MANAGEMENT INFORMATION :

DESIGN OF A

SYSTEM FOR

CHANGE IDENTIFICATION

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SUMMARY

This thesis deals with the problem of Information Systems design for Corporate Management. It shows that the results of applying current approaches to Management Information Systems and Corporate Modelling fully justify a fresh look to the problem.

The thesis develops an approach to design based on Cybernetic principles and theories. It looks at Management as an informational process and discusses the relevance of regulation theory to its practice.

The work proceeds around the concept of change and its effects on the organization's stability and survival. The idea of looking at organizations as viable systems is discussed and a design to enhance survival capacity is developed.

It takes Ashby's theory of adapation and developments on ultra-stability as a theoretical framework; and considering conditions for learning and foresight deduces that a design should include three basic components: A dynamic model of the organization-environment relationships; a method to spot significant changes in the value of the essential variables and in a certain set of parameters; and a Controller able to conceive and change the other two elements and to make choices among alternative policies.

Further considerations of the conditions for rapid adaptation in organisms composed of many parts, and the law of Requisite Variety determine that successful adaptive behaviour requires certain functional organization. Beer's model of viable organizations is put in relation to Ashby's theory of adaptation and regulation.

The use of the Ultra-stable system as abstract unit of analysis permits developing a rigorous taxonomy of change; it starts distinguishing between change within a behaviour and change of behaviour to complete the classification with organizational change. It relates these changes to the logical categories of learning connecting the topic of Information System design with that of organizational learning.

KEY INDEX TERMS

INFORMATION
SYSTEMS
VIABILITY
CHANGE
ADAPTATION

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THIS IS DEDICATED TO THE ONES
I LOVE, PASI AND ANTONIO.

. . . AND TO THE MEMORY OF ROSS
ASHBY AND THE BEAUTY
OF HIS WORK.

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INTRODUCTION

1.- The Problem, the Purpose and the Approach.

This introduction tells the history of this research and presents the structure of the thesis that summarizes its results.

The project had its origins in some evidence on the fact that current implementation of Corporate Models and in general Information Systems were failing to make an effective contribution to the actual process of decision making in organizations.

It was felt from that evidence that a fresh and uncommitted look to the subject could contribute to improve understanding of the process of decision making and consequently to shed some light on the problems of conception, design and implementation of Management Information Systems.

The research proceeded through a systematic and simultaneous study of basicaly three subject areas.

In the first place it involved a thorough analysis of current literature dealing with problems of Information Systems design and Corporate Modelling; in relation to prevailing approaches to development and to the limitations and difficulties that effective implementation was encountering.

At an early stage it was felt that Cybernetics as a science dealing with problems of information and control could provide the means to evaluate current designs and implemetations and to provide bases for a rigorous approach to Information Systems design for Corporate Management.

The third subject area was the problem of establishing adequate criteria to evaluate organizational performance. Obviously, the task of developing effective approaches to design requires consistent criteria of success, otherwise nothing can be said about effectiveness. The reader will be able to see for himself how it is that viability comes to provide the ultimate criteria.

The distinction between these three areas of knowledge is only made to specify the scope of the research; the reader will see from beginning to end that these three areas are systemically interrelated and how appropriate has been to carry out their study in parallel.

The thesis proceeds around the concept of change and its relevance to adaptation and viability. Based on cybernetic principles it develops a taxonomy of changes, whose distinctions turn out to be useful to the practical systems designer as much as to the researcher interested in the problems of organizational learning.

The main purpose of this reasearch can be summarized as: to develop an approach to the problem of conception, design, and implementation of Information Systems for Corporate Management.

The method used to achieve this purpose has been to take cybernetic principles -in particular those of the theories of adaptation and regulation- as a theoretical foundations to deduce an approach to design and implementation.

2.- Structure of the Thesis.

Part I deals with the current state of knowledge in the area of Information Systems, it maintains that knowledge in this area, as in every other field, is subject to a dynamic development resulting from the confrontation of theories and hypotheses with problems that are found in the real world.

It shows that the confrontation takes place at two levels; on the one hand it takes the form of attempts to improve current state of knowledge by formulation and testing of hypotheses within the context of a prevailing paradigm. The second level is to do with the revision and questioning of the basic assumptions that support that paradigm in order to develop alternative approaches from different epistemological bases.

Chapter I describes knowledge as a systemic unit which is subject to some specific pattern of development; from this it deduces a model of the dynamics and uses it in the rest of Part I as a framework to analyse the state of knowledge in the area of Information Systems.

Chapter II presents and discusses the ideas on management that are considered to be prevailing , and which define the content and direction of most of current research in this area. It starts with a brief discussion on the connotation of the early scientific management and shows how its later development is linked to development in other disciplines like Social Psychology and Sociology.

The Chapter concludes with an indication of the elements that constitute the current basic rationale for design and implementation.

Chapter III shows the main directions that the efforts to formalize knowledge in this area have followed. It starts by discussing the development of frameworks for systems design and shows the way that prevailing ideas on Management define a certain basic approach which is followed by a number of variations within the same outlook.

It discusses how the proliferation of methodological approaches to systems design follows similar lines, and argues that most of currently available methodologies only differ in the emphasis that various authors place on different aspects of design. It concludes with a discussion on the results of approaching the problem information for corporate management with the application of Corporate Models.

Chapter IV is entirely devoted to review evidences of dissatisfaction with the performance of Information Systems and examines the currently believed main causes for failure. It shows that there are reasons to believe that the problem of effective design requires to be approached from different epistemological basis, and provides a justification to the content and direction of this research.

The rest of the thesis develops an approach to design based on cybernetic principles, shows the method and outlines the organizational consequences of adopting this point of view.

The purpose of Part II is to present the conceptual foundations that support the approach developed in Parts III and IV; it provides the reader with the concepts and definitions that are necessary to follow the discussion on the requirements for ultra-stability and its relation to survival and viability.

Chapter V introduces Cybernetics as a general science of information and defines basic cocepts like state, change and stability. It concludes with a first look to management as an informational process.

Chapter VI presents the relevance of Regulation Theory to Management, including an initial discussion on the limits to regulation, it concludes by discussing the meaning of the concept of survival and the consequences of regarding organizations as viable systems.

The specific purpose of Part III is to develop the approach to Information System design for Corporate Management. It is developed around the concepts of change and adaptation and explains the method used.

Chapter VIII discusses the relevance of the method for dealing with complexity and describes the Ultra-stable system's components and relations. From this discussion emerges a taxonomy of change. It uses this system as an abstract unit of analysis to deduce the necessary requirements for Information Systems design.

As a result of a thorough examination of the necessary and sufficient conditions for adaptation, Chapter VIII summarizes the initial requirements for design. It states that those conclusions are rigorous, although incomplete in the sense that there are some important omissions; the rest of Part III deals with the shortcomings derived from those omissions.

Chapter IX discusses the modifications that the Ultra-stable system -as discussed in Chapter VII- requires in order to account for the properties of learning and foresight; and introduces modelling as an essential requirement for design.

Chapter X describes the three basic components that have been deduced as necessary to a system that identifies changes that may affect an organization's viability. It develops an step by step approach to actual design and implementation which concludes with the main purpose of this research.

Part IV proceeds with a discussion on the organizational consequences of using Cybernetics, particularly its theory of regulation, as a framework to deduce an approach to Information Systems design. It starts from the fundamental fact that for the purposes of survival, time for adaptation comes to an organisms as an essential variable itself, whose stability requires regulation.

Chapter XI discusses some further modifications to the initial formulation of the Ultra-stable system and shows that rapid adaptation demands that the component parts of organisms develop some independence and autonomy.

Chapter XII discusses the consequences of regarding organisms and organizations as regulators, in the light of the law of Requisite Variety shows that certain organizational conditions are necessary. It introduces degree of interconnection as a new type of essential variable and discusses how is it that greater interaction may be advantageous as well as disadvatageous.

It concludes developing a model of the functional organization of a viable organism, where the different types of essential variables and the categories of change find their place in relation to modelling and self-organization.

3.- Hints for Reading.

This thesis has been written to be read sequentially from page one to the last; the author expects that every person seriously interested in the problems of Information Systems design should do so.

People familiar with Cybernetics and Systems concepts may not need to read Part I nor Part II, although the first Chapter is strongly recomended to everybody.

Those who may find Part I interesting but unable to follow the logic of the model of knowledge dynamics may read first Part II and Chapter VII, and then go back to part one again.

Finally, people exclusively interested in practical application of new approaches to Information Systems design may go directly to Chapters VIII and X and the go back to the real world to apply the method. This way of reading, however is not recomended at all.

