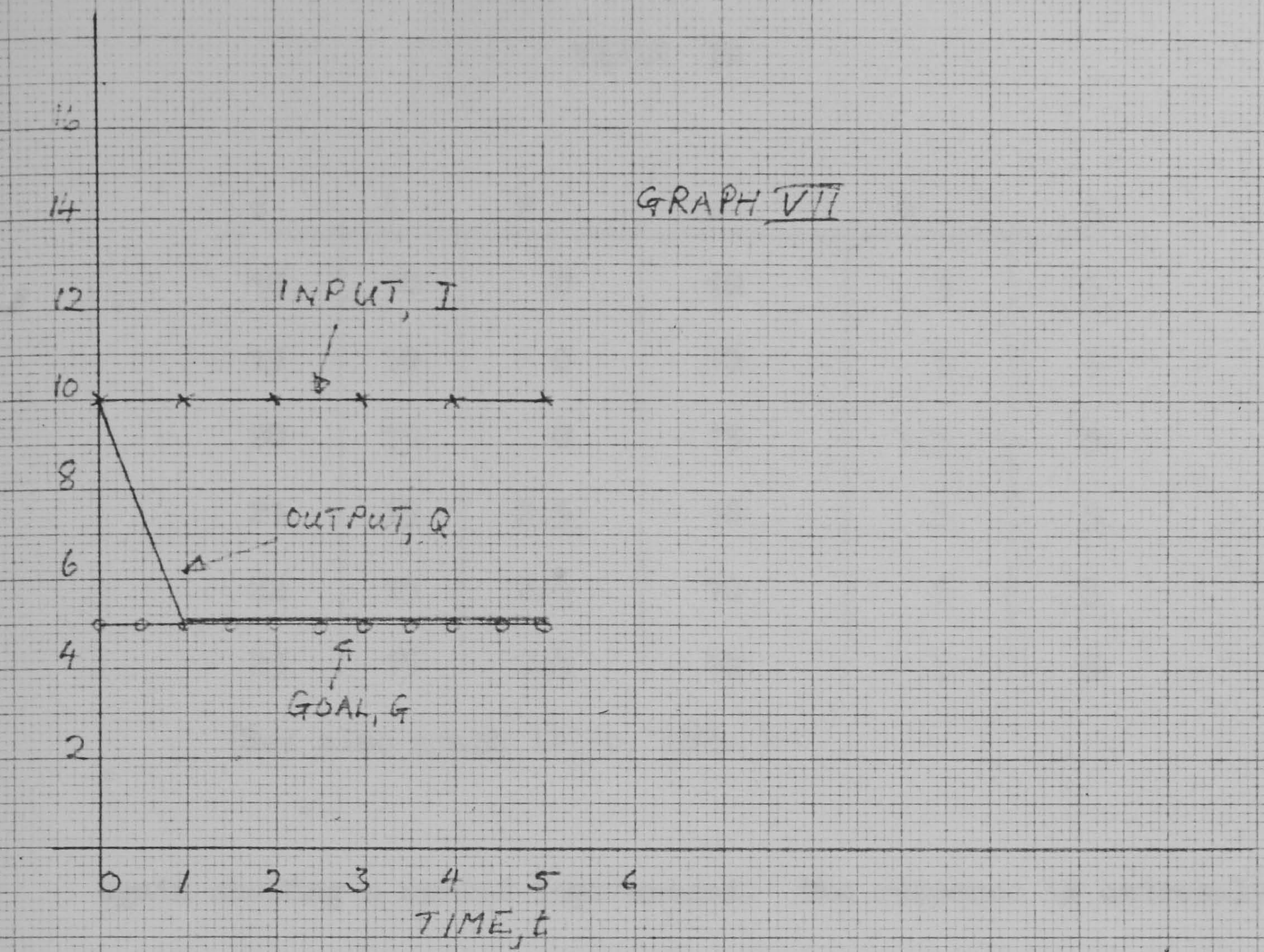
t	I	F	x	Q	G
6	10	0	10	5	5
7	11	0	11	5.5	5
8	12	.5	11	5.5	5
9	13	1.0	11	5.5	5
10	14	1.5	11	5.5	5
11	15	2.0	11	5.5	5
12	14	2.5	9	4.5	5
13	13	2.0	9	4.5	5
14	12	1.5	9	4.5	5
15	11	1.0	9	4.5	5
16	10	.5	9	4.5	5
17	10	0	10	5.0	5

(See also graph V111, p. 186a.)

This again shows a marked improvement. The control index becomes

$$C = (i - (5.5 - 4.5)/2.5) \times 100\%$$
$$= 60\%$$

a three-fold improvement, and there is no tendency to oscillation. The trajectory for a stĕp-change in input becomes as in Table IX


GRAPH VII
INPUT, I
OUTPUT, Q
GOAL, G
16
14
12
10
8
6
4
2
0 1 2 3 4 5 6
TIME, t

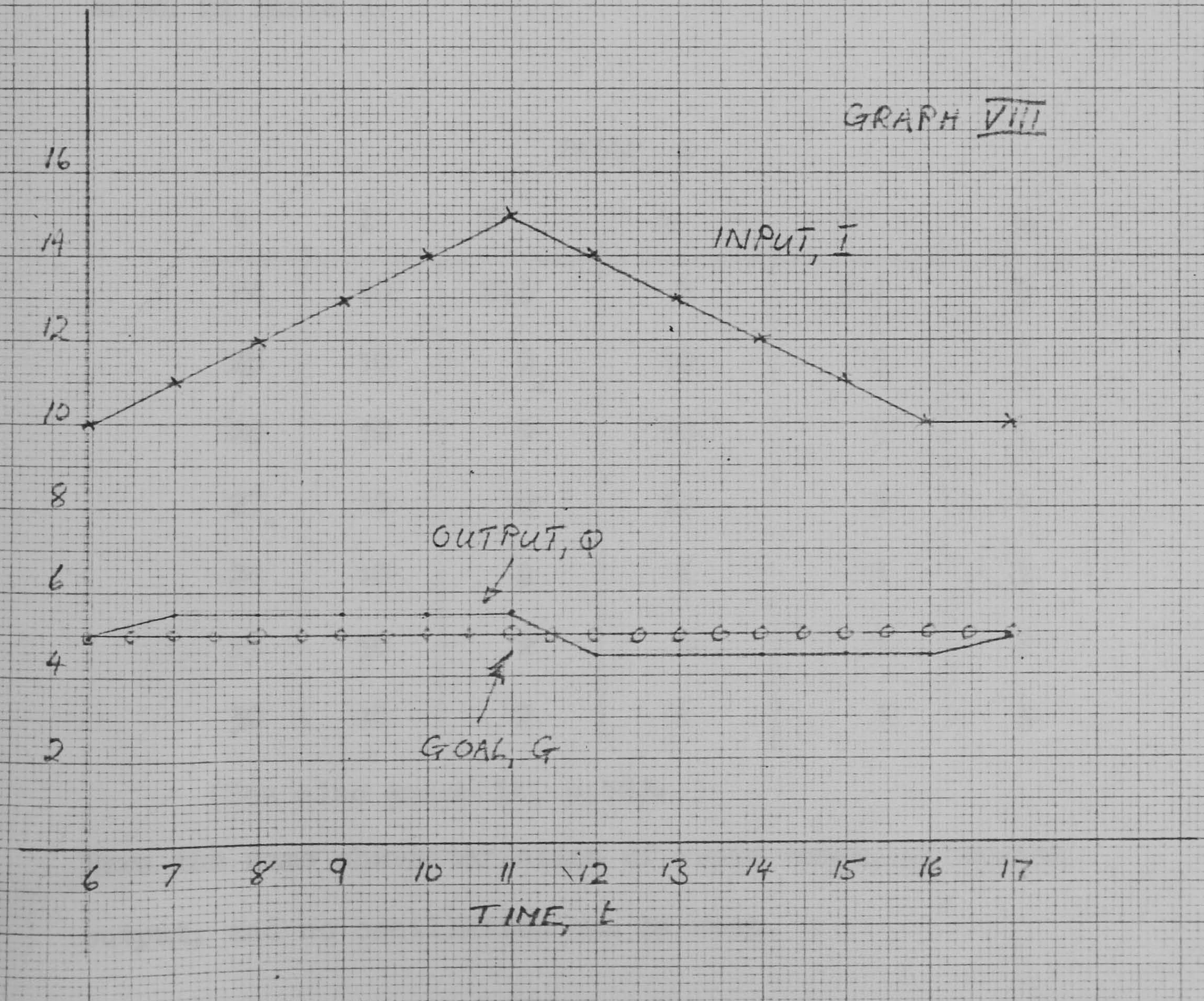

GRAPH VIII
INPUT, I
OUTPUT, Q
GOAL, G
16
14
12
10
8
6
4
2
6 7 8 9 10 11 12 13 14 15 16 17
TIME, t

TABLE IX

t	I	F	x	Q	G
18	10	0	10	5	5
19	10	0	10	5	5
20	15	0	15	7.5	5
21	15	2.5	10	5	5
22	15	2.5	10	5	5
23	15	2.5	10	5	5

(See also graph lX, p. 187a.)

again showing a marked improvement. The response is extremely rapid, the output adjusts to the goal, and there is no tendency to oscillation. The same is true for a change in goal, as shown in Table X.

TABLE X

t	I	F	x	Q	G
24	10	2.5	5	2.5	5
25	10	0	10	5	5
26	10	0	10	5	5
27	10	0	10	5	3
28	10	2	6	3	3
29	10	2	6	3	3
30	10	2	6	3	3

(See also graph lX, p.187a.)

Here the same characteristics of rapid response, correct output, and no oscillation can be seen.

A question of some interest is the relative importance of an accurate model and of input prediction. An indication of this can be obtained by examming the trajectories of the system being investigated here when the predictive factor is retained but the model is less accurate. The equations then become

10) $xt = I_t - F_t$

11) $Qt = 0.5\ x_t$

12) $Ft = F_{t-1} + (Q_{t-1} - G_{t-1})$

The starting trajectory is as in Table XI.

t	I	F	x	Q	G
0	10	-5	15	7.5	5
1	10	-2.5	12.5	6.25	5
2	10	-1.25	11.25	5.62	5
3	10	-.62	10.62	5.31	5
4	10	-.31	10.31	5.16	5
5	10	-.15	10.15	5.07	5
6	10	-.07	10.07	5.03	5
7	10	-.03	10.03	5.02	5
8	10	-.02	10.02	5.01	5
9	10	-.01	10.01	5.00	5
10	10	-0.00	10.00	5.00	5

(See also graph X1, p.189a.)

The trajectory is now not critically dependant upon initial conditions, and there is no tendency to oscillation. The time to reach the goal is, however, considerably extended.

The trajectory for a fluctuating input is as shown in Table XII.

TABLE XII

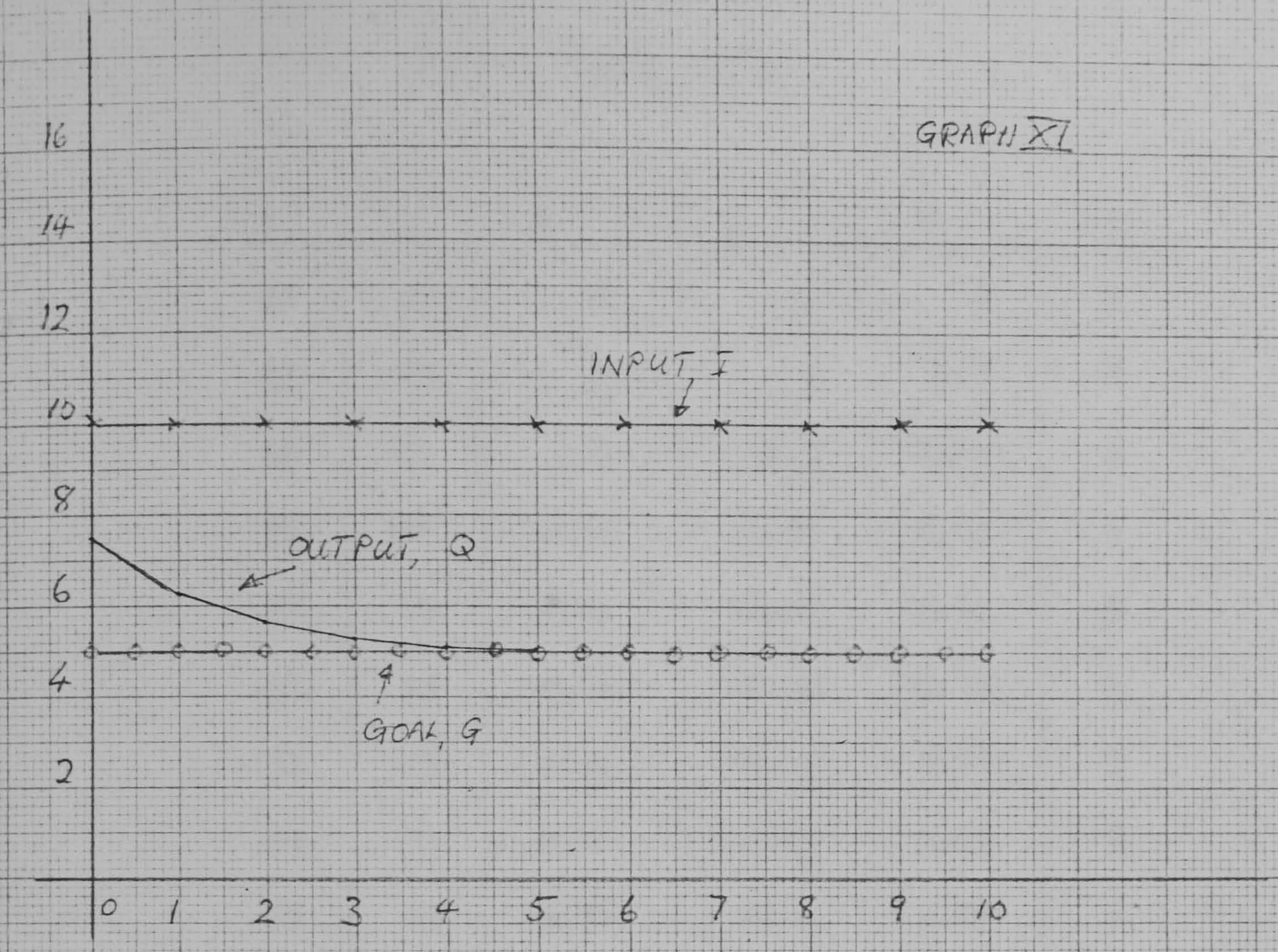
t	I	F	x	Q	G
11	11	0	11	5.5	5
12	12	.5	11.5	5.75	5
13	13	1.25	11.75	5.87	5
14	14	2.12	11.88	5.94	5
15	15	3.06	11.94	5.97	5
16	14	4.03	9.97	4.98	5
17	13	4.01	8.99	4.49	5
18	12	3.50	8.50	4.25	5
19	11	2.75	8.25	4.12	5
20	10	1.87	8.13	4.07	5
21	10	.94	8.06	4.03	5
22	10	-.03	10.03	5.01	5
23	10	-.02	10.02	5.01	5
24	10	-.01	10.01	5.00	5
25	10	-0.00	10.00	5.00	5

(See also graph X11, p.189a.)

The control index is

$$C = (1 - (5.87 - 4.03)/2.50) \times 100\%$$
$$= 27.4\%$$

a figure slightly greater than the index for a perfect model but no prediction. Again, the response is slow, and there is some tendency to oscillation, though this is well damped. The response to a step change in input is in table XIII.