PART ONE

INTRODUCTION

In this first part, it is argued that knowledge in the area of Information Systems, as in every other field is the dialectical result of confronting theoretical formulations with practice. The dynamics of this process is said to follow specific patterns whose nature is discussed in Chapter I.

The basic idea is that knowledge develops as the result of confronting theory with practice, and that the emergence of new hypotheses is somehow the expression of the failure of the present state of knowledge to provide adequate explanations to some phenomenology or problematique.

This process of confrontation takes place at two basic levels, on the one hand it manifests itself as the attempt to improve the present state of knowledge by formulating new hypotheses, testing them or rejecting them.

The second level is not solely to do with the generation of hypotheses, but with the revision and questioning of the basic assumptions on which present prevailing knowledge is supported. The result of this process is to generate a revised or new framework for for scientific work, providing the possibility to formulate theories whose validity may cover a wider range of phenomena.

In Chapters II and III it is argued that knowledge in Information Systems Design is not an exception to the general pattern and that it is somehow possible to identify the conceptual basis of current develpoments and observe how they have been determining the direction of a great deal of research work and practical implementation.

Finally Chapter IV shows that current state of knowledge in this area fully justifies the efforts to improve the present understanding of Information Systems; and that it is worthwhile to conduct research as much within the present prevailing set of assumptions as to try it from a different epistemological position.

CHAPTER I

KNOWLEDGE AS A SYSTEMIC UNIT AND ITS DYNAMICS

1.- Knowledge and Underlying Assumptions.

Human knowledge, as every other cultural manifestation comes as a result of the complex interaction that takes place among the members of a particular socio-economical formation; and between them and their environment. For as long as a culture remains valid to its creators, so their values, knowledge, beliefs -and in general all other social practice- generate and evolve into systemic units.

Knowledge and science in particular occupy a special place in a culture, because they deal with difficult matters such as truth, predictability and, of course with their practical consequences. For this reason scientific knowledge is not only socially encouraged, but social practice subjects it to a permanent and systematic questioning.

In its most elementary form, scientific knowledge can be questioned in terms of the validity of its generalisations. A very natural question that is usually put to a scientist is to ask about the extent to which his hypotheses are valid.

The question has not an easy answer. It is perhaps sometimes appropriate to accept the idea that hypotheses are valid to the extent to which experimentation shows that reality behaves as hypothesized.

Many times, however such a reply is far from being satisfactory -specially when the possibility of experimentation is difficult or it does not exist at all- as for instance when the problematique is about human and social affairs. Then it is perhaps more appropriate to recognise, first of all that the validity of the hypotheses is more clearly dependent on the validity of the assumptions that -explicitly or implicitly- generate them.

For this reason it is convenient to distinguish -particularly in the field of social sciences- at least two possible levels of enquiry. One is to do with scientific work within a particular set of assumptions; and a second level at which that very set of assumptions is questioned and possibly changed.

In the field of experimental sciences, the scientist may usually be satisfied with the results of experimentation as the basic means to consistently enhance more precise and universal knowledge. But even at this level experimentation results may be questioned.

The philosophers of science tend to be more demanding, for they are not necesarily satisfied with experimental validation as the final proof of the truthfulness of a theory. As for example in Popper's terms the activity of testing hypotheses and theories by experimental inference can only serve as a means to establish preferences between competing theories.

According to this view, the inductive method of empirical sciences is questionable on the grounds that any universal conclusion arrived at by inference from a singular statesment "may turn out to be false". (Popper 1968).

Alternatively, Popper puts forward a deductive method that submits new ideas (theories and hypotheses) to successive logical tests finally to confront them with empirical applications. If a theory passes the tests all it can be said is that the theory has been verified, and for the time being passed its tests.

Popper's ideas can be seen not only as a contribution to the phylosophy of science, but also valuable to the scientists themselves and to the practical designer whose occupation is that of designing and implementing systems to fulfill practical needs or to solve everyday problems.

The approach developed and discussed in part III it is consistent with this way of looking at knowledge; it will be noticed that the information system design proposed there is supported in a model (explicit set of asumptions about the nature of the interaction between an organisation and its environment) whose validity is tested on a regular basis by confronting with to observations of day-to-day dynamics. The model is thrown away or kept, according to its ability to explain the current situation.

It is of course not a purpose of this Thesis to give an account of Popper's philosophy nor to discuss the validity of his criticism of the inductive method, nevertheless, these comments are important to illustrate two things.

First, that epistemological approximations under whose -explicit or implicit-presuppositions a scientific work is carried out, can be challenged and that the challenge may have important practical consequences. And secondly, to underline the relevance of epistemology to scientific development at even very practical levels.

As the first part of this Thesis goes along, it will argued that there is a case to approach the task of information systems design from a epistemological position that is different to the one that supports most of current practices.

The basic assumptions that prevail in current practice are discussed in Chapter II and they are followed by a consideration of the consequences to practical design and implementation.

Part II, and up to some extent part III aims to make an explicit summary of the assumptions that support the results of this Thesis. The rest of part I is devoted to unveil the basic assumptions of current practice and to present a framework for this analysis.

1.2.- Knowledge as a Systemic Unit.

This framework's basic assumption is that science, and knowledge in general are socially created dynamic systems that over the time describe trajectories towards states that are more elaborated and stable than the precedents. To this view, Waddington's definition of a "progressive system" is particularly appropiate.

Waddington's distinction establishes as progressive systems those "...which either do not have an end state, or at least are so far away from it that it can be neglected. Probably most of systems that we have to deal with in the human and social world are of this kind, either because they involve time intervals which are very long in human terms (such as the growth of human populations), or because they are small part of ecosystems which are also changing, so that the inputs into the smaller system will have altered before it has been able to reach its end state".

A formal definition of stability is contained in Part II for the moment it is sufficient to consider it as the property of a system's state of being resilient to the presence of a disturbance. Therefore, a state is said to be more stable than other if it is resilient to a wider set of disturbances

In the context of knowledge dynamics, the stability of a theory for example may be measured by its resilience to the questions that social practice -in particular that of the scientific community- puts to it. For instance it is possible to say that Newtonian physics is less stable than Einstein's for the latter respond to a wider set of interrogants and are capable of solving a wider range of problems.

The process of transition from one state of knowledge to the next, has been studied by Kuhn. In his work (1970), he introduces the concept of paradigm as "...a set of recurrent and quasi standard illustrations of various theories in their conceptual, observational, and instrumental applications. These are the community's paradigm, revealed in its text-books, lectures, and laboratory exercises".

The prevailing paradigm is then, what characterises the state of knowledge at a given time in history and its stability is defined for its capacity to respond to society's current necesities.

In his hystorical analysis, Kuhn distinguishes period of crisis as when the scientific community perceives a growing concern about the ability of the prevailing paradigm to respond adequately to the problems that are being currently encountered. The crisis period normally precedes a major change in the state of scientific knowledge.

In this sense, the force that defines the dynamics of knowledge towards more stable forms is provided by the confrontation of theoretical knowledge with experimentation and social practice on one hand; and with the epistemological reformulations that such a confrontation provokes, on the other.

Thus scientific knowledge can be regarded as a system that is being permanently tested and by this means reinforcing or denying its validity, depending on how well is capable of contibuting to the solution of the current social problematique.

Theories and hypotheses as socially created units arise in the context of problem solving. Society confronts -during its development- problems whose solutions require new knowledge. The problematique tend to be specific to a particular field of human activities, therefore hypotheses and theories develop around specific type of problems.

In this way scientific activity gives origin to units and sub-units of knowledge that are perceived as specific disciplines or sciences.

The subject matter of this thesis is Management Information , which can be considered as a discipline in its own right, with its own community of theoreticians and practicioners, with its text-books and syllabuses , and of course with a prevailing paradigm. This discipline in turn can be looked at as being part of a wider one -Management Sciences- and the latter as integral part of Social Sciences.

1.2.1.- The Dynamic Elements of Knowledge

Looking at knowledge as a progressive system -that is to say- as describing a trajectory towards more stable forms may suggest that this process is undergone in a smooth and easy manner. Certainly that is rarely the case.

As Kuhn explains it, every important enhancement of knowledge is preceded by a period of crisis where the prevailing paradigm is confronted in a rather dramatic way with the emergence of new propositions. This stage is characterised by an acute confrontation of views that normally ends up with the consolidation of the new propositions into a new prevailing paradigm. Therefore knowledge development is not necesarily a smooth consistent and coherent displacement over time; in Kuhn terms, it is a revolutionary process analogous to a political revolution.

However, once the new paradigm is established, developments seems to follow a cumulative trajectory free from major obstacles. This is the period of consolidation of the emergent new paradigm.

As systems that are achieved through social practice, knowledge and science in particular, are linked to the historical-cultural experience, in that its evolving development is not divorced from every other cultural aspect. Thus, values, beliefs, uses and costumes affect the way knowledge develops, as it also does the way a society organizes itself to provide material conditions for the survival of its members.

A consequence of this mutually conditioning interrelations expresses itself in the role that prevalent social values and beliefs play in the development of knowledge. Society as a system itself fixes the references for development of knowledge within limits that ensure or tend to ensure the viability of its prevalent institutions.

This situation has been indicated by a number of scientists and philosophers. Waddington for example calls it "Conventional Wisdom of the Dominant Group", to emphasize its undesirable character he refers to it by the acronysm COWDUNG (1977).

In contraposition to this constraining tendency, the social effect of knowledge generated within the conventional wisdom of the dominant group may provoke problems that demand from the scientific community to challenge and try new epistemological references.

The idea of considering scientific knowledge as a system that progressively develops towards more universal and stable forms is useful because provides a coherent rationale for description. However its use in this thesis is also due to the fact that this view is already a well formalised systems theoretical formulation.

As Boulding puts it, "Human knowledge is the result of an interaction between an extraordinary biological structure, called the human brain, together with its appendages through the body, plus some artifacts like books and laboratories, and the real world". (1979)

Although this view may be considered purely theoretical and as the product of a particular way of looking at the social phenomena, a similar point of view is developed by Bateson, on perhaps more rigo rous grounds (1978).

Next section presents a framework for analysis of the state of knowledge in Information Systems design; as it will become apparent by the end of part III, this analytical structure is also supported by cybernetics principles.

In this context, knowledge on Information Systems design is considered as a particular discipline which in its turn can be seen as a component of a wider one, in this case Management Sciences.

The non-experimental character of Management Sciences makes hypotheses' testing of little use to the enhancement of knowledge. For this reason the method used in this thesis is nothing to do with the rather conventional methodology of social sciences where hypotheses are tested against some statistically processed data that is considered to constitute evidence.

The method used here consists of looking at the natural phenomena -in this case corporate managerial activity- and focussing attention on what looks to be invariant. These invariances are then taken as starting points to formulate hypotheses and theories.

For the purposes of this work, organisations are considered to be invariably adaptive, displaying the properties of adaptability and being -in principle- capable of learning. Therefore, the necessary conditions for adaptive behaviour -under a changing environment- constitute the corner-stone on which the whole design rests.

As these hypotheses can not be experimentally tested nor does it make much sense to test them against the results that a model may provide, the view embraced in this thesis is that in Management Sciences the hypotheses testing takes place in the socio-historical context. That is to say validation of theories occurs over the time and in the process of confrontation between theoretical knowledge and social practice.

Valid theoretical formulations expresses themselves as social practices that remains over the time in a particular societal setting. In this respect it is reasonable to state that valid knowledge is constituted by those theories that survive the selective process of confrontation with the real world. The precise meaning of the term survive is dicussed in section 6.3.

1.3.- A Framework for Analysis of Development of Knowledge

In the first place it is necessary to look at knowledge as a natural and socially determined system showing the features of an evolving unit, in particular that which is typically recognised as adaptive behaviour.

To this discussion, it is useful to consider Pask's interesting remarks about the systemic character of scientific knowledge (1979). In his work he distinguishes two fundamental components of a system of knowledge.

On the one hand that aspect of science that deals with logical consistency and factual truth, basically consisting of developments, refinements and in general confirmatory or not confirmatory work within the context of a well defined and accepted epistemological reference. This distinction is somehow equivalent to Kuhn's definition of normal science (op. cit.), Pask calls this category Working Science.

On the other hand, he distinguishes a second aspect and calls it "Science Philosophy and Innovation". This part of science is regarded as containing -in addition to the conceptual apparatus needed to arrive to generalisations- logical coherence and meaningful agreement. The distinction is important in various senses, not the least as a reference to observe the work style of a scientific community like a University Department and of the individual researchers.

According to Kuhn's views, limiting the scope of enquiry to to the problems of normal science may render negative results for it may tend to reinforce -either by verification or rejection of hypotheses- the prevailing epistemological framework.

In relation to this research, the distinction is also relevant because the author has had the deliberate intention of working on premises that are different to the ones that support most of current developments.

The idea is to explore new possibilities by removing the restrictions that prevailing management knowledge fixes upon research. In this endevour, this Thesis can be looked as a contribution to the works already developed under the approach of cybernetics.

Pask would argue that the results of doing science within "Working Science" -without questioning its epistemological basis derives into a yet more self-reinforcing consensual system that although "stable and autonomous is pointless". Under his views, a truly scientific style of work must integrate the two aspects of scientific enquiry into a unique activity; in a way that the scientist does not limit his work to solely confirm or reject propositions generated within the established setting of cultural practices that prevails in a society.

The scientist should be aware of the very foundations of the consensual paradigm under whose assumptions he works, and should be capable and ready to question his presuppositions; thus innovation -in the form of change of the investigation rules, new hypothesis and invention- is promoted.

Pask calls the process of innovation "Abduction" and maintains that this is the mechanism that makes knowledge systems informationally open, whereas all other sort of scientific work can be regarded as "noise". He argues that the basic mechanism to enhance abductive behaviour is analogy, which is said to provide the major mode of reasoning.

Although analogous reasoning and the establishing of iso- and homomorphic relations play a central role in the advancement of knowledge, it is convenient to look first to two important processes that in the case of social sciences, precede and possibly generate analogy construction. They are uncertainty or incompletness of knowledge and social practice.

The first step to develop the framework for analysis requires further cosideration of the relations between Working Science and Consensual System.

1.3.1.- Consensual System and Working Science.

A basic hypothesis in this Thesis is that the state of affairs in the Consensual System, its questioning and in the last event changes that may occur, are dynamically linked to the current state of affairs of the society as a whole. These relationships express themselves in the social process of providing material conditions to the individual members for their survival and reproduction, and to the society as a whole.

Under this point of view, individuals in a society establish complex relations among them and with their environment in a way that their own individuality can be maintained over the time. This process repeats itself

-isomorphically- at an organisational, social and ecological level. Inserted within this processes, knowledge develops into new forms by the dialectical confrontation between the general state of knowledge at a particular moment and the demands that social progress makes, in the form of problems to be solved.

In the context of this dynamics, one can see that analogy construction cannot account by itself alone as the force behind changes in the Consensual System. The contention is that there is a more significant force behind epistemological questioning originated at the social level; it takes the form of disatisfaction with the social consequences of applying conventional knowledge to the current problematique.

The point can be illustrated by the present growing concern for the ecological consequences of today's industrial society. In relation to Information Systems in particular, disatisfaction is perceived by the feeling that current designs have failed to make a significant contribution to better decision making, a discussion on this specific topic is contained in section Chapter IV.

For the moment it is convenient to return to the relations between a prevalent Consensual System and Working Science. A simple description of the interrelations between them is presented in figure 1.1.

In Pask's terms, the stable consensual system represents the realms of "coherence truth" or that of meaningful agreement within a scientific community. In practical terms is defined by the observational norms used in the process of scientific enquiry by the theories that are currently believed to be true.

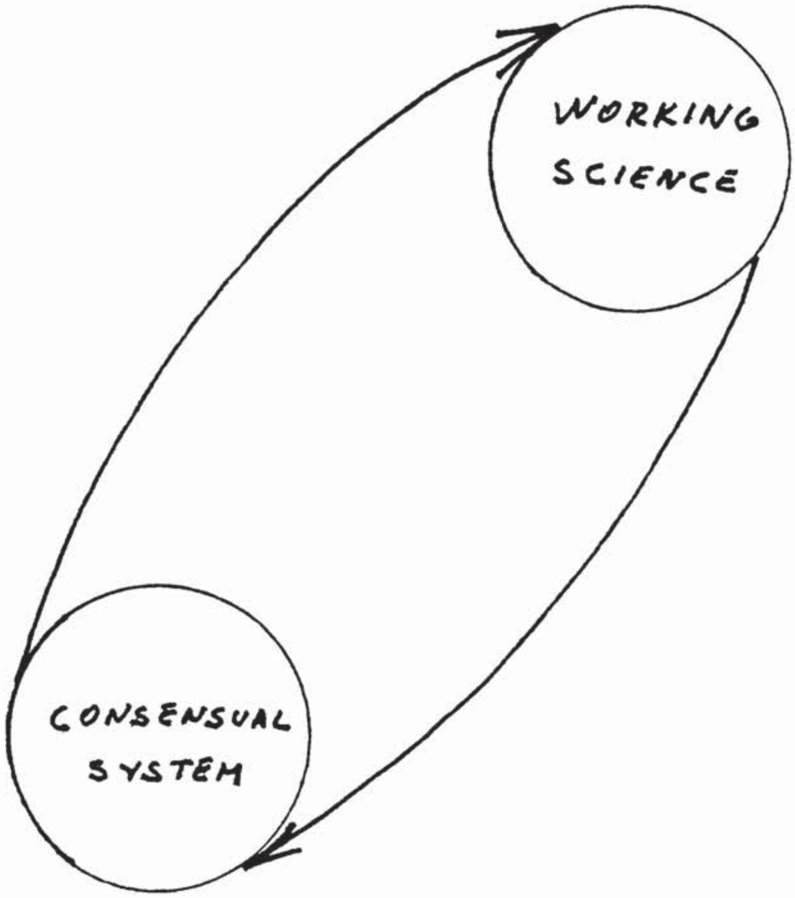


Fig.1.1 Consensual System and Working Science

The term working science is reserved for the number of "verified hypotheses" and theories whose closure or stabilty as systems contributes to establish and re-establish the accepted observational norms and and currently believed theories. The figure can be looked at as a coupling of two dynamic systems where the arrows represent a positive feed-back loop, in the way that further scientific developments within the consensual basis tend to reinforce the validity of its assumptions, whereas the validation of the latter generates more and more work within the paradigm.