GRAPH XI
INPUT, I
OUTPUT, Q
GOAL, G
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10

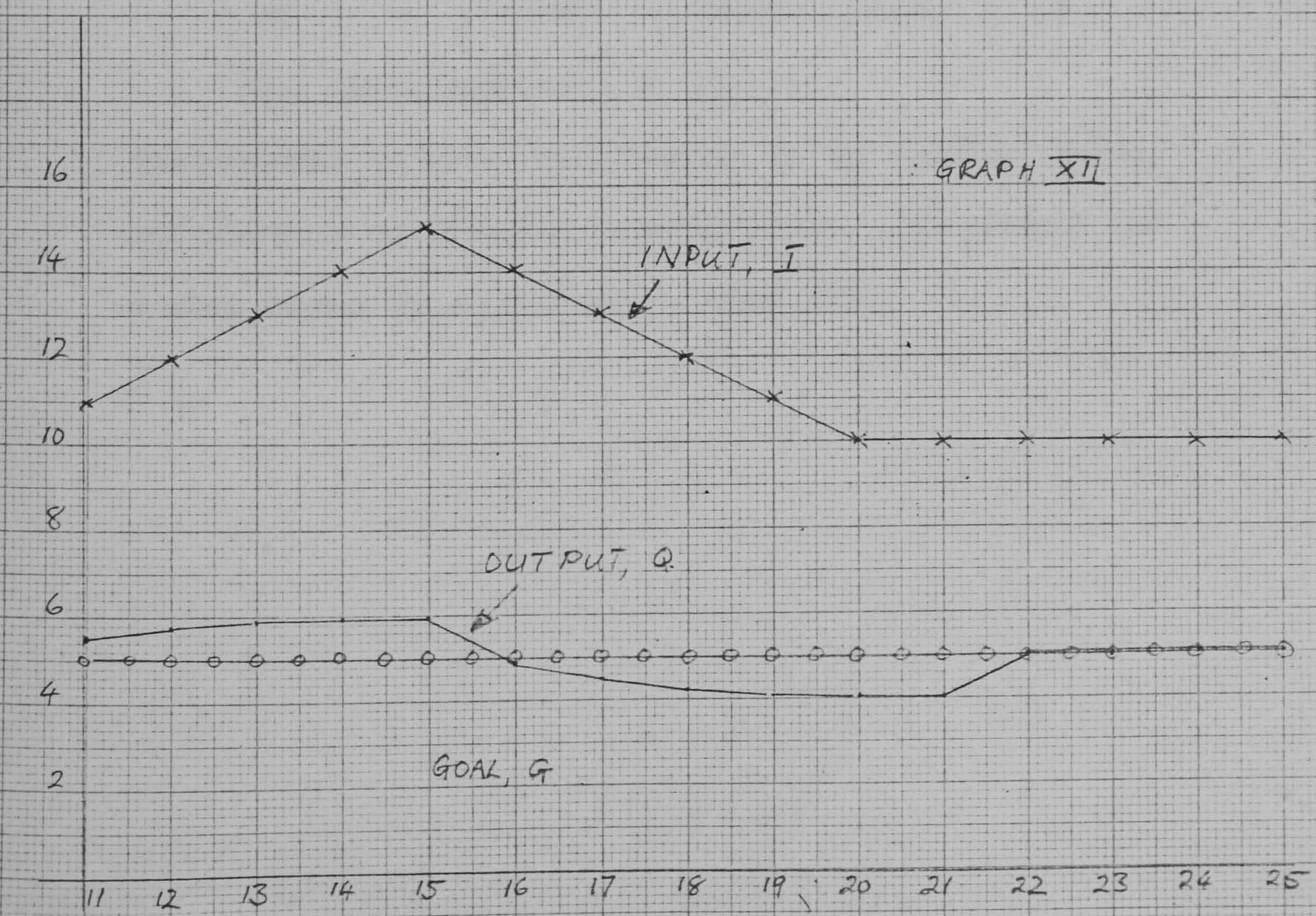

GRAPH XII
INPUT, I
OUTPUT, Q
GOAL, G
16
14
12
10
8
6
4
2
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

TABLE XIII

t	I	F	x	Q	G
26	10	0	10	5	5
27	15	0	15	7.5	5
28	15	2.5	12.5	6.25	5
29	15	3.75	11.25	5.62	5
30	15	4.37	10.63	5.31	5
31	15	4.68	10.32	5.16	5
32	15	4.84	10.16	5.08	5
33	15	4.92	10.08	5.04	5
34	15	4.96	10.04	5.02	5
35	15	4.98	10.02	5.01	5
36	15	4.99	10.01	5.00	5
36	15	5.00	10.00	5.00	5

(See also graph X111, p. 191a.)

The response is slow, but accurate to the required value, and there is no tendency to oscillation. The picture for a step change in goal is as in table XIII.

TABLE XIII

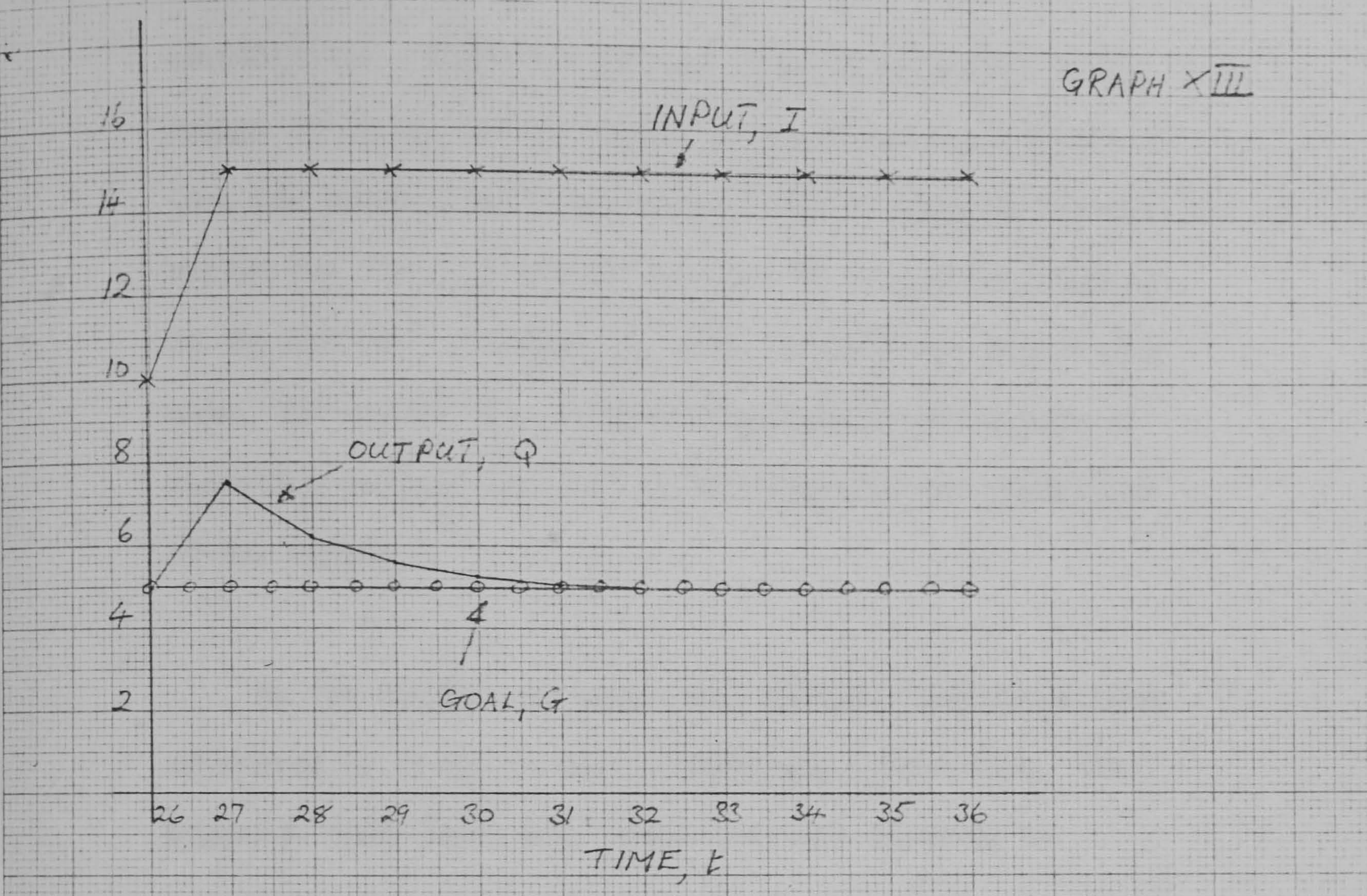
t	I	F	x	Q	G
37	10	0	10	5	5
38	10	0	10	5	3
39	10	2	8	4	3
40	10	3	7	3.5	3
41	10	3.5	6.5	3.25	3
42	10	3.75	6.25	3.12	3
43	10	3.87	6.13	3.07	3
44	10	3.94	6.06	3.03	3
45	10	3.97	6.03	3.01	3
46	10	3.98	6.02	3.01	3
47	10	3.99	6.01	3.00	3
48	10	4.00	6.00	3.00	3

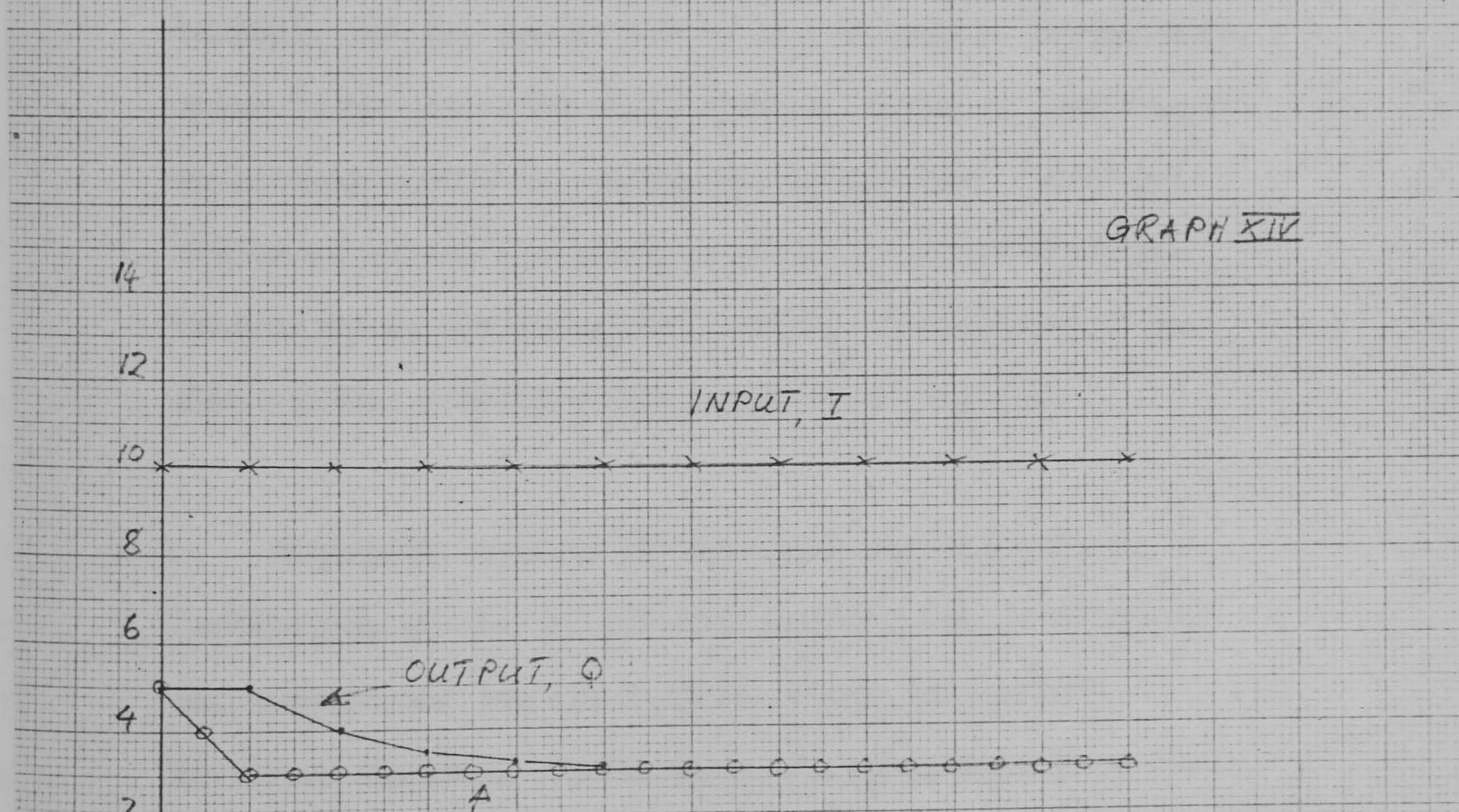
(See also graph X111, p. 191a.)

Again, the same picture emerges, a slow but accurate response with no oscillation.

The overall conclusion that emerges from this examination of an absolutely minimal feedback loop is that rapid response to an input depends upon having an accurate model, but that stability and accuracy of response depend upon prediction of future input within the feedback loop. Only the most elementary form of this prediction has been considered, but its value has been clearly demonstrated.

This value was in part due to the extremely simple forms of input considered. More complex inputs would require more complex prediction functions, involving rates -of-change


GRAPH XIII
INPUT, I
OUTPUT, Q
GOAL, G
16
14
12
10
8
6
4
2
26
27
28
29
30
31
32
33
34
35
36
TIME, t


GRAPH XIV
INPUT, I
OUTPUT, Q
GOAL, G
14
12
10
8
6
4
2
37
38
39
40
41
42
43
44
45
46
47
48
TIME t

calculations. Such factors are commonly included in the design of servo control systems, for reasons of stability (see for example Distefano (1967) chap I, chap 5) but the reason for their inclusion is given as to provide damping in the system. Although the basic mathematics remain the same, the reason that emerges from the foregoing line of reasoning is different; it is to allow for the prediction of the input.

In the context of managerial systems, the above line of reasoning leads to some interesting conclusions. It suggests that there are three distinct elements to administrative management, namely the obtaining of information about output, the modelling of the system under control, and the prediction of future input. Furthermore, these latter two have quite distinct areas of importance. An accurate model of the system is important for speedy response, but in isolation it produces instability and inaccuracy in the controlled output. Prediction of the input allows stability and accuracy of response.

Naturally, optimum results are obtained with a combination of the two but the possibilities for trade-off between the two are limited, since they affect different factors. Furthermore, it would seem that the ability to predict an input is of relatively greater importance than the posession of an accurate system model, in that a smooth and accurate response is more dependant upon this than upon detailed knowledge of the system. As far as it goes, this offers support for the view that a good manager can manage any operation with a high level of success; he needs only a very approximate knowledge of the operation under his command, provided that speed of response is not vital.

From a theoretical standpoint, it is of interest that nominally feedback systems can (and by implication usually do) contain predicture elements. It adds weight to the view expressed earlier that the main purpose of strategic control is not to obtain faster response through a prediction of future input, but is much more concerned with problems of overall organisation.

Thus far, only the most elementary of feedback situations has been examined. As has been emphasised, a managerial situation involves multiple goals and simultaneous control of several variables. It is relevant, therefore, to examine more complex situations, particularly where variables are not separable but interact. As an archetype of such a situation, consider fig. 22

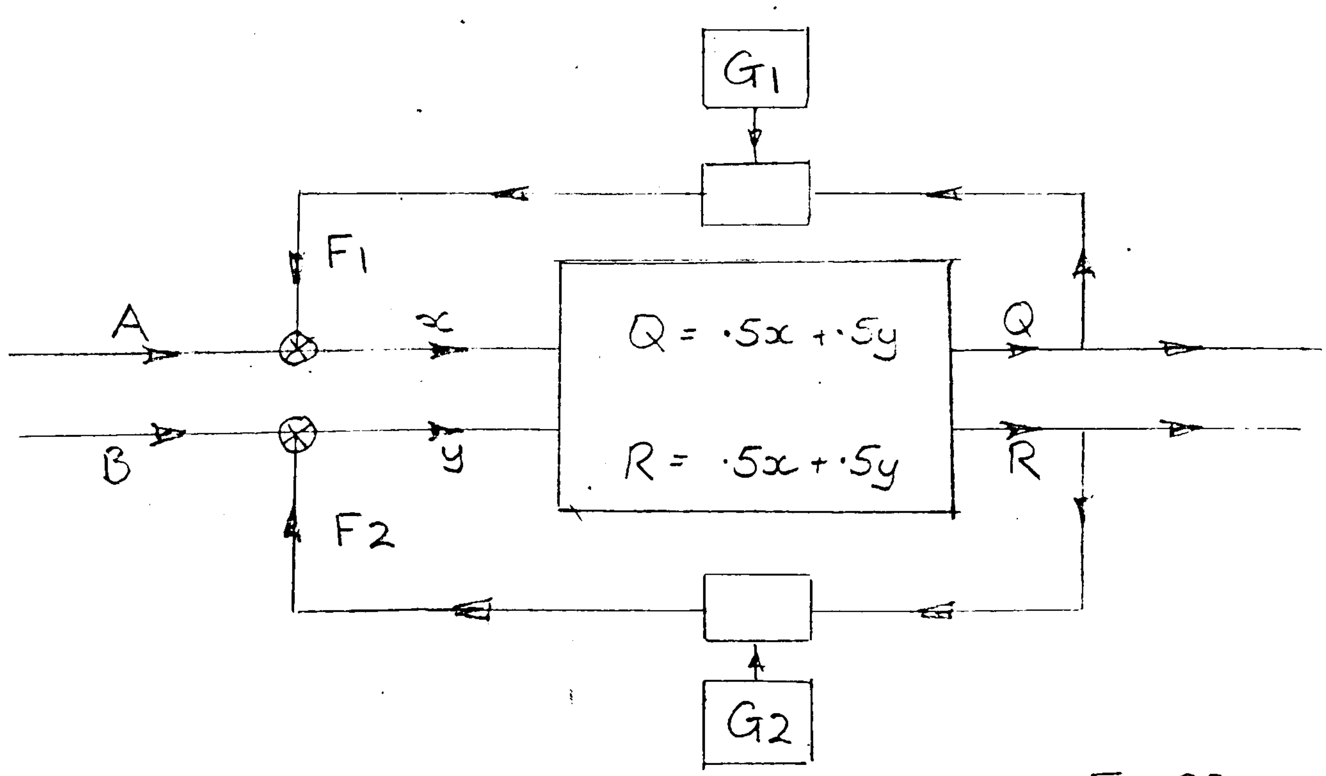


Fig 22

with equations

13) $xt = At - 2F1_{t-4}$

14) $Qt = .5xt + .5yt$

15) $F1_t = F1_{t-1} + Q_{t-1} - G1_{t-1}$

16) $yt = B_t - 2F2_{t-1}$

17) $Rt = .5yt + .5xt$

18) $F2t = F2_{t-1} + R_{t-1} - G2_{t-1}$

Here there is strong interaction of the variables, but each control loop assumes that the variables are independent. Each control loop has a predicture element, and an accurate model of the effect of the variable it controls. These features make the situation described somewhat unrealistic, but serves to emphasise the principles involved. The trajectory for a varying input is as shown in Table XIV.