As in any very complex stable system , the stability region can be large enough to permit a great deal of interesting activity (Ashby 1960), as occurs for example within an ecological system. Similarly in the field of science a particular consensual system may contain a large number of hypotheses and theories whose complex interrelationships provide the conditions to generate many new hypotheses and theories time and again.

In practice, Working Science tends to produce many variations on the same theme that take the form of propositions, debates and discussions. In the area of Information Systems it expresses, for example in the proliferation of apparently new and different methodologies for design, as the ones discussed in Chapter III. But for as long as observational norms and fundamental beliefs are not questioned, innovation is somehow precluded. Thus scientific work strictly developed within the references provided by the consensual system may yield the paradoxical result of inhibiting further developments.

The negative effect of Consensual System to the progress of knowledge takes the form of intransigent opposition to consider new observational norms by the established scientific community. Kuhns discusses this phenomenon and gives several examples taken from the history of science.

The problem has also been pointed out by Russell (1979), for instance he refers to the status of geocentric astronomy and the established pre-Copernican paradigm; and to the theory of i mutability of species and the consensual system of pre-Lamarckian zoology.

Copernicus' heliocentric theory came to be accepted years after its authors' death and as an indirect result of Kepler's discovery of the law of the planetary motion. Similarly, evolutionism gained its place in science only after Darwin's formulation of the principle of natural selection as the mechanism of evolution.

Russel points out the interesting phenomenom that the acceptance of these two important scientific break-throughs encountered great opposition from the scientific and institutional establishment of that time, and he argues that it is not only matter of the past, but such situations still occur.

More recently, Norbert Wiener himself noted the contemporaneity of this phenomenon, he said:

> "But even in the field of science, it is perilous to run counter to the accepted tables of precedence. On no account is it permissible to mention living beings and machines in the same breath. Living beings are living beings in all their parts; while machines are made of metal and other unorganised substances, with no fine structure relevant to their purposive or

quasi-purposive function. Physics -or so it is supposed- takes no account of purpose; and the emergence of life is something completely new.

If we adhere to all these tabus, we may acquire a great reputation as conservatives and sound thinkers, but we shall contribute very little to the further advance of knowledge. It is the part of the scientist -of the intelligent and honest clergyman as well- to entertain heretical and forbidden opinions experimentally, even if he is finally to reject them" (Wiener 1964).

Wiener's view is important not only as an illustration of the problems encountered by the scientist that works outside the conventional wisdom, but also because he suggests that heretical opinions should be encouraged.

This Thesis somehow responds to Wiener's demand, since it is based on premises that are clearly different to the ones that supports most of current developments.

A discussion on the prevailing assumptions in current Information Systems design is contained in Chapters II, III and IV.

1.3.1.1.- The Effect of Interdisciplinary Work

As it has been mentioned, problem oriented scientific enquiry provides the conditions for knowledge specialisation with the result of the appearance of specific sciences and disciplines. Sciences and disciplines on the other hand, do not develop completely independent from one and other; they rather influence each other giving origin to complex relationships. Figure 1.2 contains a simplified description of this

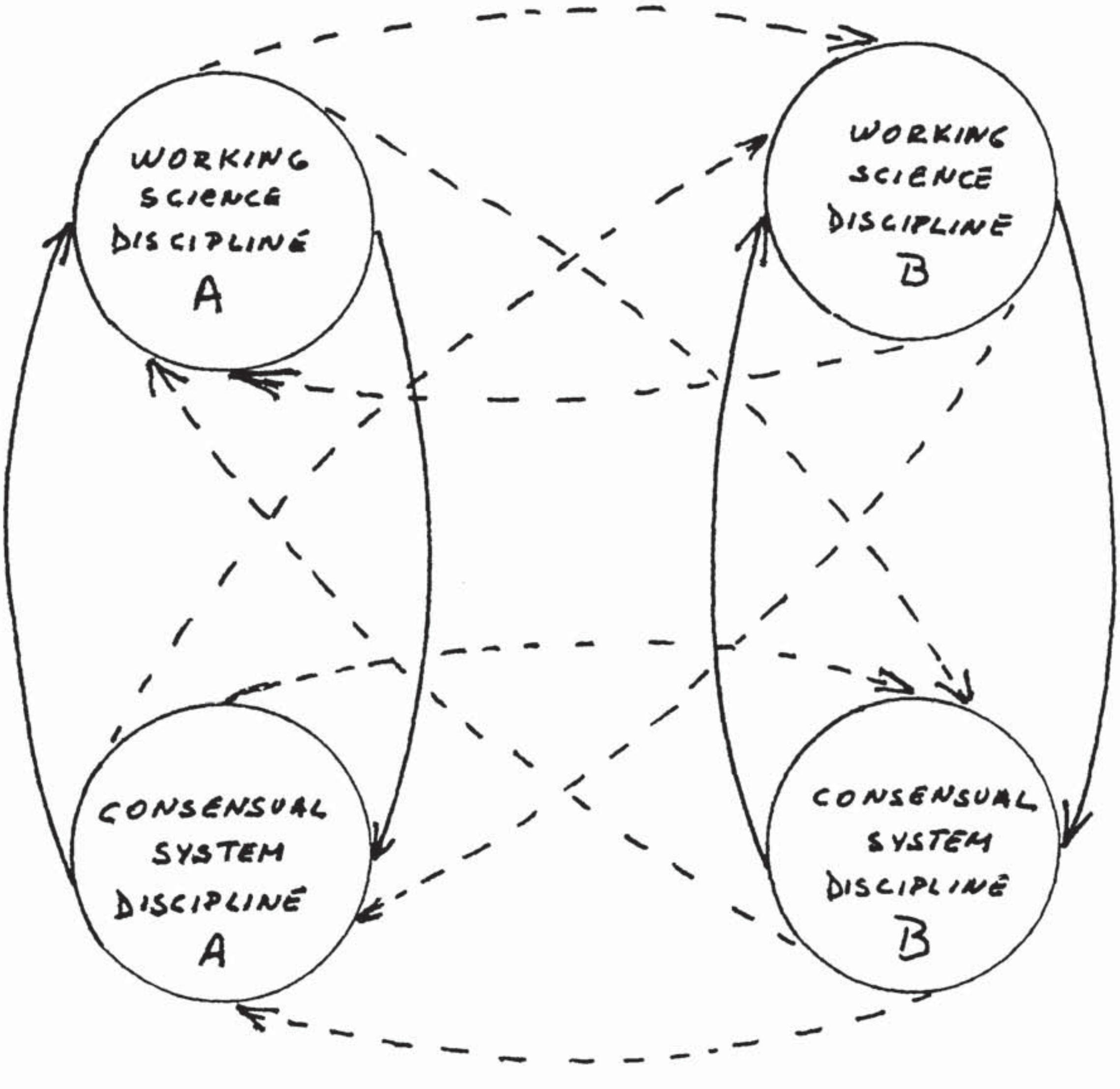


Fig.1.2 The Effect of Interdisciplinary Work

interaction.

The figure reveals the multidirectional character of the interactions and the self-reinforcing properties that such interaction may develop. However, interdisciplinary exchange does not necesarily end up reinforcing the prevailing Consensual System -since in the context of this interaction- changes in the consensual system of a particular discipline may generate changes in other's. This is probably the most important effect of interdisciplinary work, this process can be looked at as the actual information exchange among different fields of knowledge.

To this process, analogy construction and the establishment of isomorphic relationships come as major contributions to promote influences. In relation to this thesis in particular, this relations are important for the whole development of part III is based on the hypothesis that human organisations share essential characteristics with living organisms and with eco-systems. This comes as a result of supporting this development in Bertalanffy's theory of open systems and more specificaly on Ashby's developments on ultra-stability. These two theories have stemmed from theoretical biology, but in particular from the epistemological position that open systems -biological, social, ecological- share common features which can be treated as a specific subject matter.

1.3.2.- Incompleteness of Knowledge and Abductive Behaviour

Following Pask's terminology, Abduction is the name for innovation and changes in the cosensual system.

Metaphoricaly speaking, it is possible to look at figure 1.1 as the coupling of two dynamic systems. A more detailed discussion on the properties of such mechanism is contained in part III. For the moment it is sufficient to consider that according to the veto theorem (Ashby 1976) the set of possible equilibrial states of the whole is constrained to those which are mutually equilibrial to both parts of the coupling.

An application of the theorem to the model of figure 1.1 indicates that within a given Consensual System, only a limited number of hypotheses and theories can provide equilibrium to the composite system, and that a major change in the set of equilibrial states can only come from "the outside", that is from a change in the set of parameters under which the interaction takes place.

In the model, Abduction as scientific breakthrough can be shown as the change in the set of parameters or references that allows a new and wider set of trajectories and equilibrial states in the system. Figure 1.3 describes the hypothetical mode as Abduction affects a Consensual System, and consequently the whole realm of knowledge.

According to Pask, abductive behaviour comes from the field of philosophy of science and epistemology. In this Thesis, however it is argued that -in addition to purely intellectual activity generated by the scientist's uncertainty- the necessary epistemological questioning that preceedes Abduction is somehow originated at the level of social interaction where in the last event social science hypotheses are confronted with the real world.

To complete this framework for analysis it is necesary to give further consideration to the processes of change of observational rules and revision of currently believed theories.

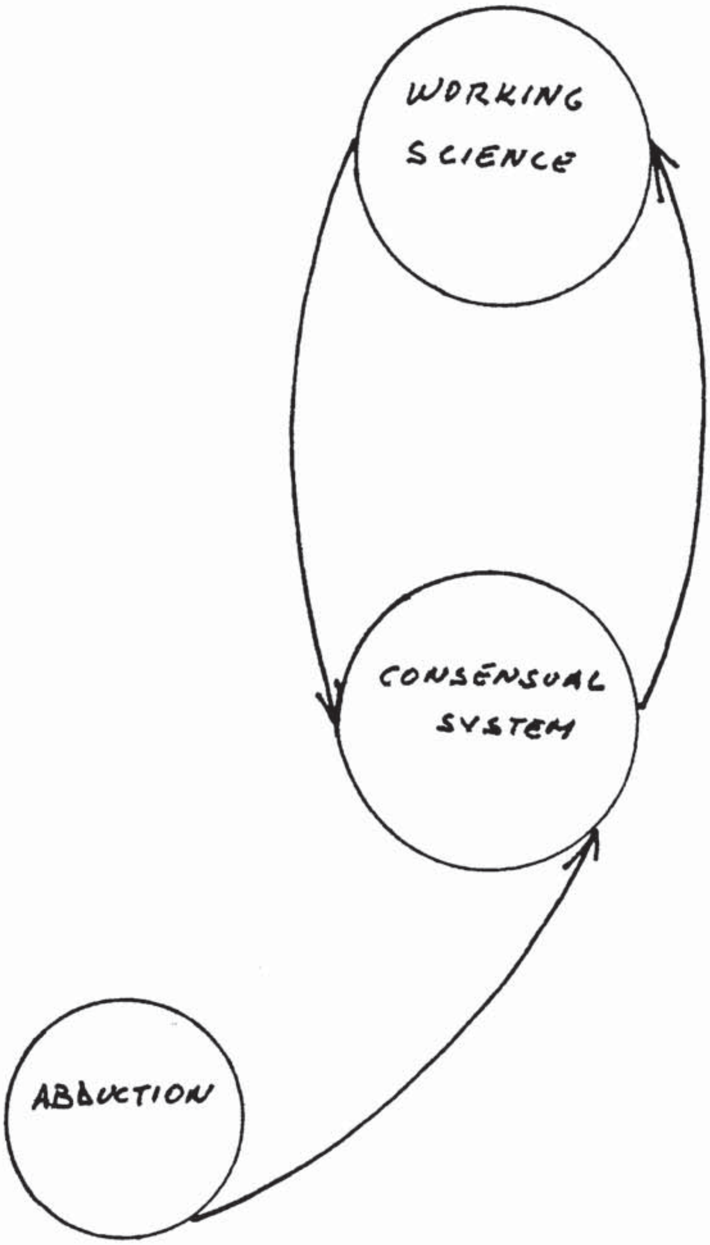


Fig.1.3 Abduction and Consensual System

According to Wiener's view, Abduction can be enhanced by entertaining "heretical hypotheses". But the question is how might this process of entertaining "heretical" hypotheses come about?. Wiener's quotation in section 1.3.1 suggests that by appealing to honesty, the scientist and the clergyman should be prepared to try entirely new hypotheses.

This call to honesty gives a clue to the question , for its ethical connotation suggests that a source for the questioning of the prevalent paradigm is encountered at the level of social interaction, particularly in the way as individuals perceive the social consequences of the present state of knowledge. Apart of this type of questioning -which is more fully discussed in next section- one can conveniently distinguish a second and perhaps more readily accepted source in the ubiquity of uncertainty or incompleteness of human knowledge.

Incompleteness of knowledge expreses itself in two forms; in the first place as a lack of accuracy in the prediction of events -probably due to experimental error- and that can be dealt with within the present Consensual System -where probabilistic approximation may find a place as satisfactory answers-. And secondly as the incapacity to provide satisfactory explanation to a phenomenon.

Figure 1.4 introduces these two forms of uncertainty and shows the way as they affect the dynamics of knowledge. The first type is mostly tackled by working within the established scientific practice, whereas the second one is mostly tried with philosophical speculation in the form of change of the observational rules.