TABLE XIV

t	A	B	F1	F2	x	y	Q	R	G1	G2
0	10	10	0	0	10	10	10	10	10	10
1	11	10	0	0	11	10	10.5	10.5	10	10
2	12	10	.5	.5	11	9	10.0	10.0	10	10
3	13	10	.5	.5	12	9	10.5	10.5	10	10
4	14	10	1.0	1.0	12	8	10.0	10.0	10	10
5	15	10	1.0	1.0	13	8	10.5	10.5	10	10
6	14	10	1.5	1.5	11	7	9.0	9.0	10	10
7	13	10	.5	.5	12	9	10.5	10.5	10	10
8	12	10	1.0	1.0	10	8	9.0	9.0	10	10
9	11	10	0	0	11	10	10.5	10.5	10	10
10	10	10	.5	.5	9	9	9.0	9.0	10	10
11	10	10	-.5	-.5	11	11	11.0	11.0	10	10
12	10	10	.5	.5	9	9	9.0	9.0	10	10
13	10	10	-.5	-.5	11	11	11.0	11.0	10	10

(See also graph X1V, p.196a.)

The control index (for a single variable) is

$$C = (1 - (11.0 - 9.0)/2.5) \times 100\%$$
$$= 20\%$$

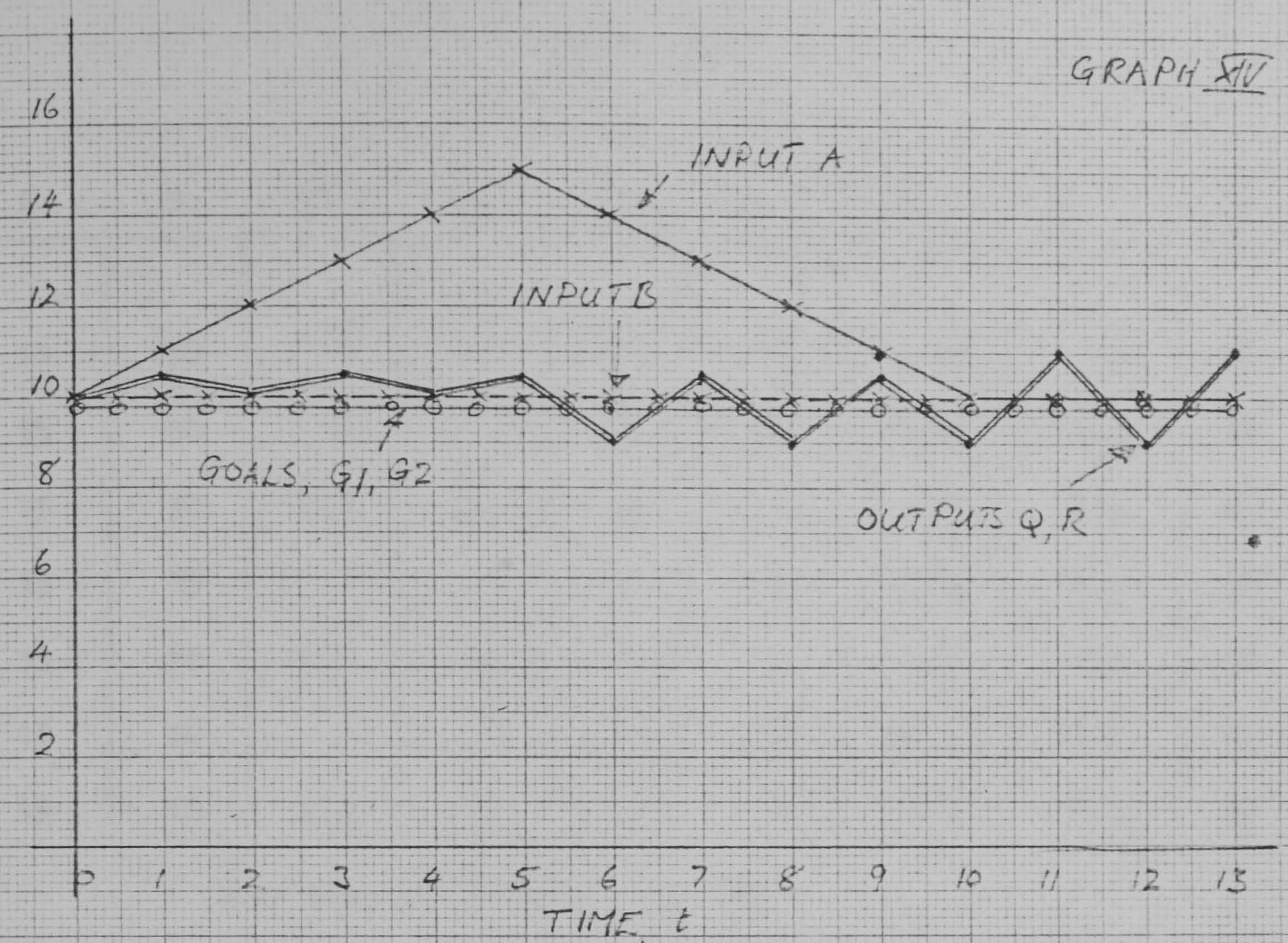
which is not very high. Response is rapid, as would be expected, but the output enters a cycle. The trajectory for a change in one goal is shown in table XV

TABLE XV

t	A	B	F1	F2	x	y	Q	R	G1	G2
0	10	10	0	0	10	10	10	10	10	10
1	10	10	0	0	10	10	10	10	6	10
2	10	10	4	0	2	10	6	6	6	10
3	10	10	4	-4	2	18	10	10	6	10
4	10	10	8	-4	-6	18	6	6	6	10
5	10	10	8	-8	-6	26	10	10	6	10
6	10	10	12	-8	-14	26	6	6	6	10
7	10	10	12	-12	-14	34	10	10	6	10
8	10	10	16	-12	-22	34	6	6	6	10
9	10	10	16	-16	-22	42	10	10	6	10

(See also graph XV, p.196a.)

The system never settles, but oscillates between the two goals. A feature of interest is the ever-increasing feedback activity involved. The trajectory for a step-change in input is


GRAPH XIV
INPUT A
INPUT B
GOALS, G1, G2
OUTPUTS Q, R
16
14
12
10
8
6
4
2
0 1 2 3 4 5 6 7 8 9 10 11 12 13
TIME, t

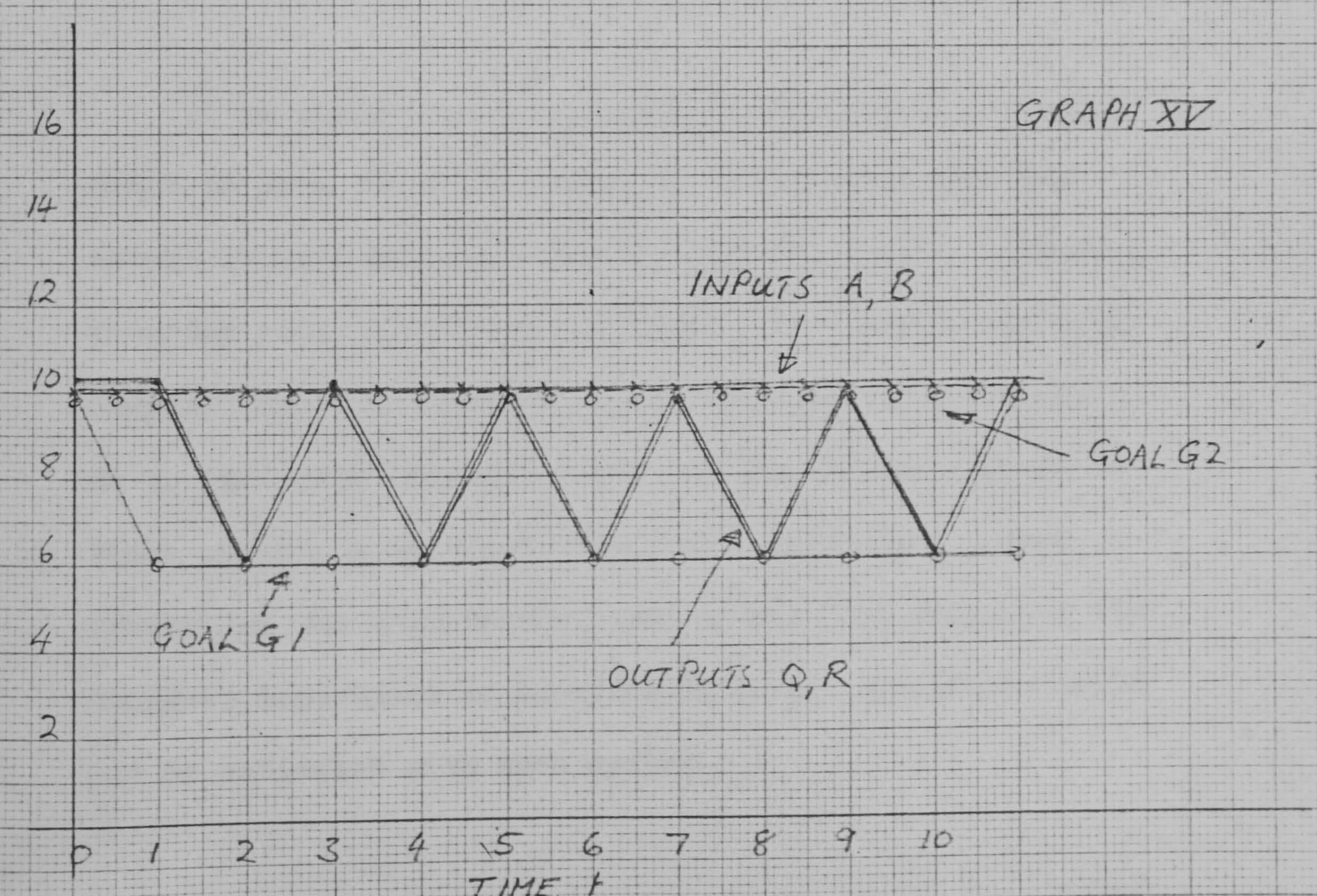

GRAPH XV
INPUTS A, B
GOAL G2
GOAL G1
OUTPUTS Q, R
16
14
12
10
8
6
4
2
0 1 2 3 4 5 6 7 8 9 10
TIME, t

TABLE XVI

t	A	B	F1	F2	x	y	Q	R	G1	G2
0	10	10	0	0	10	10	10	10	10	10
1	15	10	0	0	15	10	12.5	12.5	10	10
2	15	10	2.5	2.5	10	5	7.5	7.5	10	10
3	15	10	0	0	15	10	12.5	12.5	10	10
4	15	10	2.5	2.5	10	5	7.5	7.5	10	10
5	15	10	0	0	15	10	12.5	12.5	10	10
6	15	10	2.5	2.5	10	5	7.5	7.5	10	10

(See also graph XVl, p. 197a.)

Again, the response enters a cycle, oscillating around the goal values but in this instance the amount of feedback activity does not increase.

It is perhaps worth pointing out here that it is not meant to infer that the system is unstable because its output cycles; the cycle itself is quite stable. However, from the point of view of a manager, such cycles may well suggest that his operation is out of control, especially as in real life the cycles will not be so clear-cut as in these grossly simplified examples. Furthermore, other members of the organisation, who receive the output of the managers department as input to their own operations, will not be satisfied with such cycles.

Since the feedback loops described already have input prediction methods that have been found adequate, it is logical to look at the system models in the loops to attempt to improve the situation. The models used ignored the interaction between variables. To improve them, this needs to be taken account of - but only in one of the loops. If the equations are modified to become

19) $xt = At - 2FI_t$

20) $Qt = .5x_t + .5yt$

21) $F1_t = F1_{t-1} + (Q_{t-1} - G1_{t-1}) - (R_{t-1} - G2_{t-1})$

22) $yt = B_t - 2F2_t$

23) $R_t = .5x_t + .5yt$

24) $F2_t = F2_{t-1} + (R_{t-1} - G2_{t-1})$

which models the interaction in the G1 control loop, the trajectory for a disturbed input becomes as shown in Table XVII

TABLE XVII

T	A	B	F1	F2	x	y	Q	R	G1	G2
0	10	10	0	0	10	10	10.0	10.0	10	10
1	11	10	0	0	11	10	10.5	10.5	10	10
2	12	10	0	.5	12	9	10.5	10.5	10	10
3	13	10	0	1.0	13	8	10.5	10.5	10	10
4	14	10	0	1.5	14	7	10.5	10.5	10	10
5	15	10	0	2.0	15	6	10.5	10.5	10	10
6	14	10	0	2.5	14	5	9.5	9.5	10	10
7	13	10	0	2.0	13	6	9.5	9.5	10	10
8	12	10	0	1.5	12	7	9.5	9.5	10	10
9	11	10	0	1.0	11	8	9.5	9.5	10	10
10	10	10	0	.5	10	9	9.5	9.5	10	10
11	10	10	0	0	10	10	10.0	10.0	10	10

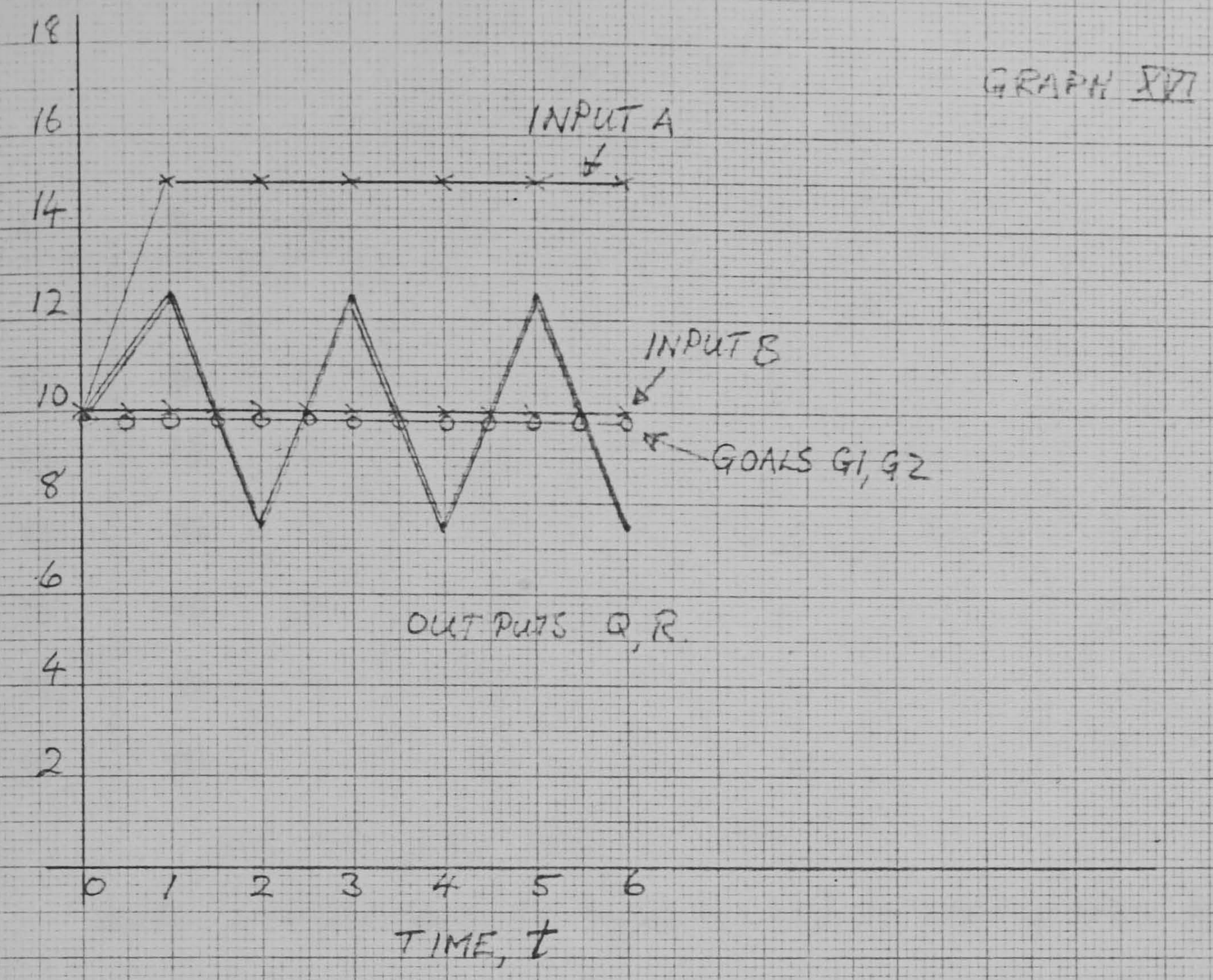
(See also graph XV11, p. 199a.)