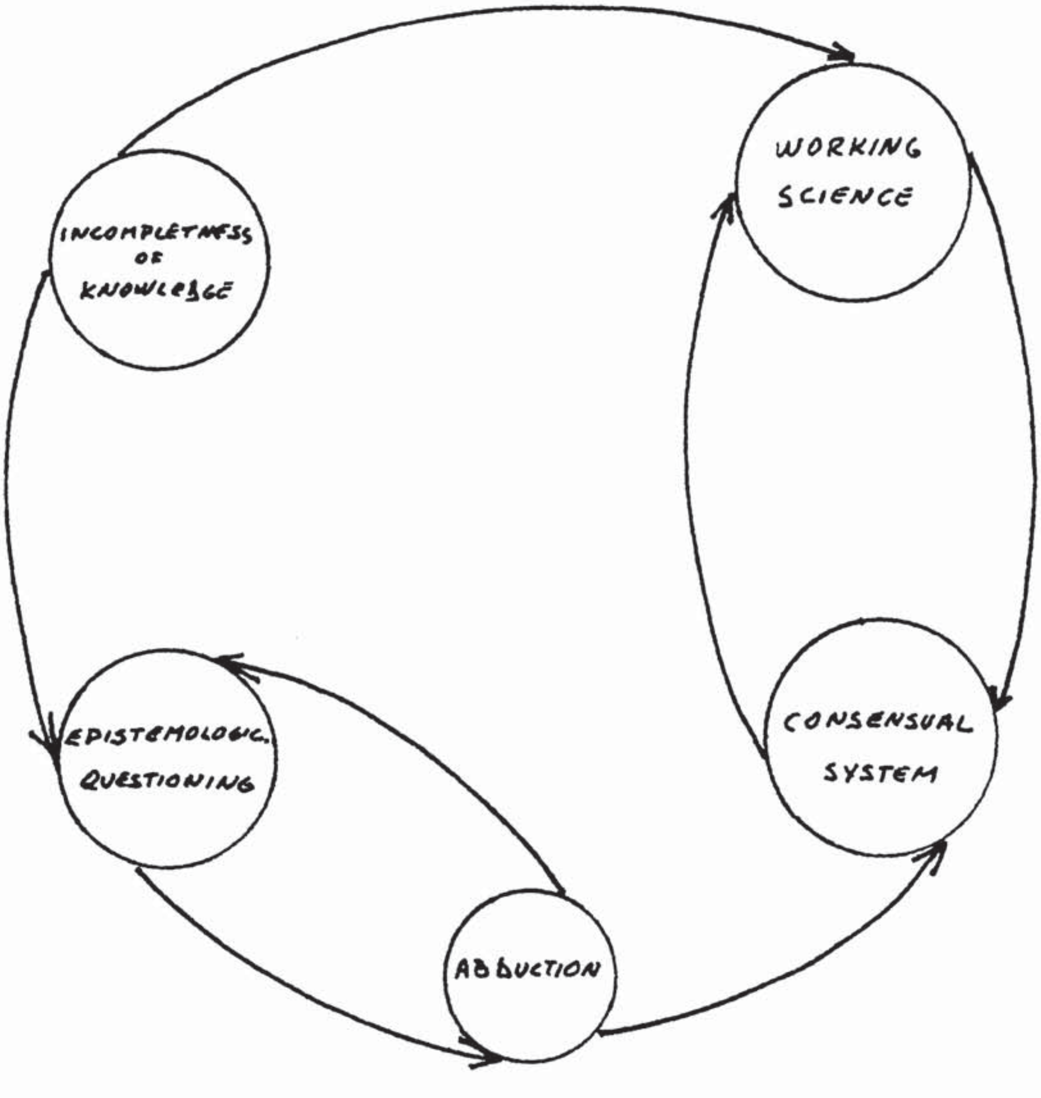


Fig.1.4 Incompleteness of Knowledge and Knowledge Dynamics

In the area of Information Systems and in general in management the validity of the distinction can be ilustrated with examples, for instance the first type of uncertainty determines that a great deal of efforts are spent in developing algorithms applicable to some specific problems, whereas epistemological questioning is observable in the growing concern about the future of Management Sciences and Operational Research as a profession (Ackoff 1979a,b).

A very good example of epistemological questioning is provided by Einstein's position with respect to Heinseberg's principle of uncertainty in quantum theory. Einstein being unable to find out paradoxes in the theory, resorted to a purely phylosophical speculation summarized in his famous phrase "God does not play dice with the world" (Bernstein 1973).

The figure summarizes and describes the relations among uncertainty, Working Science and Consensual System. The arrow from Incompletness of Knowledge to Working Science represents the effect of uncertainty over the work of a scientific community under a prevailing paradigm, the second arrow represent the influence of uncertainty on epistemology and in the last event on the Consensual System.

The arrow from Abduction to Epistemological questioning indicates that they stimulate each other, as Einstein's reaction to Heisenberg's principle somehow illustrates.

1.3.3.- Social Practice as a Source of Epistemological Questioning.

According to what has been suggested in section 1.3.2, the second source of epistemological questioning is provided by the practical effect that scientific advancement has at a societal level. The view embraced in this

Thesis is that Social Practice plays a dual role in the dynamics of knowledge, particularly in relation to social and managerial sciences.

In the first place, Social Practice provide the means for hypotheses testing. Those theories that successfully cope with some particular problematique tend to survive in the sense that they remain as part of society's bagage of knowledge; in this respect Social Practice tends to reinforce and provide stability to the Consensual System from which the theories are originated. This process can be regarded as the successful contribution of Working Science to solve the society's problems. In this role, Social Practice can be looked at as it tended to enhance stabilty to the stablished set of observational practices and currently believed theories.

But on the other hand, the practical effects that social internalization of knowledge either affect the way as different individuals and organisations perceives the results of new knowledge or generate new problems whose solution demands a revision of the prevailing paradigm.

At present, the necesity of revising the prevailing Consensual Systems can be observed in the form of growing awarness of the danger of an ecological collapse, which in its turn is perceived as being -to some exten - provoked by the successful application of knowledge to the problem of material production of goods and services. For instance, pollution, unemployment and crime appears closely related to technological development and economic growth.

In relation to the ecological crisis, Bateson argues that "... the basic causes lie in the combined action of a) technological advance; b) population increase; and c) conventional (but wrong) ideas about the nature of man and his relation to the environment". (Bateson 1978)

Historically, the point can be illustrated by the emergence -in the XIX Century- of Marxism as a philosophical system that responded to the social problematique generated by the Industrial Revolution.

More recently and in rather more specialised context, "Keynesian Revolution" can be seen as an alternative to the then prevailing paradigm in economics. By lifting some basic assumptions of the classic Economics -in particular those that have to do with employment and the role of goverment- Keynes was capable of formulating a theory that responded more efficiently to the problems of unemployment and over-production (Keynes 1936).

No comparable change in the Managerial thinking has had the impact that Keynes' theory or Marxism have had in Economics and Social Sciences. Although in Chapter II some important changes of emphasis are distinguished. Perhaps the most recent and -from the point of view of epistemology- most important attempt to a reformulation of the discipline is found in Beer's work, specially as developed and discussed in Platform for Change (1975).

Figure 1.5 introduces to the diagram the dialectical effect of social practice on the development of knowledge. The framework, as illustrated is simple though comprehensive except in that does not show interaction among diferent disciplines.

The two dialectical elements in the figure are Social Practice and

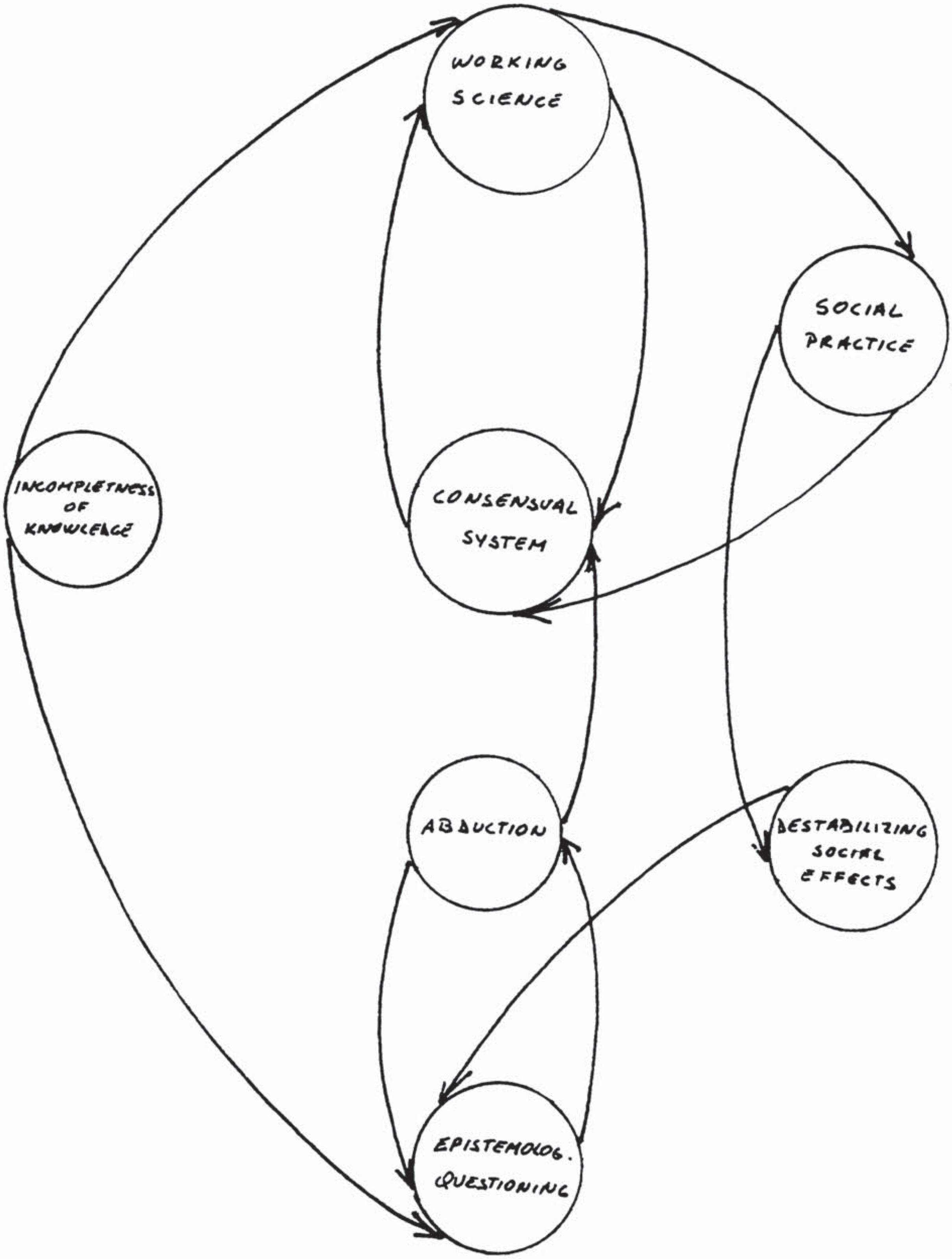


Fig.1.5 Social Practice and Knowledge Dynamics

Incompleteness of Knowledge, in rigour both can be regarded as social practice, however the distinction is useful for the left hand side refers to social intercourse at a micro level -i.e. laboratory, department, profession- whereas the right hand side indicates the interaction at macro level for instance socio-political.