The control index is

$$C = (1 - (10.5 - 9.5)/2.5) \times 100\%$$

$$= 60\%$$

showing a good level of control. There is no tendency to oscillation. Examination of the F1 column (the feedback with the accurate model) shows that there is no activity from this loop - it has been 'shorted out' so to speak, with considerable benefits. The trajectory for a step change in input is similarly improved, as shown in Table XVIII


GRAPH XVI
INPUT A
INPUT B
GOALS G1, G2
OUTPUTS Q, R
18
16
14
12
10
8
6
4
2
0 1 2 3 4 5 6
TIME, t

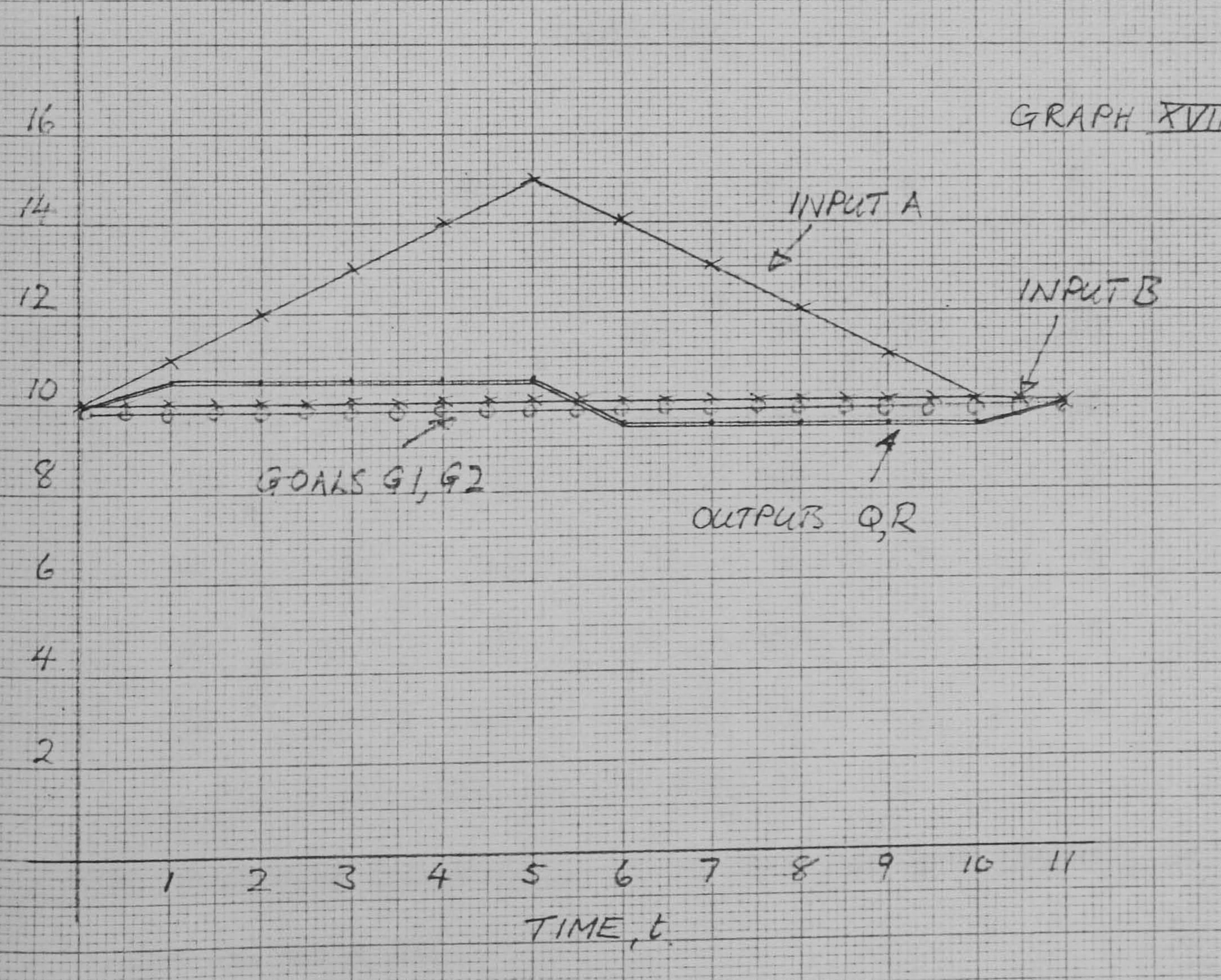

GRAPH XVII
INPUT A
INPUT B
GOALS G1, G2
OUTPUTS Q, R
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7 8 9 10 11
TIME, t

TABLE XVIII

A	B	F1	F2	x	y	Q	R	G1	G2
10	10	0	0	10	10	10	10	10	10
15	10	0	0	15	10	12.5	12.5	10	10
15	10	0	2.5	15	5	10	10	10	10
15	10	0	2.5	15	5	10	10	10	10
15	10	0	2.5	15	5	10	10	10	10
15	10	0	2.5	15	5	10	10	10	10

(See also graph XV111, p. 201a.)

Again, a well-controlled response, with F1 showing every sign of masterly inactivity. The response to a change in goal is as in Table XIX.

TABLE XIX

A	B	F1	F2	x	y	Q	R	G1	G2
10	10	0	0	10	10	10	10	10	10
10	10	0	0	10	10	10	10	6	10
10	10	4	0	2	10	6	6	6	10
10	10	8	-4	-6	18	6	6	6	10
10	10	12	-8	-14	26	6	6	6	10
10	10	16	-12	-22	34	6	6	6	10

(See also graph X1X, p. 201a.)

The situation for a change in G2 is slightly different, as shown in Table XX.

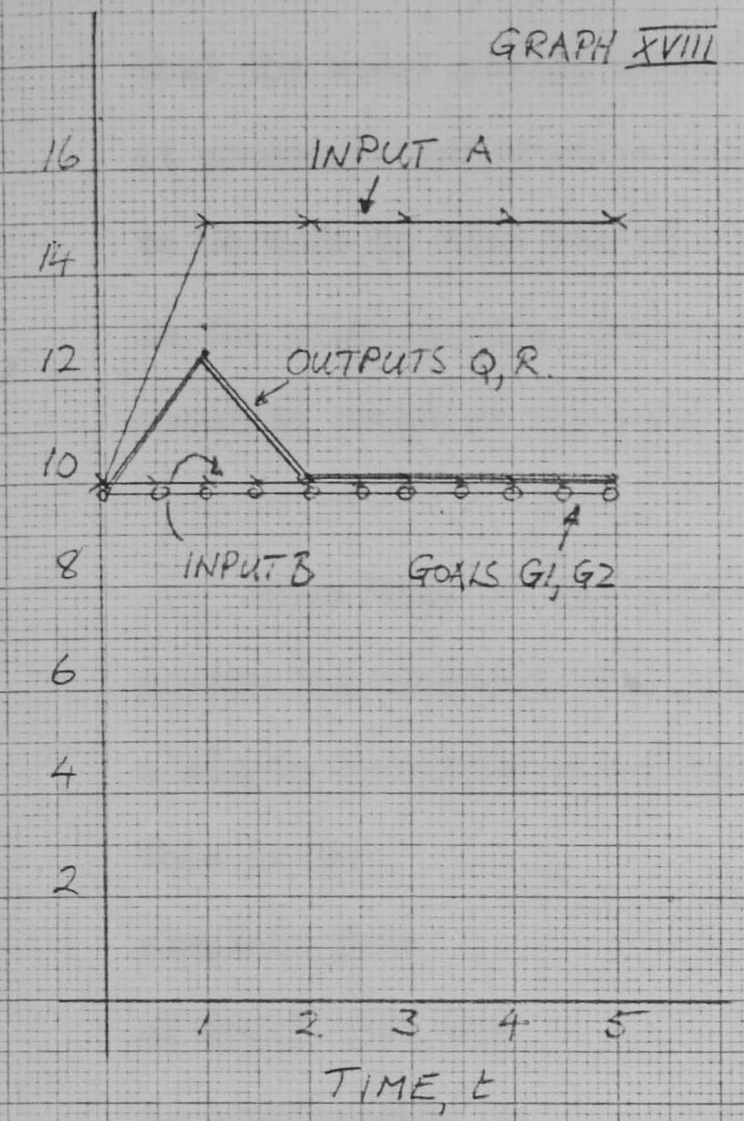
TABLE XX

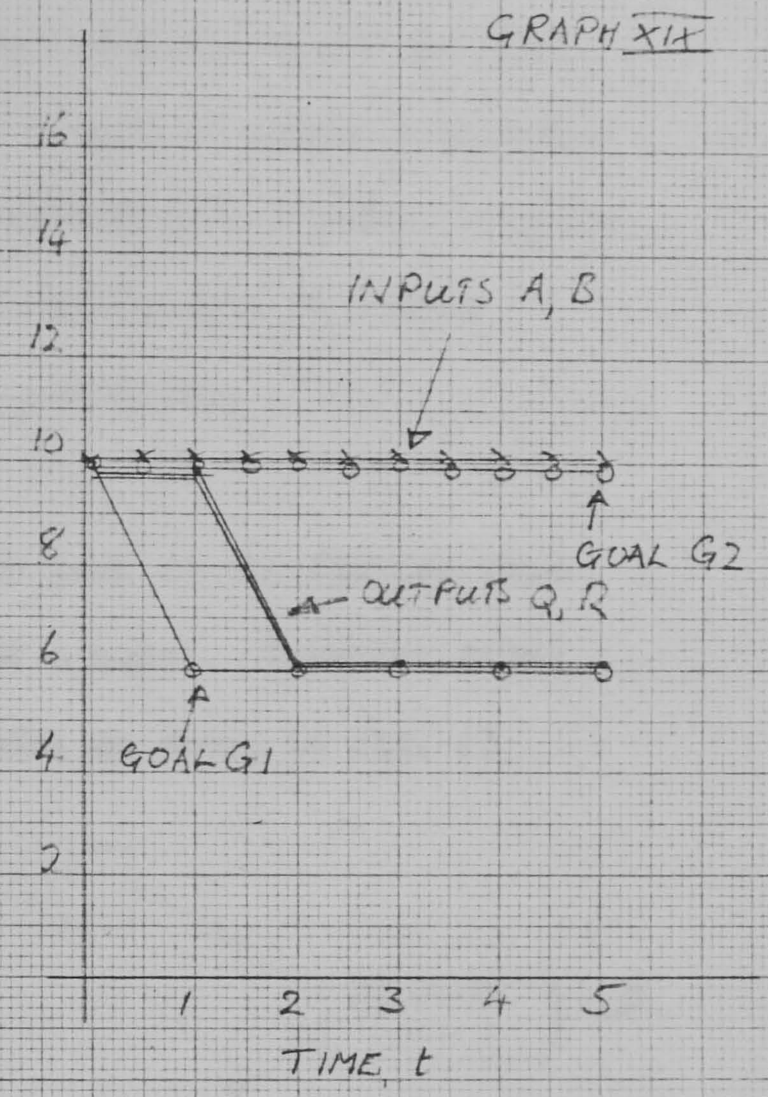
	A	B	F1	F2	x	y	Q	R	G1	G2
0	10	10	0	0	10	10	10	10	10	10
1	10	10	0	0	10	10	10	10	10	6
2	10	10	4	4	2	2	2	2	10	6
3	10	10	0	0	10	10	10	10	10	6
4	10	10	4	4	2	2	2	2	10	6
5	10	10	0	0	10	10	10	10	10	6

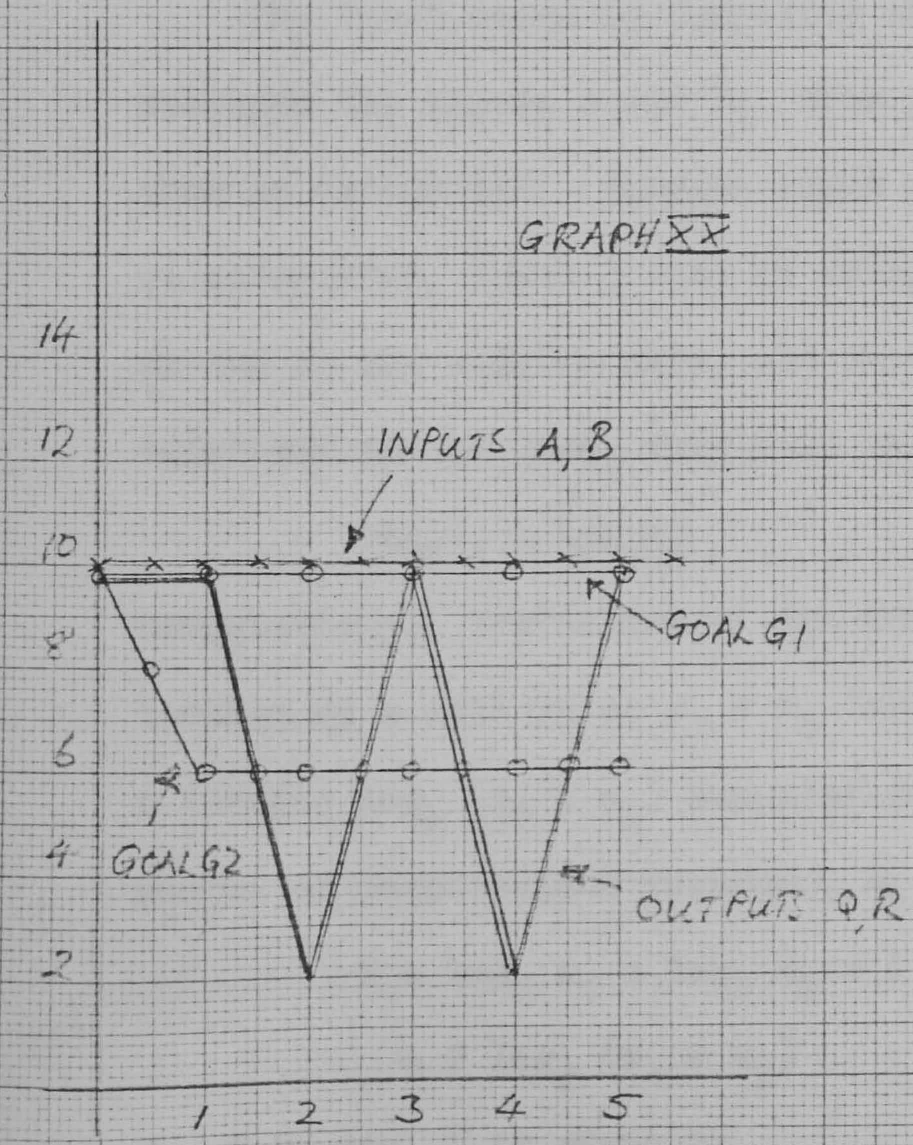
(See also graph XX, p. 201a.)

In the first case, G1 is achieved (at the expense of G2) but is only maintained rapidly increasing feedback. If F1 and F2 are limited, as is normally the case, the situation will reach oscillation. In the second case, a cycle sets in, and neither target is reached, although both feedback channels are active.