The figure has several interesting features:

i.- It shows where Abduction is generated -that is to say the source of change of parameters of the coupling Consensual System-Working Science.

ii.- Clock-wise arrows represent the forces that tend to preserve the Cosensual System and that provide stability to Working Science. They are what Pask calls "noise" (1979).

iii.- Anti-clock wise arrows describe the negation of prevailing Consensual System, and therfore the element that make the system informationally open.

The system described by figure 1.5 more than to a homeostat resembles a homeorhetic mechanism -as described by Waddington (1979)- where homeohersis appears as the property of "progressive systems" that rather than to stabilize a particular state ensure the continuation of a given type of change.

Next section is devoted to discuss the process of interaction among knowledge from different disciplines, at this stage analogy becomes particularly relevant.

1.3.4.- Interdisciplinary Work and the Role of Analogy in Science.

Figure 1.5 was said to have been comprehensive except for the fact that it provided no clue about the way that different types of specialised knowledge interact. Empirical evidence leaves little doubt about the proposition that universal knowledge is somehow affected by the way that different disciplines develop.

In the same way as problem oriented work favours specialization, the attempts to face complex social problematique has created conditions for interdisciplinary work and for developing mutual influences among different scientific communities. The result of this process yields at least two important effects.

On the one hand, it provides the grounds for fruitful interdisciplinary work, whose effectiveness tend to manifest itself in terms of improvement and speeding the learning process.

A second and possibly more important effect has been to provide the basis for the formulation of a General System Theory whose subject matter are the commonalities to the whole area of knowledge.

Thus Systems Theory comes to the field of knowledge as a science of the general, that is to say as science whose subject matter is the class of phenomena rather than phenomena in particular. As a framework, it enhances development of specialised disciplines by giving the possibility of learning from other areas. It is in this context that analogy plays its role.

Analogy does not necessarily yields true knowledge, but it is important to knowledge generation because focusses attention on similiraties and disimilarities between different subjects of observation. By this means, the researcher attention falls onto the realm of difference and invariance, and open the possibilities to the search of invariant features among the observed phenomena.

Analogy as a means of knowledge development is susceptible to superficial appearances, for this sole reason it can not account for explanation. However it is an important source of inspiration for the researcher since it provides clues to look for invariant aspects of phenomenology being this is what defines its importance.

A valid analogy may expressed as isomorphism between two or more phenomena belonging to deifferent areas of knowledge. When isomorphisms can be established then analogy becomes if not proof a basic ingredient in an argumentation for the presence of invariance.

In terms of interdisciplinary work, and in relation to integration of knowledge, analogy construction provides a basic glue. In the model of figure 1.6 it is introduced as a connective linkage between different areas of knowledge; as such it constitutes a determining element in reinforcing or denying the prevalence of a Consensual System.

At the level of Working Science the mathematical notion of isomorphism permits to look for abstract hypothetical mechanisms that may account for type of behaviours that are typical of systems of very different nature. This point is well ilustrated by Wiener's account of the origin of Cybernetics as a formal science (Wiener 1975). It was the result of interdisciplinary interaction around a set of "analogous" phenomena what

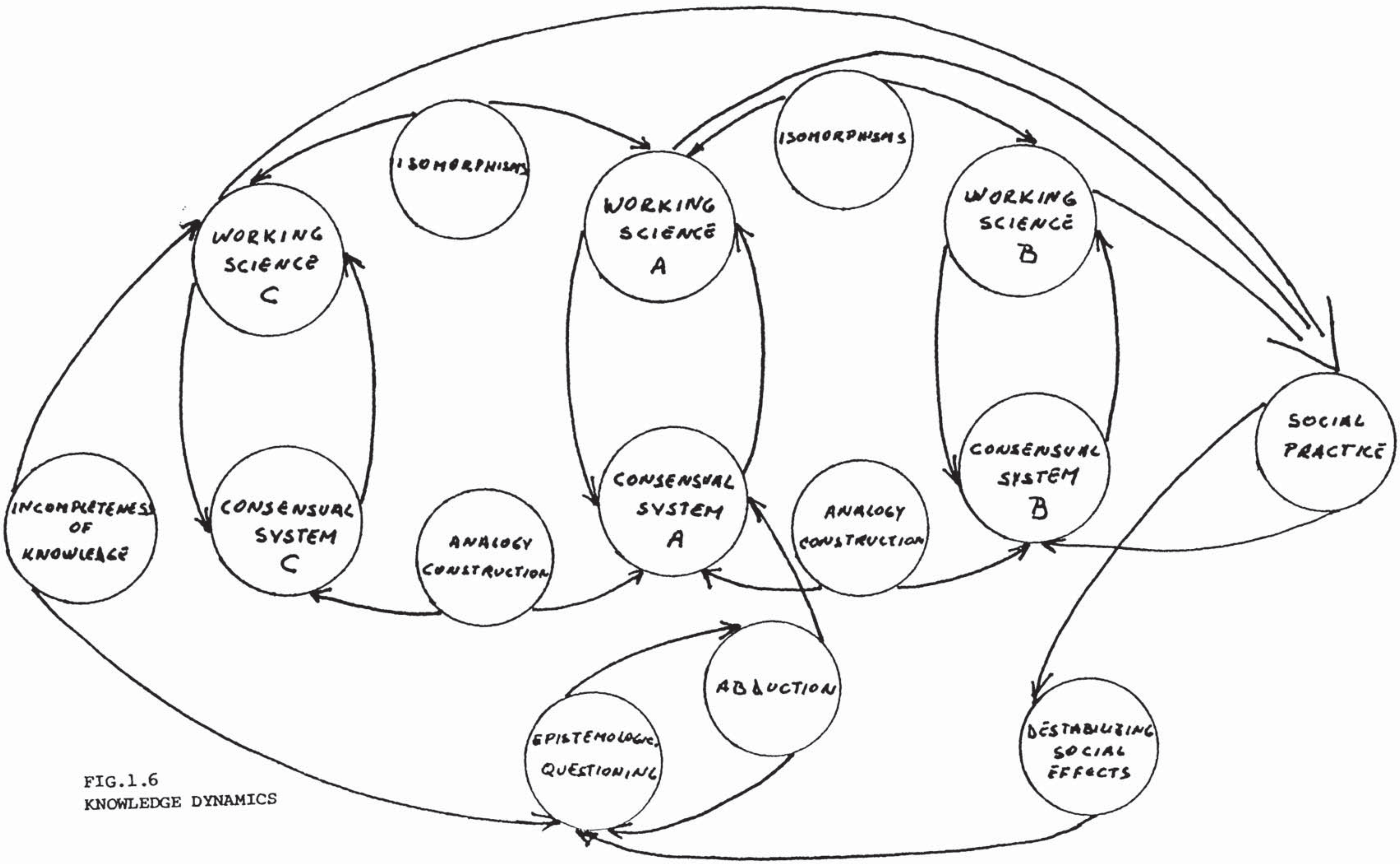


FIG.1.6
KNOWLEDGE DYNAMICS

made Wiener and colleagues realize the universality of feed-back structure in control systems; and to envisage that the informational aspects of this process was somewhat "no man's land" in the then current scientific practice.

In Wieners own terms "... the group of scientists about Dr. Rosenblueth and myself had already become aware of the essential unity of the set of problems centering about communication and control, and statistical mechanics, whether in the machine or in the living tissue" (1975).

This universality of informational process is what makes Cybernetics a transdiciplinary science, and what legitimates an attempt to develope an approach to the the problem of design of Information Systems for Corporate Management based on the properties of a mechanism that display ultra-stability.

Figure 1.6 completes the framework for analysis of knowledge dynamics. It contains the distinctions that give context to this Thesis, both to legitimate its theoretical basis and to justify the effort.

With respect to its theoretical basis, a fundamental hypothesis is that human organisations, living systems and ecosystems share the property of ultra-stability. This hypothesis permits the use of the Homeostat as a basic referential mechanism to work out the design.

In relation to the justification of the effort, the basic argument can be summarized in the following terms:

Most of Management Information Systems design have been developed within a prevalent Consensual System about the nature of the managerial process and decision making; there is sufficient evidence to believe that those designs have had limited value to provide effective support for Management activities -particularly to those of longer term- and that is reasonable to try new avenues in the development of an approach.

The design discussed in part III aims to be abductional in the sense that the conclusions arrived at stem from premises that are different to the ones that support most of current developments. Next chapters are devoted to examine prevailing ideas in Management and to envisage their effect on Information Systems design.

CHAPTER II

ON THE PREVAILING IDEAS ON MANAGEMENT

2.- The Basis of the Consensual System.