The conclusions to be drawn from the above examples seem to be as follows. In the first place, where a system contains interacting variables, an accurate model of it is required for acceptable control. In the second place, attempting joint control of all variables does not necessarily lead to improvements in overall control, and may well impair results rather than improve them. This is of relevance to the design of organisational control systems. In the third place, attempting to change the goals of such a system without at the same time modifying the system is fraught with difficulty. In other words, a multi-variable


GRAPH XVIII
INPUT A
OUTPUTS Q, R.
INPUT B
GOALS G1, G2
16
14
12
10
8
6
4
2
1 2 3 4 5
TIME, t


GRAPH XIX
INPUTS A, B
GOAL G2
OUTPUTS Q, R
GOAL G1
16
14
12
10
8
6
4
2
1 2 3 4 5
TIME, t


GRAPH XX
INPUTS A, B
GOAL G1
GOAL G2
OUTPUTS Q, R
14
12
10
8
6
4
2
1 2 3 4 5

system will not behave as a servomechanism.

Table XIX contains a point of considerable relevance here, to which reference has already been made. Goals may be maintained for a period of time by the expenditure of consider able feedback effort, until the available resources are exhausted. There will then be a sudden step-change in output, with little or no apparent immediate cause. Industrial relations problems have these characteristics, and it may be that some such mechanisms are involved in these circumstances. The earlier discussions on organisational style and conflict between personal and organisational goals are also of relevance here.

This leads to a further point of relevance. Reference has been made to the importance of accurate modelling for control purposes. Yet, by definition, organisations contain people, and accurate models of human behaviour are not available. Thus, the strictly deterministic equations that have been used in the above examples are not truly representative of the managerial situation. This does not, however invalidate the nature of the conclusions drawn, which are qualitative rather than quantitative in nature.

Thus far, only extremely simple cases have been examined. Enough has been said, however, to establish the complexity of interrelationship that exists within organisations, and the problems of control and stability that this entails.
It is also clear that Ashby's (1960) concept of a multistable

system is applicable to organisations (Indeed, this could have been assumed from the start, but it appeared advisable to establish the identity rather than to assume it) Ashby has studied the general problem of stability in such systems ((1960), chap 20) and concluded (though not proved) that the probability of stability decreases as the number of variables increases. He says (p261) "These results prove little; but they suggest that the probability of stability is small in large linear systems assembled at random." Porter (1972) has come to similar conclusions. This does not mean that large systems are necessarily unstable - the prolonged existence of many organisations demonstrates this - but it does imply that such stabilities are not easily found, are are easily disturbed. This may well be the instinctive reasoning behind the conservatism of many large organisations.

Ashby's work also suggests a reason for the departmentalisation found in many large organisations. His work on adaptation (1960, ch.16) shows that the time taken for a multistable system to adapt to its environment can be descreased by many orders of magnitude if the total is partitioned into subsystems, with minimal communication between the subsystems. Many organisations are in fact patterned in this way (e.g Buying Division, Production Division, Sales Division, with further sub divisions in each), though it does not of course, follow that such partitions necessarily correspond to operational reality. Further, it suggests strongly that attempts to break down such organisational barriers and encourage communication are ill-advised and may be strongly counter-productive.

It also adds evidence to the previous conclusion that there is a clear distinction between administrative and strategic management. The former has to run the organisation as it exists; the latter has to re-shape and re-structure the organisation as the environment changes. This distinction is often not made clearly in actual organisations, where the same group of individuals carry out both functions. The required distinction is akin to the distinction between line and staff management, but with clearer responsibilities and more authority accorded to the staff.

There is a further point of relevance to be made. Ashby's formulation was intended to propose a model for the functioning of the brain. If this formulation also applies to the organisation, it follows that lessons about the functioning of the brain can be drawn from a study of the functioning of organisations. Since the latter are much more open to inspection and experiment, it seems that much could be gained from such studies. Clearly, there is room for much further work.

2. Consistency of Models Among Managers

Considerable discussion has been afforded already to the importance of models in the managerial process. One aspect of this topic which has not been examined is that of consistency amongst the different models used by different managers in the same organisation, and it merits a brief examination here.

It is well-known that the same phenomenon (or system) can be modelled in a variety of incompatible ways, yet each model yield valid results. For example, light can be modelled as a wave process, or as a particle process - these two models have only recently been reconciled one with another. McGregor's (1960) Theory X and Theory Y form another such pair. Thus, it is to be expected that two managers confronted with the same situation may model it in entirely different ways - each of which can be valid.

To some extent - particularly in the administrative situation, where only a black box model is required - this is of no great consequence. However, it is well-known that organisations tend to develop their own "style". The most obvious examples of this are perhaps the "City Gent", the 'Civil Service Mind' or the Military Manner". This implies a certain degree of consistency amongst the managerial models in use in a particular organisation, and it is of interest as to how this uniformity develops, and what some of the consequences may be.

The most obvious solution to the problem of how uniformity develops lies in a process of 'natural selection', akin to Ashby's 'selection by equilibruim'. For managers will interact with each other, both formally and informally, and communication will be easier amongst those with similar models and hypotheses. Groups will tend to coalesce and co-here on the basis of similarity of models.

A case of particular importance is that of promotion. Other things being equal, the individual who thinks like his superiors is more likely to be appointed to a senior position, on the basis that he will fit in better with colleagues, will more easily form part of a team, and will be less likely to "rock the boat". Indeed, it could even be that such considerations might outweigh considerations of merit and achievement - particularly when it is extremely difficult to measure managerial performance in any meaningful way.

Thus there is a natural tendency for organisations to select individuals who conform to the organisational pattern. People with widely dissenting views then find themselves as misfits, and either leave or make no further progress. Ultimately, the recruiting procedures are likely to reject such individuals before they even join the organisation. Conversely, there will be the opportunity for people who fit in exceptionally well to make rapid progress, almost regardless of ability. Since "fitting in" is a function of background and education, it is to be expected that large organisations will develop well-defined "ruling castes" or cliques.

3 The Modelling Process

Much attention has already been directed to models, but little has been said about the ways in which they may be developed, apart from the fact that information outside normal feedback channels is used. This reflects the paucity of attention that has been paid to the subject within management literature. Whilst cybernetic literature deals quite specifically in models, again there is comparatively little attention to the process of how models are arrived at. For example, though Ashby (1956) examines the way that scientific models are developed - and pays great attention to how state-determined system models are developed - he does look at the basic problem of how the initial variables are selected for study. This is a crucial problem, which Ashby is apparently prepared to leave to chance.

This initial selection of variables is a deep problem which is taken up again in more depth in Part IV of this thesis. For the moment, Ashby's starting point will be taken, and related to the more immediate practical context of managerial modelling.

First, let it be admitted that there are specialists in modelling in management sciences such as O.R Much of this type of work lies in developing models and analysing them. These, however, are not the immediate concern - they are too cumbersome to be used in the day-to-day hurly-burly of management life. The concern is more with the basis for the immediate 'seat-of-the-pants' control.

First, there is a point to be made about the general nature of organisational work at the operational level. Tasks are designed to be performed in isolation from each other, i.e. the total system is generally assumed to be serial in nature. There is seldom any intrinsic feedback between the tasks themselves, there is not the sort of complex interrelation found in the organic, or biological or ecological fields. The tasks are designed to be regulated by external feedback. As has been seen, the complexity of organisations arises from interrelations amongst these external feedback mechanisms rather than direct interaction amongst the operations themselves.

Such design facilitates enormously the problem of controlling the organisation. In passing, it should be noted that the sphere of government does not accord with this principle; a nation is much more analagous to an organic entity that to a serial process, and the basic task of government is not so much to ensure that x amount of goods and services are produced as to ensure that there is a proper set of checks and balances available to presserve the viability of the social order. Because the social order is itself a complex interaction between individuals and groups of individuals, it would appear that the basic philosophy of government should be different from the basic philosophy of organisations.

However, the manager in an organisational context is faced basically with an input - output situation which he is required to control. For this, he requires an input - output type of model. If he were starting from scratch, he could of course use the methods described by Ashby. Usually of course, he is not in this position. He comes equiped with a variety of models, one of which he will select as appropriate and proceed to use.

These models will almost always contain the equivalent of adjustable parameters (such as feedback fraction, delay time, inertia) the values of which will need to be adjusted to the particular situation. Thus in a parallel-management operation (such as Sales Management) it may well be that the sales manager has one basic model of his retail outlets which is adapted to each one by the substitution of appropriate values for parameters such as outlet size, number of different type of goods sold, number of staff, and so on. (This is not necessarily the case; it may be that a single set of parameters is used for all. There is no guarantee that a manager will do what theory prescribes)

The ways in which such 'tuning' may be achieved is well understood, and have been described by Garner (1968) for electronic systems. The technique is to apply the same input to both system and model, and adjust the model parameters until identical outputs are achieved, i.e. basically the model and system are run in parellel. In the present context, however, this implies that the model cannot be used for control purposes whilst this 'tuning' is carried out, or the interaction would produce undecideable results.

The manager cannot afford to spend too long 'tuning' before he starts on his job.

It can of course be the case that the form of a model and the form of the reality are quite different, and yet by suitable adjustment of the parameters the input - output relationship may be identical, or at least approximately equal over the range of inputs studied. As a simple example the functions

$$y = \sin x$$

can be modelled by

$$y = x$$

for small values of x. Thus a manager may select an entirely unappropriate model, yet operate successfully - at least over a limited range of input.

Should the input vary beyond this range, the manager may find himself with serious problems, and locked in to a very difficult situation. In his attempts to exert control through an inappropriate models, he will find himself using higher and higher levels of feedback activity. It is easy to say that what he needs to do is to stand back from the situation, select a new model, and adjust its parameters to the situation. Yet, the situation is probably such that to temporarily abandon control (which is what is implied) could have major consequences. Furthermore, his experience has taught him that his model is right - it has always worked before - and thus he is psychologically reluctant to abandon it. He may well feel that a step-change has occured in the environment - though he is unlikely to use that terminology to express his views.

The probable sources of a managers initial models are fairly obvious, either training or experience. Training will have equiped him with a variety of theoretical models of the process of which he is to be in charge. Alternatively, experience may have taken him through positions as an operator of various sections of the process. This latter will have enabled him not only to 'time' his model to the process but also to model the influence of the people in the process, an element not present in the theoretical background. A variant of this situation is where a manager is recruited from outside the organisation; a quite usual requirement for appointing a recruitee is experience in a similar position. This is particularly true for senior positions in management. Whilst the reasons for this requirement are obvious, it has its dangers. A normally similar job in a different organisation, being in a totally different situation, may have produced models that are not applicable in the new organisation. The process is in some ways analagous to tissue transplants; the body may well reject the graft.

Brief mention was made above of modelling the people involved in the process. There are two aspects to this. The first is to model the performance of the worker whilst performing his duties - this can be done by observing the performance of the total man/task system. This however will provide only extremely limited information about how he will perform on other duties. To do this, a model of the person himself is required, which can only be acquired through social interaction. This point is worthy of comment chiefly because of the efforts which many organisations make to limit any such interaction between different levels in the organisational hierachy. The whole apparatus of status and position is brought into play, in an attempt to ensure that people interact only in their organisations roles and not as people. Whilst this acts to preserve the organisation as a serial process rather than an organic whole, and thus ensure ease of control, it has serious implications for the extent to which individuals can expect to achieve their personal goals - or indeed to maintain their self-respect - and hence for industrial relations. It also has implications for the speed at which change can be implemented, i.e how rapidly the organisation can respond to the environment. Large bureaucratic organisations need to plan in more detail, being less able to depend upon individual initiative to cope with new situations. On the other hand, organisations only become large and bureaucratic in a basically stable environment.

It has been stated earlier that, for administrative management, only a 'black-box' (i.e input - output transform) model is required. - though it was not asserted that these are necessarily what is used. However, for strategic management, it is necessary to have a more detailed model showing how the various components interact. This is because strategic management involves re-shaping the organisation, either re-arranging its constituent parts, replacing them with new ones, or adding further operations. This cannot be done adequately without some knowledge of how the existing organisation is put together and what the potentials of these parts are.

Developing this type of model is rather different from developing a black-box model; essentially, it consists of stringing a series of black-box together, the characteristics of each of which are known. (The possession of this type of model is, of course, equivalent to being able to "explain" the process under consideration)

Generally, such models cannot be inferred simply from knowledge of the overall transfer function. (Because, to repeat the quotation from Ashby and Conant (1970), "almost anything may serve as a model for almost anything else" in the context of black-box models). It must be built up from knowledge (or special study) of the internal functioning of the organisation.

This is because the final model must bear structural similarity to the real situation. This, in turn, is because the planning process is, in essence, to permute the structure of the model, changing the connectivity between sub-functions, changing the nature of some of the sub-functions, or adding (or deleting) sub-functions. The overall transform of each permutation is then predicted, and the optimum one for a given set of goals is chosen. (Or perhaps, a satisfactory rather than optimum solution may be sought).

Obviously, the number of permutations available depends upon the number of identified sub-functions - or, in other words, the degree of detail in the model. Frequently, there are heuristics available to limit the number of permutations examined by indicating which set are unlikely to yield reasonable results. These are necessary to limit the search time to reasonable bounds. Such heuristics are not infallible, and significant advances can sometimes be made by abandoning them and searching through combinations not previously examined. This may be described as "lateral thinking" or as the breaking of pre-conceived ideas. Beer (1966) gives a good example of this in his description of the project to re-site a production location, with the attendant effects upon a distribution network.

Also of interest in this example is the amount of work it entailed, both in the initial preparation of the model and the subsequent computation performed upon it. (It is also of interest that Beer does not discuss how the model was validated). It illustrates very well the amount of computation required for full exploration of even a relatively simple model, at the level of factories and depots. Usually, such time is not available. This consideration is, however, leading on to a topic more fully explored in the subsequent section.

Before leaving the topic of the modelling process, it should be mentioned that in practice it is made more difficult by what may be collectively described as 'noise'. This can take several forms. The most obvious is noise in the classical sense of errors in figures, and reports. Another is what may be termed 'false impressions'. These may arise either from attempts by subordinates to show themselves in a good light, or by what may be thought of as a sampling error, in that the manager observes various parts of his operations intermittently rather than continuously. A third form is imposed by the managers percepted limitations; he will filter the information he receives and may, in so doing, distort it.

All these factors make the process of modelling more difficult, in addition to which must be considered the variable nature of the tasks being performed. The performance of an organisational system is essentially statistical in nature, a compound of peaks and troughs in demand, variability in raw materials and operations, breakdowns, and other unforeseen occurrences.

In principle, such factors present no great problem (once they are recognised) apart from time. Given a sufficiently long sample of behaviours they can be allowed for. However, in organisational life, such time is not always available. The result will be less accurate models at managerial level.

4 Speed of Data Processing

The question of speed of data processing has occurred previously, in the context of channel capacity. There it was argued that the required channel capacity was determined by the speed at which the models used could process information. This is an extremely important topic, which is examined in greater depth in this section.

It is as well to start with a reminder of the purpose of processing information through a model. It is to gain control, either of the enviornment or of an organisation. An important point to remember is that this control does not have to be absolute, in the sense that it may not be essential to maintain the controlled variable at a precise level; it may well be sufficient to ensure that it does not exceed prescribed, fairly wide limits, or even that it does not fall below a certain critical value. This is perhaps most clearly seen in relation to controlling the enviornment. Obviously the organisation cannot expect to exert close control over all the features of the environment, yet it may be able to gain great advantage from being able to bring to bear a limited amount of influence over some of them. A ease in point, for business organisations, is furnished by the various forms of sales tax; whilst firms cannot expect to exercise absolute control over such taxes, it is clearly in their interests to keep them as low as possible.

It follows then that what is important is not so much that the model yields precise and detailed results as that it processes information rapidly enough to enable a response to be made in time for it to be effective. A timely response in the right general direction is preferable to a more accurate response too late to be effective.

Therefore, it is relevant to look at the factors that govern the computational speed of a model. Consider first a simple two-input one-output model as shown in fig. 23 This is the simplest form of model that can be constructed; in its very simplest form, one of the inputs is held constant.

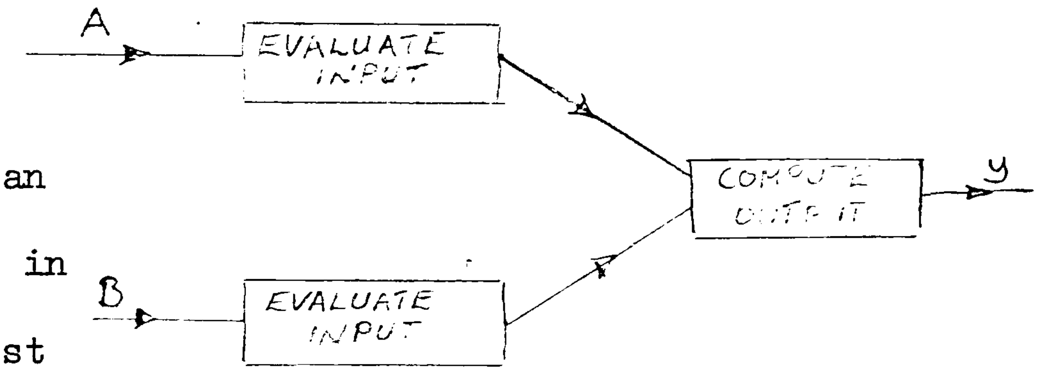


fig. 23

The first stage in computing the output, y, is to evaluate the inputs A and B. This is equivalent to placing them in categories. Suppose input A can be classified into xa categories, input B into xb categories. Assuming that xa and xb are ordered sets, and that a 'split half' technique can be used, this will require

$$\log_2 x_1 + \log_2 x_2$$

computations. Evaluation of the output is equivalent to looking up a cell in an $x_1 \times x_2$ table, which will require a further $\log_2 (x_1 \times x_2)$ computations. Thus the total number of computations required, N, is given by

$$N = \log_2 x_1 + \log_2 x_2 + \log_2 (x_1 \times x_2)$$
$$= 2 \log_2 (x_1 \times x_2)$$

For P inputs, N is given by

$$N = 2 \log_2 (x_1 \times x_2 \cdots xn \ldots xp)$$
$$= 2 \sum_1^p \log_2 x_n$$

If the model is in two stage, α and β as shown in fig. 24, then the stages will require

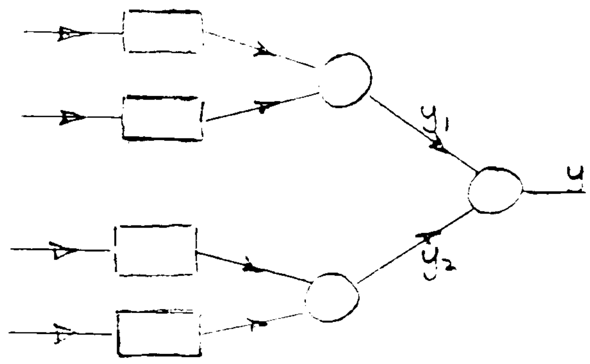


Fig. 24

$$N_1 = 2 \sum_1^{p_\alpha} \log_2 xn + 2 \sum_{p_{\alpha+1}}^{p_\beta} \log_2 xn$$
$$= 2 \sum_1^p \log_2 xn$$

computations. The final stage will require

$$N_2 = \log_2 (y_1 \times y_2 \cdots y_n \times y_q)$$

calculation, where there are q inputs to the final stage.

since $\quad y_1 = x_1 \times x_2 \cdots x_a$

$\qquad y_2 = x_{a+1} \times \ldots x_b$

etc,

$$N2 = \log_2 (x_1 \times x_2 \cdots x_n \ldots \times x_p)$$

Hence $\quad N = N_1 + N_2$

$$= 3 \times \sum_1^p \log_2 x_n$$

and for an f - stage model,

$$N = (f + 1) \sum_1^p \log_2 x_n$$

If the mechanism that is running the model is capable of K computations per second, then the rate R at which output signals can be produced is

$$R = K/_N$$

$$= \frac{K}{(f+1)} \cdot \frac{1}{\sum_1^p \log_2 xn}$$

In the above, it has been assumed that there is no computable relationship between input and output, and y has to be looked up in a contingency table. If there is a computable relationship, i.e. if

$$y = f(x_1;x_n)$$

that requires only F computations, then the value of N will obviously change. In the first example, we have

$$N = F + \sum_{1}^{p} \log_2 x_n$$

and for the more general case, assuming that each mode requires $F\alpha$ computations

$$N = \sum_{1}^{\beta} F\alpha + \sum_{1}^{p} \log_2 x_n$$

for β modes. The response rate becomes

$$R = K/N$$

$$= K/\left(\sum_{1}^{\beta} F\alpha + \sum_{1}^{p} \log_2 x_n\right)$$

In order to maximise R, with a fixed value of K (i.e. with a given computing mechanism), N must be minimised. Here there are two cases to consider, firstly where there are no computable functions, secondly where there are.

In the first case we have

$$N = (f + 1)\sum_{1}^{p} \log_2 x_n$$

and this implies three possible strategies

i) <u>minimise</u> x_n - i.e. use fewer (and therefore possibly broader) categories to classify the orginal inputs.

ii) <u>minimise</u> p -i.e. restrict the number of inputs used to the model.

iii) <u>minimise</u> f - i.e. reduce the number of stages in the model.

It is of relevance here to examine the relative efficiencies of each of these strategies. To illustrate this, assume an initial model with 10 stages, 10 inputs, each of which is classified into 8 categories.

This will require

$$N = 11 \times 10 \times 3$$
$$= 330 \text{ computations}$$

If the number of stages is halved, this becomes

$$N^{1} = 6 \times 10 \times 3$$
$$= 180 \text{ computations}$$

If the number of inputs is halved, this becomes

$$N^{11} = 11 \times 5 \times 3$$
$$= 165 \text{ computations}$$

If the number of categories is halved, this becomes

$$N^{111} = 11 \times 10 \times 2$$
$$= 220 \text{ computations}$$

Thus, in general, (except for the special case where $n \leqslant 4$), the maximum effect on R is gained by reducing the number of inputs to the model. An almost equal effect is gained by reducing the number of stages. The least effect is gained by reducing the number of input categorisations. (These examples ignore any interactions between f, p, and n. Thus, in particular, reducing the value of p may enable simplification of the model to take place, with consequently greater effect. Such interactive effects will depend upon the specific model being used. However, one would not normally expect an interactive effect to arise from changing n.)

The situation where the model consists of computable functions is different.

The problem is to minimise

$$N = \sum_{1}^{\beta} F\alpha + \sum_{1}^{P} \log_2 x_n$$

Here there are four basic strategies,

i) minimise β - i.e. reduce the number of stages in the model.

ii) minimise α - i.e reduce the number of computational steps required for each calculation.

iii) minimise P - i.e. reduce the number of inputs.

iv) minimise n - i.e reduce the number of input catergories.

(It should be noted that n here is at least partly determined by the requirement of $F\alpha$. To operate in a decimal system, n will need to be at least ten).

For purposes of illustration, assume again a model with 10 inputs, 10 stages, and each input classified into 8 categories. (This transgresses the above requirement for n, but it enables comparisons to be drawn more easily with the previous illustration) Assume further that each calculation is of the simple type

$$y = ax + bz$$

requiring 3 computations. Then we have

$$N = 10 \times 3 + 10 \times 3$$
$$= 60 \text{ computations}$$

If the number of stages is halved, this becomes

$$N^1 = 5 \times 3 + 10 \times 3$$
$$= 45 \text{ Computations}$$

If the number of inputs is halved, this becomes

$$N^{11} = 10 \times 3 + 5 \times 3$$
$$= 45 \text{ computations.}$$

If the number of categories is halved, this becomes

$$N^{111} = 10 \times 3 + 10 \times 2$$
$$= 50 \text{ computations.}$$

The most immediately striking feature of this illustration is the greatly reduced number of computations required compared to the earlier example. The reason for this is that the second approach utilises redundancies in the environment that were not employed in the first approach. Thus it can be concluded that the search for such redundancies (i.e. laws of nature) is worthwhile.

It was pointed out that the use of computable functions might well require the use of finer categorisation of the input. It is of interest to ask how many categories can be used before the computational advantages are lost, i.e. for what value of n is

$$\sum_{1}^{p} fx + \sum_{1}^{p} \log_2 x_n = (f + 1) \sum_{1}^{p} \log_2 x_n$$

Using values from the above examples, we have

$$10 \times 3 + 10 \log_2 x_n = 11 \times 10 \times 3$$

Hence $\log_2 x_n = 27$,

and $n = 2^{27}$ categories

a number sufficiently large for most practical purposes.

It is also of interest to enquire how complex can individual calculations be before the advantages of the method are overcome. Again using the above values for illustration, we have,

$$10\,\delta + 10 \,.\, x\, 3 = 11 \times 10 \times 3.$$

where δ is the average number of computations required per calculation.

The above expression yields

$$\delta = 30$$

which is sufficient to cope with, for example, polynomials up to the quartic of the form

$$Z = ax^4 + bx^3 + cx^2 + dx + ey^4 + fy^3 + gy^2 + hy + i$$

Again, this is sufficient for most normal purposes.

Apart from these considerations, the example serves to illustrate that, in order to increase R, the most effective strategy is either to decrease the number of stages or the number of inputs. Decreasing the number of input categories has less effect than either of these two.

In the organisational situation, a high value of R is of great value. The pressures on managerial time are considerable, and the ability to make a reasonable decision quickly is often of more value that the ability to make an optimal response slowly. Thus it can be concluded that there are pressures that will drive managerial models towards having few stages, a restricted range of input and only broad discriminations of the input - in other words, towards simple black-box models.

It is thus to be expected that management thought about organisations will be of an apparent simplicity, showing a certain roughness and crudeness of approach. They will tend to be stereotyped responses, classifying the world into extremely simple chains of cause-and-effect relationships, such as 'lower price leads to higher sales' or 'high morale leads to high productivity'. This is no reflection on the general level of intelligence and sophistication of managers, but rather a consequence of the fact that these models have evolved as working tools for a specific job.

However, the approximate, black-box nature of such models has certain theoretical consequences. In the first place, it has been shown previously that good control, in the sense of a high control index, was dependant upon having an accurate model of the system being controlled. A simple model and an accurate model are not necessarily incompatible requirements, but there are obviously difficulties in reconciling the two. The quality of a manager (in the administrative aspect of his jbb) may well be a function of how well he can achieve this reconciliation.

In the second place, it has been argued that models for strategic control need the opposite characteristics. They need to be accurate and detailed. This contributes to the line of reasoning that suggests that administrative and strategic management are different in nature, and should be more clearly and definitely defined in organisations.

It can also be suggested that organisations should seek to take more advantage of the power available in computational models. Technologically, with the advances in computing power now available, this is feasible, The need is for more quantitative modelling. This may well be difficult especially in the field of industrial relations, but the effort seems potentially worthwhile.

Much of the above argument has been based on the need to maximise the rate of output. A question of interest is how is the computation affected when the rate of input exceeds the rate at which the model can compute. Experimental evidence that this does occur, and the effect this has on control, has already been presented.

To examine this question, it is convenient to use the formulation of Porter (1972), following on from the earlier work of Ashby (1960). The control situation is characterised in matrix terms, with the general form

$$Y = AX_t + BZ_t$$

where Y is the output, X_t is the input, A is the transfer matrix of the uncontrolled system, Z_t is the control input and B the control transfer matrix. (Thus B is equivalent to a model of the uncontrolled system. In what follows, it is assumed that the model is analytic, for the purpose of illustration) The problem of control can then be considered as the problem of the computation of BZ_t. What is in question is how this computation is affected by overload of the input.

To take a simple example; suppose BZ_t contains only three components

$$Z_1 = a_1y_1 + b_1y_2 + c_1y_3$$
$$Z_2 = a_2y_1 + b_2y_2 + c_3y_3$$
$$Z_3 = a_3y_1 + b_3y_2 + c_3y_3$$

(where the t subscript has been omitted for convenience). Before overload occurs, the supposition must be that the control mechanism has sufficient computing power to calculate this function in each time interval tn+1 - tn. When overload occurs, it is no longer able to do this, and must resort to strategies that allow approximate solution to be obtained. The possibilities seem to be as follows

i) Compute BZ_t at longer intervals. This will allow Y to vary over a wider range, and consequently more vigorous control will be required. As the interval between computations gets longer, the control mechanisim will approximate more closely to an on-off device.

ii) Round off values of other constants or variables, to produce approximate rather than exact values. It should be noted that the value of Z_t can be very sensitive to the values of the constant terms, and therefore such approximations may produce values well wide of the correct solution.

iii) Combine elements together and treat e.g Z_1 and Z_2 as a single variable.

The matrix could then take the form

$$Z_1 = d_1y_1 + d_2y_2 + d_3y_3$$
$$Z_2 = K.\ Z_1$$
$$Z_3 = a_3y_2 + b_3y_2 + c_3y_3$$

where k is a constant, and

$d_1 = a_1 + ka_2$

$d_2 = b_1 + kb_2$

$d_3 = c_1 + kc_2$

iv) Various terms in the matrix can be set to zero (i.e. omitted) This can take several forms, such as the omission of single terms, or the omission of a complete row or complete column. The effect will be equivalent to introducing noise into the system.

It is of interest to compare these strategies with the types of behaviour reported by Miller (1962). These were;

i) Omission - the input is ignored and not dealt with

ii) Approximating - the system emits a response that approximates to the desired output

iii) Chunking - similar inputs are grouped together and treated as a unit.

iv) Filtering - inputs of lesser importance are not attended to.

There are obvious similarities between the theoretical strategies under overload and the description of systems behaviour provided by Miller. It is of interest that he reports that the most frequent behaviour is omission, corresponding to computing BZ_t at intervals longer than those required by the rate of change in the input. This suggests that the control mechanism generally does little to change the nature of its model of the system, but preserves with it. This is obviously true of mechanical or electronic devices, and it has been suggested elsewhere that managerial systems will also have this characteristic under stress.

However, such a strategy implies that the control action will lag further and further behind the input, until eventually (with a pure sine wave input) the system will switch from negative to positive feedback. This transition will be abrupt. With a complex input, the control output will have a lower correlation with the input, and there may be a point at which this correlation falls abruptly in value if the input contains strong periodic components. Thus overall the control index can be expected to follow the general form of fig. 25.

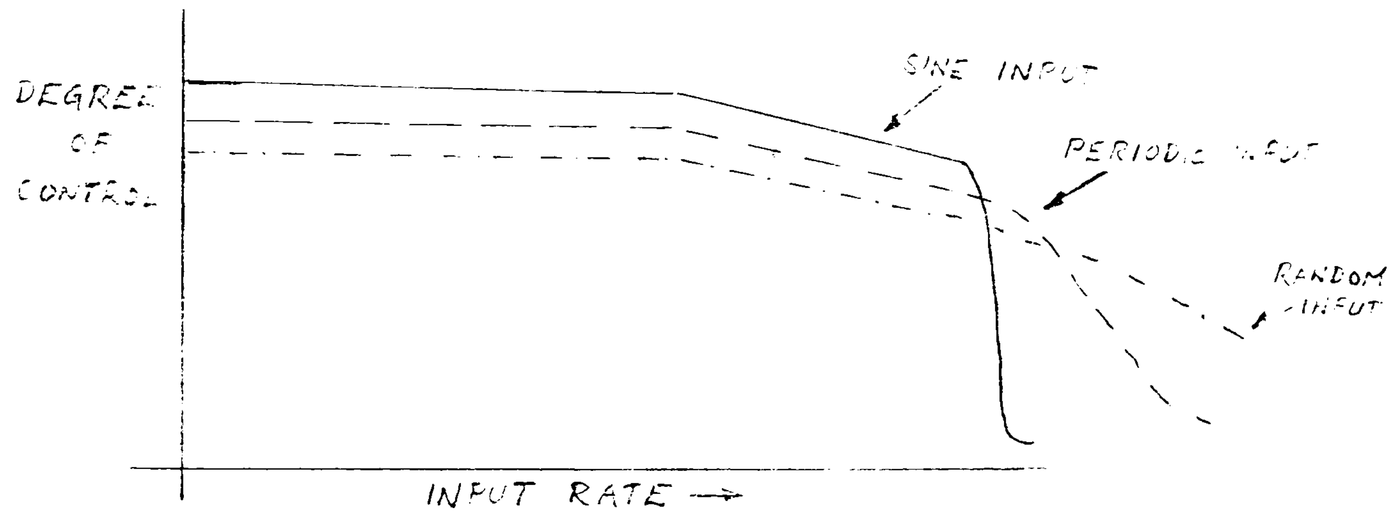


fig. 25

These curves have the general nature of the results reported by Miller (1962). This tends to confirm the importance of speed of data processing to the adequacy of control and hence also confirm the importance of simple models. Although the discussion has been in terms of computable models, the conclusions are also applicable to the non-computable models which have also been described. It is worth reiterating that management models - in the sense of the managers perception of his environment, which he uses in his day-to-day decision making - are likely to be of this latter type. The advantage of this type of modelling is that it can be used in situations that are mathematically interactable; they do not depend upon knowledge of the mechanism whereby variables interact. Although computationally inefficient, they are usable in a much wider variety of situations.

5. INTELLIGENCE

When discussing managerial models, the possiblity of the models evolving was mentioned, particularly evolving towards simpler forms. The possible mechanisms by which such changes might occur were not discussed, largely because they appear to have much wider relavance in understanding the general nature of human intelligence and as such deserve a treatment outside the purely organisational context. This is to be attempted here.

The discussion falls into three sections. The first section, on the nature of intelligence, sets out the general view of intelligence that will be taken. The second section deals with possible ways in which models might evolve. The third applies these mechanisms as a psychological theory, and seeks to explain psychological phenomenon in terms of this theory.

5.I THE NATURE OF INTELLIGENCE

The concept of intelligence is not a particularly precise one. There have been many discussions of its nature, chiefly, as far as cybernetics is concerned, revolving around the question of 'Could machines be made to think?' (George, (1956)). These discussions often rapidly become entangled in semantic issues, such as the meaning of 'think' or 'machine' in this context. Alternatively, they may involve empirical tests for 'intelligence' as typified by the 'Turing Game' (Turing (1959))

In an attempt to avoid such difficulties, a different approach will be followed here. The starting point is to take the view that intelligence, whatever it may be, is a tool adapted to a specific end, namely the survival of an organism within its environment. As such, this is an essentially Darvinian notion, and is similar to the view taken by Ashby (1960) or Stevehouse (1973)

In order to survive as an identifiable unit for an appreciable time, a system must protect itself against the operation of entropy and the third Law of Thermodynamies. This implies some form of regulation, which can only be achieved by exploiting some features of the environment. The means that are used can be grouped into four categories.

i) Physical forces. Everyday objects (e.g. stones, crystals) maintain stability through the use of physical forces, restraining the constituent atoms in constant relative positions.

ii) Chemical regulation. Many systems of equilibria in chemical processes. Many living systems such as plants or amoeba use chemical means to regulate their activities.

iii) Neurological direction. More complex systems use some form of neural net to achieve stability with their environment.

iv) Symbolic communication. This is used to achieve cohesion (and hence stability) between otherwise separate entities. It is typically (and, arguably, exclusively) a human activity, particularly relevant to organisational activity.

This classification has obvious parallels with inanimate, vegetable, animal and social forms of system, and is of some interest from that standpoint. Obviously, it is not a particularly rigorous classification, and there are many grey areas in it. However, it does serve to point out the different levels of complexity that can be found in systems. A feature of interest is that lower orders in this hierarchy are subsumed by, not replaced with, higher orders. For example, the human system contains much chemical regulation (e.g. thyroid, pituitary, etc.) as well as a nervous system.

The classification can also be considered as having parallels with theDarwinian evolutionary process. The first single-cell forms of life were regulated entirely by chemical means. Agglomerations of such individual cells would at first be naturally regulated by an extension of chemical control. The alternative strategy, for some cells to specialise in the co-ordination of the activity of the agglomerate, (i.e a primitive nervous system) could be expected to arise at a latter stage of evolution.

Clearly, both approaches are capable of great elaboration. Chemical means of regulation leads to plant life, whilst specialist regulatory cells lead to animal life. It is perhaps worth noting in passing that chemical regulation is not without some merit; it is apparently capable of co-ordinating much larger amounts of material than neurological methods. The most massive forms of plant life are heavier by a factor of 5 or so than the most massive forms of animal life. Its limitations are its slow speed of response, governed by the rate of chemical diffusion, and its lack of proprioception.

Proprioception would confer significant advantages upon a mobile form of life, either for sensing danger or food. It isreasonable to suppose that initially sense-organs would react only to certain specific features of the enviornment. An example of what is meant here is provided by McCulloch and Pitts (1962) description of the visual system of the frog. They showed that the frog's eye analysed the visual environment into broad categories, such as 'brighter' or 'darker', In particular, they showed that a curved boundary moving across the visual field (a signal highly correlated with the presence of insects) elicited a reflex feeding movement.

Thus, quite complex neural systems could be arrived at from evolutionary pressures. Along with this increased complexity of structure goes the possbility of an increased complexity of function. Furthermore, it is not necessary to hypothesise any inbuilt goals or purposes; the neural system would function as it did because it produced a more viable total organism.

The origins of symbolic communication (i.e. language) can be proposed to lie in a line of evolution that elaborated upon natural alarm calls and other signals. A major change in brain functioning seems to be required to account fully for this, the nature of which will be discussed later, but the necessary precursors of this change can be seem to be available in such signals. Once developed, symbolic communication allows for yet more complex systems, consisting of the co-ordinated activity of several organisms. For this type of activity, it does seem necessary - or at least convenient - to hypothesise the concept of goal or purpose.

Thus it can be seen, in a broad way, that complex neural nets and information processing structures could arise through the natural progress of evolution. Furthermore, these structures ('brains') would be, in the first instance at least, strictly utilitarian in function serving to increase the probability of the survival of the organism.

In achieving this function, a critical parameter would be the speed at which incoming data could be processed. The general significance of this has been examined already in the context of organisations, and some ideas developed. The next part of this thesis examines how these ideas can be adapted to the context of brain-like mechanisms.

5.2 THE EVOLUTION OF MODELS

It has previously been shown that the rate at which a model can process input information is given by

$$R = \left(K/_{f+1}\right)\left(1/\sum^{p}_{1}\log_2 x_n\right) \qquad \text{signals/sec.}$$

where K is a constant determined by the processing mechanism, f the number of stages in the model, p the number of inputs, n the number of categories into which each input can be classified. Various strategies by which R could be increased were examined, but no process by which such strategies could be achieved were discussed. It is the intention here to investigate possible ways in which these strategies could be implemented.

The basic modelling procedure described was in terms of a contingency table, built up on the basis of experience. The general form of such a table is given in fig. 26 for a 2 -input model.

where x_1 and x_2 are divided into four categories (a, b, c, d and p, q, r, s, respectively). The numeric entries in the table are used purely norminally, and could well be substituted with any series of symbols; numbers are used purely for convenience. Thus the interpretation of the table is that, in the organism's experience, the combination of input x_1 category b combined with input x_2 category r has resulted in outcome 1. (Such a table is, of course, equivalent to a

x_2 \ x_1	a	b	c	d
p	9	2	7	30
q	14	11	26	8
r	99	1	4	28
s	12	6	5	22

fig. 26

black-box model of a state-determined system. It has obvious similarities with Ashby's (1956) tabular form).

The problem is to find ways in which tables such as fig. 26 can be simplified. It is obvious that, in general, this cannot be done. However, given that the initial selection of x_1, x_2, and their categories is arbitrary, there are special forms which do admit of simplification. The most obvious is shown in fig. 27. The absence of entries in some cells indicates that (in the experience of the organism) certain combinations of input do not occur, implying a casual relationship between x_1 and x_2. Clearly, in this instance, one of the inputs is redundant, and can be eliminated. (The diagonal form is not necessary; it merely serves to make the point more clearly). It is worth noting that, since the table is built up on a limited sample of experience, it may well be the case that the inferred relationship does not truly exist, but is a statistical fluke.

x_2 \ x_1	a	b	c	d
p	-	-	-	7
q	-	-	6	-
r	-	5	-	-
s	8	-	-	-

fig. 27.

Clearly, the elimination of one input is computationally advantageous, offering a saving of

$$\log_2 4 / 2 \log_2 4 = 50\%$$

A modification of the above form is of interest. Suppose that the table approximates to the diagonal form, as shown in fig. 28. This suggests the possiblity that fewer discrimination of the input could produce the diagonal as shown in fig. 29. The question is, whether such a refinement is advantageous in terms of computation.

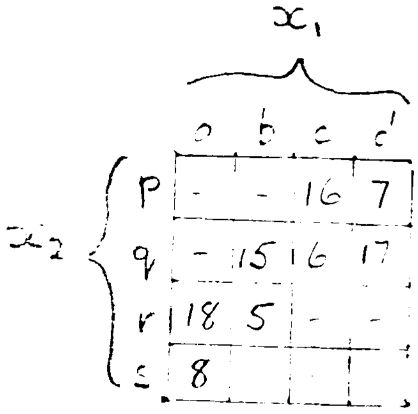


fig. 28

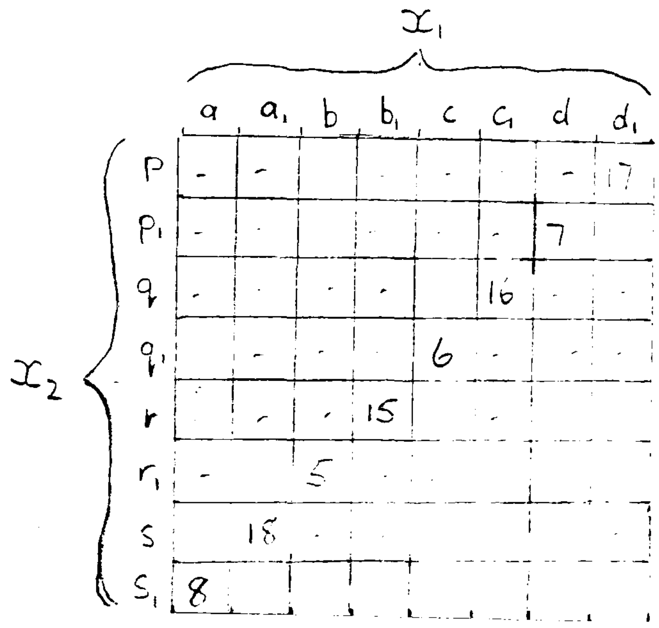


fig 29

The processing rate, R, for fig. 28 is

$$R = K/2 \log_2 4 = K/4 \quad \text{signals/sec,}$$

whilst for fig. 29 it is (when x_1 or x_2 has been eliminated)

$$R = K/\log_2 8 = K/3 \quad \text{signals/sec,}$$

an improvement of 25%. Thus the extra discrimination required at the input stage has an overall beneficial effect.

Even if the tables do not exhibit the diagonal form, som e simplification may be possible, as illustrated by fig. 30

Here it is evident that one of the two inputs b or d is redundant, and the table can be re-arranged without loss as in fig. 31. This is a process of using to advantage redundant cues in the environment. The processing rate for fig. 31 is given by

x_2 \ x_1	a	b	c	d
p	9	2	7	2
q	14	4	41	4
r	7	6	19	6
s	42	4	24	4

fig. 30

x_2 \ x_1	a	b	c
p	9	2	7
q	14	4	41
r	7	6	19
s	42	4	24

fig. 31

$$R = K/(\log_2 4 + \log_2 3)$$
$$= K/3.58$$

an improvement of 10% over fig. 30.

The foregoing examples have utilised redundancy in the input. Other forms of reorganisation are possible. One form of interest is the converse of the diagonal form discussed above and illustrated by the table of fig. 32 Here, the diagonal is blank, dividing the table into two natural subsets. In terms of speed of computation, this feature can be exploited by re-arranging the table as shown in fig. 33. The rate of computation is

x_2 \ x_1	a	b	c	d
p	6	13	28	
q	4	7		10
r	19		15	27
s		30	9	11

fig. 32

$$R = K/\log_2 2 + \log_2 6$$
$$= K/3.58$$

again an improvement of 10%

x_4	x_3: f		x_3: g
ap	6	dq	10
aq	4	dr	27
ar	19	ds	11
bp	13	cr	[illegible]
bq	[illegible]	cs	[illegible]
cp	[illegible]	ts	30

fig. 33

However, there are two points that require some mention about such a re-arrangement. Firstly, it involves a complete re-organisation of input categories -a major perceptical re-organisation. In the second place, in order to take advantage of the possible increase in effective computation rate, the order in which the inputs are evaluated is of significance; x_3 must be evalu-ated before x_4.

The other form of re-organisation is illustrated by the tables of fig. 34 and 35.

If the mechanism establishes that in fig. 34 outcomes 12, 19, 14, 8 are equivalent as are outcomes 77, 11, 36, 2, and 27, 6, 30, 21, and 44, 10, 17, 42 then the table can be re-arranged as in fig. 35.

x_2 \ x_1	a	b	c	d
p	12	19	77	11
q	14	8	36	2
r	27	6	44	10
s	30	[illegible]	17	42

fig. 34

It can be readily seen that fig. 35 can in turn be arranged as a 2 x 2 table, with consequent reduction in computation.

x_2 \ x_1	a	b	c	d
p	101	101	110	110
q	101	101	10	110
r	201	201	210	210
s	201	201	210	210

fig. 35

This form of re-arrangement can be considered as a conceptual process; the mechanism discovers new descriptors that cover a group of previously disparate events or objects. - e.g. 'beverage' to cover a variety of liquids, or 'work' to cover a variety of activities.

Thus far, it has been assumed that a given set of inputs determine a unique output, - i.e. the system being computed is state-determined. This is not always the case; a system with an element of chance in the outcome can be shown in tabular terms as in fig. 36, which indicates that the conjunction of 'c' and 'q' may yield either '9' or '22'. (This principle could be readily extended to show more outcomes, and indeed, to indicate their relative probabilities.)

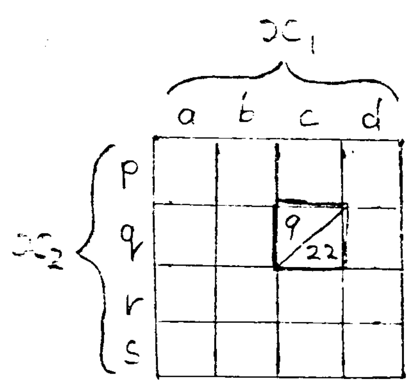


Fig. 36

The mechanism may seek to resolve this ambiguity by using extra cues, or in other words use a finer discrimination of the input. (To turn aside from the discussion of mechanisms for a moment, it can be noted that this search for extra cues can go to great lengths, as is illustrated in an extreme form by various means of supernatural divination). Alternatively the mechanism may select one of the possible alternatives at random. This selection may take place after some form of evaluation of the possible consequences of selecting each of the possible outcomes.

The main point, however, remains; it is possible to simplify an initial black-box model, by the use of redundancy in the environment or by perceptual or conceptual re-organisation, with consequent gains in the effective rate at which input can be processed. It is worth noting that the path which such simplification will follow is not necessarily unique; given an initial table containing several potential simplifications, the mechanism may select any of these as an initial step. Furthermore, subsequent possibilities for simplification may be affected by the initial step chosen. Consider for example the table of fig 37. This can be re-arranged in a variety of ways, two of which are shown in fig. 38. These two are quite distinct, and cannot be transformed one to another. Furthermore, subsequent stages of simplification will yield different models again, one of which will require twice the computation time of the other. Thus, in principle, the mechanism can arrive at a variety of final models, using quite different perceptual and conceptual categories, and with differing computational requirements.

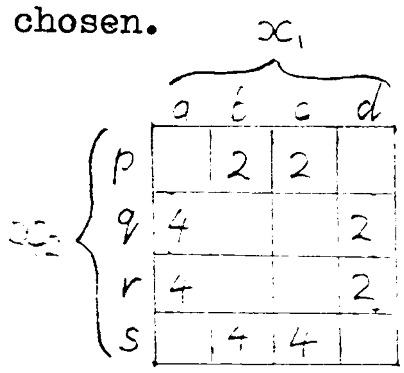


fig. 37

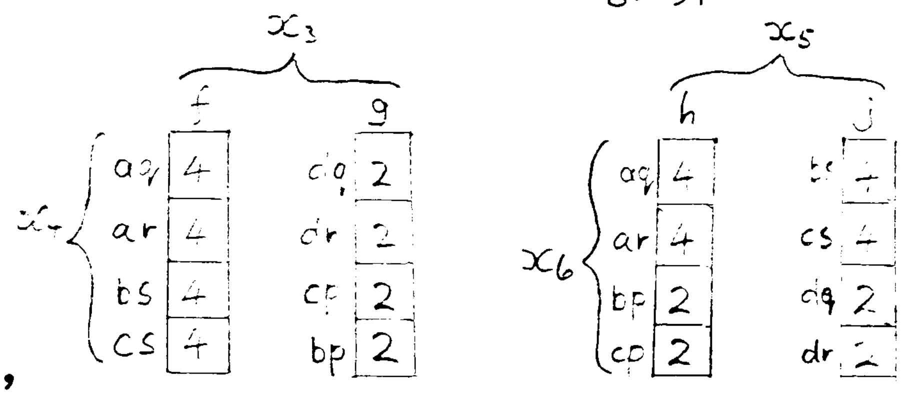


fig. 38

Up to this point, only isolated black-box models have been discussed. Similar considerations apply, however, to more complex models built up from such black-box units:

This type of model is illustrated schematically in fig. 39, Successive reductions in the computations A, B, and C may eventually enable the model to be reduced to a single computation. Once

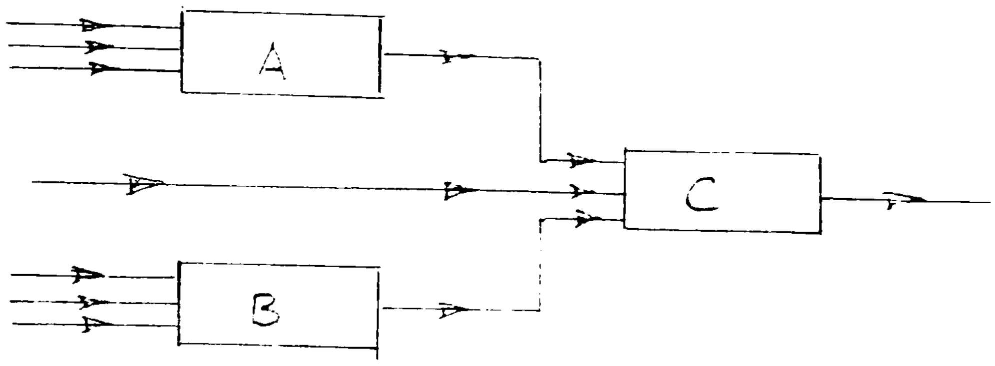


fig. 39

this has been achieved, a more complex model may be built up again by putting together a further series of single computations, which may in its turn be simplified.

Thus, progressive gains in rate of computations may be expected, as more comprehensive models evolve. Again it is worth noting that the particular model developed may be unique to the mechanism involved; different mechanisms exposed to identical environments may well develop entirely different models.

Although black-box models serve admirably for increasing speed of input processing, their drawback is that they do not enable cause - and - effect relationships to be traced and isolated. They represent only the overall transfer function and do not allow any of the internal activity to be discovered. The ability to discern such internal detail can be of use. In particular, if a model is of modular construction, the elements in it can be dis-assembled, re-arranged, and the new outcome computed. This is equivalent to examining ways in which the environment could be re-structured, and the possibility exists that some of these re-structurings are to the advantage of the computing mechanism.

To take a simple, but important, example, primitive man can be assumed to have noticed that unshaped stones used as hammers and clubs would fracture in use, and sometimes leave sharp edges. The realisation that fracturing was a process separable from the actual use of the tool, and could be made to precede such use rather than be consequent upon it was a major step forward.

The extent to which the environment can be examined in this way depends upon the amount of detail in the model. There is thus a conflict between the requirements for rapid processing of input and for re-structuring the environment. The former of these must take precedence, to enable the mechanism to survive, until there is sufficient surplus time to allow a more analytical approach.

To recapitulate briefly, the discussion so far has been in terms of possible strategies that a mechanism of limited computing power could employ to improve its rate of information processing in a redundant environment. The overall intention has been to relate this to the nature of intelligence in general, and human intelligence in particular, and this relationship is examined in the next section.

5.3 A THEORY OF PSYCHOLOGY

The basic question to be answered is how would a computing mechanism of the type described be expected to behave, and how does this compare with the known characteristics of human behaviour. It is convenient to discuss this under a number of headings.

.1 Sleep

The computing strategy described above depends upon the re-arrangement of a model, and this re-arrangement itself requires computing capacity. It is not immediately obvious that a mechanism with the necessary additional capacity to perform this re-arrangement would not devote it to the processing of input rather than the re-structuring of a model. A possible answer is that the same computing capacity is used for both purposes, but that the processing of input is an 'on-line' activity, whilst re-arranging the model is an 'off-line' activity.

If this re-arrangement takes all (or at least a large part) of the available capacity, this then implies that the mechanism is unable to process input whilst this 'off-line' activity is taking place. This is a state which is readily indentifiable with sleep.

This view of sleep accounts for several of its reported features. It predicts that sleep is most needed during periods of great development of models of the enviornment, which can be expected to be during the early stages of life. Thus babies require much sleep, elderly people comparatively little. It accounts for dreams, which in these terms are models in the process of review and re-arrangement; during this process, it can be expected that many novel arrangements of models will occur, and thus dreams can be expected to have an unreal nature. A further consequence is that these re-arrangements can lead to a suddenly successful solution to a given problem - the 'Eureka' phenomenon, which is (as would be predicted) not under conscious control.

If it is further assumed that the function of 'sleep' is to maintain mental models as well as to restructure them, it can be seen that lack of sleep will have an effect upon mental performance, though the precise nature of these effects is not predictable in detail.

2 Learning

The fundamental property of the mechanisms that have been discussed is that they increase the rate at which they can process input. This in turn will manifest itself as an increase in observable performance. - i.e. a shorter amount of time will be needed to compute a given environmental situation.

However, this increase in performance will be a discontinuous process, occurring in distinct stages, corresponding to discrete re-arrangements in the mental model. Furthermore, if it is assumed that the most obvious redundancies will be utilised earliest, and that these offer the greatest gains in performance, then the general shape of the curve of performance against time will be as shown in fig. 40. If it is assumed that the effect of the n^{th} re-

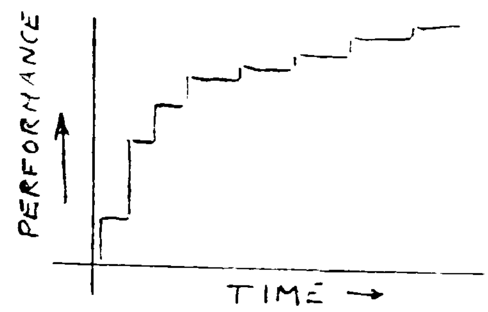


fig. 40

organisation of the model is proportional to log n, and that re-organisations are a linear function of time, then the familiar logarithmic learning curve results as an envelope to the step-functions. However, perhaps the most intriguing aspect of the curve is that it predicts that increasing performance (or learning) should occur in a series of discrete steps rather than as a smooth function. This is in accord with the facts of learning.

Moreover, it can be expected that learning will not necessarily proceed along a smooth path. Individual improvements in rate of computing may depart from the overall log n curve. A major re-structuring of internal models may well initiate a whole new learning cycle. There may well be irregular intervals between gains in performance, depending upon how difficult the mechanism finds it to recognise redundancies. Indeed, the re-organisation of the model may not occur until some time after the experience that caused it - a process analagous to latent learning.

Another form of latent learning appears to be possible. It can reasonably be expected that the organism will not posess one overall model of the environment, but will (initially at least) possess a series of models applicable to specific situations. These will be stored separately, and 'called' according to the demands of the situation. Some of these may have similar structures, and a succesful strategy for re-organising one of these models will be applicable to other similar models. Thus learning may be transferred from one situation from another.

3 Perception

A feature of the mechanism described is that it involves selection of specific features of the input information, and that this selection evolves over time. Thus, for example, the decision to classify a certain object as a 10p piece may originally depend upon information as to its size, weight, colour, shape, surface texture, embossed patterns, and possible other features as well. Through experience, this list will be reduced - perhaps to "milled edge" and "size" which are a sufficient discriminatory cues with the current coinage, or to a variety of other possible cues. It is not possible to predict which of the reduced cues will in fact be employed by a particular mechanism.

It is worth noting that operating on reduced cues can have its dangers. In the instance of a 10p piece cited above, the job of a forger is made easier by the extent to which the general populace use reduced cues.

This reduced use of available input information is a characteristic of the perceptual process. Another well known phenomonon of perception is that of 'set', where an extremely similar set of cues can give rise to different perceptual responses depending upon the overall context. This can be understood in terms of the mechanism if the general context determines the model which is called to be run, and the model in turn determines the interpretation placed upon any given set of cues. Thus in this sense the psychological 'gestalt' is represented by the particular model that is being run at any given instant, and specific input sensations are interpreted in terms of this 'gestalt'.

It is perhaps worth emphasising that different mechanisms, even if given the same external environment, could be expected to develop different interval models. These differences could be profound, or matters of minor detail and thus it would be predicted that perception would be as much a function of the particular mechanism involved as of the external stimulus. A striking parallel to this prediction can be found in the psychology of Kelly (1955), with his emphasis on the 'person' as the basic unit of psychological study. Indeed, Kelly's first principle is stated as "A person's processes are psychologically channelled by the ways in which he anticipates events" (The remaining principles serve largely to define the terms of this principle) Clearly, such a statement is consistent with the approach to intelligence being put forward here.

A further point of particular interest is that the Kellian approach is developed in terms of an individuals concepts (which correspond to models in the approach adopted here) and that these concepts tend to have a binary 'black or white' nature. This is exactly what would be predicted in terms of maximal speed of signal processing.

A problem that has not been discussed so far is that the proposed mechanism always starts from an initial set of input categories. No mention has yet been made of the mechanism could set up its very first set of primitive initial categories. The answer seems to be that this set (which can be very primitive indeed) is built into the mechanism, either through genetic inheritance or through hardware wiring patterns. As far as genetic inheritance is concerned, it does not seem too great a load on the information capacity of the genes to ask that the ability to discriminate straight or curved boundaries, movement, and colour, should be inherited in the visual system. This initial set would provide sufficient scope for the eventual development of a highly sophisticated <u>perceptual</u> visual system.

4 Memory

Another feature of the human brain is the ability to remember. In terms of the mechanism being discussed, memory is represented by the individual entries in the table of a particular model. These are vital to the functioning of the computing mechanism and thus memory can be accounted for in general terms.

Difficulty in remembering can be thought of as a difficulty in accessing exactly the right combination of stimuli that led to the original memory being laid down. If a slight error is made in recalling one or more of the features of the situation it is desired to remember, then an incorrect selection from the table will be made.

A slightly different problem is the decline in performance that occurs if a skill is not practised. The whole emphasis of the mechanism is towards a one-way evolution of models. A reversal of this process - i.e. a move from a less redundant to a more redundant form - is not catered for.

There appears to be two ways of approaching this problem. The first is to assume that the last table of each of the progression of models is stored (i.e. the table preceding a re-organisation of the model) As time passes any particular table is disturbed by noise, and 'fades'. The effect of such noise could be expected to be countered by the effects of rehearsal, and thus a skill not practised will decline. When it is resumed, it will be with an earlier version of the model. What is not clear with this approach is why the final model should be more subject to noise than an earlier version, unless it is that they have been the subject of more rehearsal and thus are more deeply ingrained.

The second approach is to remember that (as discussed above) with each model is associated a set of timing constants (lead and lag factors) which as it were 'fine tune' the model to its environment. If it were these that were subject to decay, then again, a decline in performance would be expected on resuming a skill, but progress would be much more rapid. The only re-learning to be done would be of the timing constants. This type of explanation seems more closely in accord with the reported facts.

5 Language

The foregoing sections (IV3.1 to IV3.4) have been in terms applicable to either a single black-box model or a model composed of a serially joined black boxes. A model of this latter serial type possesses a property of importance not applicable to single black-box model; in that it can be divided up and the individual sections stored separately. Furthermore, a variety of models can be built by re-assembling such units in different patterns with a variety of permutations and combinations.

It is hypothesised that the human brain employs this serial form of modelling, and moreover that it, uniquely amongst organic brains, has the functional ability to divide, store, and re-assemble such models. On this view, the difference between animal and human intelligence is to be found not in neurological structure but in neurological function. It may be that a certain minimum amount of "hardware" is necessary to support the type of information processing being discussed, but possession of that does not guarantee that the brain will function in a particular way, any more than the fact that an IBM computer has certain facilities guarantees that it is running a particular program.

Moreover, on this view, it is to be expected that in some - indeed many - situation, the human and animal brain will show similar characteristics. In general, when running a particular model to interact with the environment, the two will be largely equivalent. It would not be altogether surprising if the animal brain showed some superiority, particularly in its natural environment, for its models would be absolutely specific to the situation. The differences manifest themselves during periods of relaxation, when not interacting with the environment, and then are largely internal to the mecahanism.

However, one specific consequence of storing model elements is of especial interest. Storage and retrieval of such elements if greatly facilitated by the use of labels - indeed, it is virtually essential. Labels attached to model elements form the basis for a language capable of exchanging information between different organisms, in a way quite different from the communication possible between simple black-box models.

There will be difficulties with such a language. As has been mentioned, it is to be expected that each brain will develop its own unique set of models. Given a reasonably similar environment, many of these models will have a degree of common content between different brains, but they will be by no means identical. Thus language can be expected to be fuzzy, with each brain applying its own slightly different interpretation to each element of the common language. This, of course, is exactly the situation found with natural languages.

Since the external sign or symbol used for a particular model is a matter of convention only, with the sign having no inherent meaning of its own, it can also be expected that two or more groups of individuals isolated from each other will develop entirely different sign - systems or languages. This again accords with common experience, not only at the international level but also at the level of dialect and jargon. Indeed, the fact that the grammars of different languages have so much in common - they consist of nouns, verbs and various description and connectives - argues strongly that the underlying psychological processes are extremely similar.

6 Creativity

There is a further facility available to a mechanism with partionable models. This is the ability to re-arrange the elements into new models, and compute their behaviour.

These models need not necessarily have any relationship to the outside world - they are not derived in any direct fashion from experience. Moreover, the ability to do this can be of great use to the organism. As has been argued elsewhere, it forms the basis for planning and for controlling the environment.

This process of assembling new models from existing elements forms the basis of creativity. The essence of creativity is to produce something new, something that has not existed before, which is equivalent to outputting a new model.

As far as artistic creativity is concerned, this model need not necessarily have any direct relationship with the 'real' world. Abstract painting and certain forms of music fall into this category. Alternatively they may seek to emulate the 'real' world (or certain aspects of it) with great accuracy. Examples of this can be found in the literary and theoretical arts. The majority of art falls somewhere between the two extremes., generally emphasising some aspects of reality at the expense of others in order to make a particular point.

Nor it it altogether surprising that art in its various forms should be of interest to people other than the artist. It can be argued that succesful art provides a different view of the world which assists others to make sense of their own experiences - i.e. enables them to re-organise their own internal models in a more satisfactory way.

Scientific creativity would seem to belong to a slightly different category. In general, it could be said that the nature of scientific creativity is to de-compose a given black-box model of an aspect of reality into smaller sub-units, thus 'explaining' the original black-box model.

A specific example is the modelling of Dalton's atom in terms of electrically charged particles.

This, in a sense, is an unnatural activity, reversing what has been argued is the basic functioning of the brain, condensing and simplifying models. It would thus be expected to be a difficult and perhaps unusual activity. Furthermore, it is subject to a restriction not imposed on artistic creations, that it must map exactly onto the external environment.

Nevertheless, its usefulness cannot be denied. In terms of the hypothesis put forward here, the more detailed a model of the environment, the greater is the extent to which the real world can be manipulated. Indeed, much scientific effort is devoted to exploring and refining particular models, largely with this end in view.

It can be seen that there is a conflict between the requirements for creativity and the requirements for coping with the environment. The former is more likely to be succesful with highly detailed and therefore sub-divided models, the latter is more likely to be succesful with highly condensed models.

These two needs are not necessarily irreconcilable, if the models in question refer to quite different environments, and are kept separate. However, it can be predicted that a highly creative person will tend to spend more time withdrawn from the environment examining and restructuring his internal models, possibly to the extent that his models for interaction with the environment do not develop fully, or even become distorted through the influence of the 'creative' models.

As a final word, it is worth pointing out that, with this view, creativity is confined to mechanisms that operate on serially joined but separable models. The fact that creativity is not observed in the animal kingdom argues strongly that their brains do not function in this way.

7 Artificial Intelligence

Much effort has been devoted to the creation of artificial intelligence. It is not inappropriate therefore to add a few remarks on this topic.

The first point to be made is to query the usefulness of such projects. If the view of intelligence that has been put forward here is correct, then an electronic duplicate of these processes would be bound by the same limitations. The models that would be developed would be unpredictable, and as liable to error as human models. There can be no certainty that artificial intelligence would be any more reliable than human intelligence. Furthermore, the distinct possibility exists that artificial intelligences could lie, just as people can, and lie in the full sense of deliberately computing the effect of false information on the probable future conduct of another entity.

On the other hand, it can be argued that the construction of an artificial intelligence would serve as the easiest way to test the theories put forward here, and thus gain a deeper understanding of human nature. What is more, the vastly greater speeds of computation available on modern computers might yield some results of value, particularly in the field of creativity.

Another possibility of interest would be to adapt the functioning of the machine to algrebraic rather than tabular models. Given the generally greater power of analytic models, as discussed above, and the facility with which they can be handled by machines, then significant advances may be possible.

Summary

This section has been a brief attempt to explore the possible nature of human intelligence in terms of a mechanism of limited computing power developing models of the environment. This has been done in terms of tabular models, though the general principles involved are not necessarily limited to this form.

In particular, it has been proposed that the human brain acts on a model composed of a set of serially joined sub-models, and that the model can be decomposed and reassembled using these sub-models as units.

In these terms, it has been possible to account for topics such as learning, perception, memory, language, and creativity, albeit at a superficial level. Obviously, there is scope for a great deal of further work in this field. However, the view has been taken that greater depth would be inappropriate in a work whose primary concern is with the structure and functioning of organisations.

The basic premises of this approach to intelligence have been derived from consideration of the problems facing organisations. Therefore, in conclusion a point made earlier can be repeated; the study of organisation from a cybernetic viewpoint is likely to yield much material of general scientific interest.

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