According to the framework for analysis discussed in Chapter I, it is possible to look at managerial knowledge as an evolving systemic unit. Like a non-experimental science that develops by trying hypotheses and theories in the social context of adminstrative affairs, where socially valuable knowledge tend to survive as validated current practice, while less valuable knowledge tend to be replaced by the former over the years.

Hypotheses and theories gain their place in the accepted managerial culture displacing the olders by direct confrontation or by complementation of already well established practices giving in this way, form to newer and temporarily more stable formulations.

This chapter contains a discussion on the prevailing ideas on management and a brief account of some important contributions to this discipline received from other areas of knowledge. As a corollary there follows a description of what is regarded as the prevailing rationale for the design of Information Systems.

2.1.- The Early Scientific Management.

Management's origins as a subject of systematic scientific enquiry can be traced back only until very recent times. It was just from the begining of this century that it emerged as a discipline in its own rights; its origins appears closely related to the Economic Theory of the Firm and consequently to the set of assumptions that support that theory.

The most fundamental assumption in this theory is that the firm's owner or entrepreneur and the individual consumers in the market behave rationally.

From the point of view of the administration of the firm., rationality means aiming to the greatest money profit by maximizing revenues and minimizing costs (Stonier & Hague 1961). Implicit in this view is the idea that the firm, the entrepreneur and the individuals engaged in the productive process follows the same rational pattern of behaviour.

Under these views, the firm and the individual participants in the productive process have the sole objective of maximizing profits which in turn is regarded as non-conflicting.

In F.W. Taylor's terms, "Scientific management, has for its very foundation the firm conviction that the true interest of the two (employer and employee) are one and the same" (1947).

Management practicioners, scientists and the general public have -since long ago- been aware of the limited practical value of those assumptions.

Taylor's statement is somehow responding to those who, already then were thinking "... that the fundamental interest of employers and employees are necesarily antagonistic" (Taylor 1947).

Although Taylor's views can now be regarded as old fashioned and not any longer influential in formal Management teaching, they still reflect fairly common management practice. Particularly in the areas that deal with rationalization of processes, for instance Industrial Engineering and Organization and Methods.

2.2.- Some Important Contributions to Management.

From Taylor's time however, Management has developed, receiving important contributions from other disciplines, specially from social psycology and sociology.

According to Koontz (1964), Management is about getting things done with people and a lot of attention has fallen onto the study of interpersonal relations. From social psycology Management has taken the concepts of leadership and motivation, whose importance to Management theory and and technical developments cannot be over-emphasized.

In Parallel, Management has taken from sociology the notions of structure and function that were going to be the basis of a functional theory of organizations that -as will be discussed later- has had possibly the most important single impact on Information Systems design.

According to the functionalist view, an organization can be viewed as a natural social system embracing an arrangement of necesary functions to achieve organizational goals. The functional-structuralist approach had the capability of providing a coherent framework for the understanding of the ongoing activities in organizations (Roethlisberger 1964).

Developments in Decision Theory and Operational Research have also result in important contributions to Management as discipline. Decision Theory as the formalization of "... the logic of deliberated choice under uncertainty" (Schlaifer 1964) aims to help Managers to cope with complex problems that involve high risk, as for example when dealing with capital investment. According to this view Management is essentially the activity of making decisions, therefore this process is given systematic attention as the central topic of study.

With respect to Operational Research, the most significant initial contribution is perhaps the attempt to apply the Scientific Method to administrative problems. This endeavour resulted in the development of a number of mathematical methods and refinanments to deal with fairly structured organizational problems. More recently the emphasis has been changing to the problems of methodology for problem solving (Checkland 1972, 1976).

Later and possibly at lesser degree, Control Theory and Cybernetics have had their own impact. Industrial or Systems Dynamics as a branch of Control Theory focusses on the feed-back loop structure of decision making where the time variable is explicitly considered (Forrester 1968).

It stresses that policy design must take into account the feed-back loop structure of the process that determines the behaviour of the system and that whenever -for analytical reasons- the closure of the loop is broken, the analyst will most likely fail to understand the system.

Systems Dynamics as a theory provides a comprehensive framework to understand managerial dynamics and policy making, although some practicioners tend to see it as mere simulation technique (Ansoff and Slevin 1968). In part III it will be argued that a systems dynamics type of model is necessary to the design of Information Systems for Corporate Management.

The influence and contribution of Systems Theory and Cybernetics are to be discussed with some detail later on.

These contributions and others not considered in this discussion have in general emerged in the context of specific problem solving. Contributions from Social Psycology, for example have come as the result of the effort of looking for better explanations of human behaviour in organizations than the one provided by theories based on the assumption of human rationality.

Similarly Decision Theory develops knowledge around the decision making processs under conditions of uncertainty, and so on.

Some authors, Koontz for example (1964) envisage these contributions as the emergence of well defined schools of managerial thought, and as if they were competing theories. This way of looking at managerial knowledge may be very useful for analytical purposes, but care should be taken of not to lose sight the fact that the schools are nothing but conventional distinctions that an observer makes and that the competition that defines the validity of hypotheses does not take place among diverse schools.

Scientists as individuals work in a concrete situation, their work can be looked at as belonging to a particular school of thought that competes for supremacy with other schools. However, what defines the survival of theories and hypotheses is not the purely intellectual discussion on the advantages of such and such approach, but it is social practice in its historical development that determines in the last event what knowledge deserves to be culturally internalised.

Those different streams or schools are the result of specialization within the problematique of management being more related to the type of problems that their authors were facing rather than to a conscious purpose of alignment with a "better" theoretical approximation in particular.

Whilst some people was engaged with the study of the problems of financial management others were more concerned with human behaviour in organizations, with corporate decision making and so on.

Within this multilateral approximation to management, Systems Theory may be considered as providing a unifying framework for synthesis and further development to deal with particular types of problems. In this sense the Systems Approach to Management cannot be regarded as as a development to deal with a particular type of problems, but as providing a framework for the synthesis of these several contributions into a coherent theoretical body.

2.3.- The Impact of Systems Theory and Cybernetics on Management.

Management -possibly more than any other single discipline- has been influenced by the ideas of Systems Theory and Cybernetics; particularly those areas concerned with organizational design, a planning and control.

The scientific character that Management was taking during and after the years of World War II was affected and speeded up by the rapid technological developments in Computer Science. The capabilities that computers have as managerial tools for operational control, their potentialities to improve long term decision making and the changes that their introduction were causing, resulted in a great deal of attention to the development and design of computer based mangement systems.

As it will be discused in chapter III, the design and implementation of these systems created conditions for the development of methodological approaches that were clearly influenced by the emergent concepts of Systems Theory.

For this reason, terms like Systems Analysis and Information Systems are generally associated with the application of computers to management and tend to be deprived of their more general connotation. (Kelly 1970, Johnson et. al. 1973, Clifton 1974).

In a rather wider sense, the term Management Information System is sometimes understood as the set of formalized procedures to collect, record, process and distribute infomation within an organization. Information Systems are regarded as special case of operational systems sharing the same features and problems with any other operational system (Lee 1970). More recently, the trend seems to be changing as to include the wider aspects of planning and policy making (Higgins 1976).

Before continuing with the discussion on Information Systems design, it is convenient to give a closer look at the way managerial knowledge has been affected by Systems Thinking.

The conception of human organizations as open systems that display purposeful behaviour has had a considerable impact in organizational theory. According to this view, an organization is thought as an assembly of parts synergisticly related that mantain with their environment a permanent exchange of matter, energy and information in a way that its purposes are achieved.

Under the systems approach, organizations are regarded as '... open sociotechnical systems composed of a number of subsystems and in continuing interaction with its environmental supra-system". (Johnson et. al. 1973).

Because of the synergy property of organizations, the mainly analytical nature of traditional scientific method is regarded as inadequate to deal with organizational problems, for the interrelationships among parts are considered to be an essential element to explain the behaviour of the whole.

As an alternative, systems theoretical methodological developments shift attention towards the relation system-environment and stresses the that the understanding of organizations requires to look at them as wholes, where interrelations among components are considered to be determining behavioural elements.

The property of equifinality -as defined by Bertalanffy (1973)- makes of teleology a basic ingredient to methodologies based on systems approach. Teleology -in opposition to the dominant principle of causality in the classical sciences- is a pervasive element in systems methodologies, in the sense that definition or finding out of objectives is regarded as primary and essential stage (Hall 1962, Newfville & Stafford 1971, Optner 1975).

It is argued that only once the the objectives are properly described, the analyst is prepared to consider the problem in a way that he does not lose sight of the wholeness of the organization. Decomposition of organizational objectives is supposed to provide the analyst with the thread that relates parts into a unique and coherent body.

Teleology, hierarchical decomposition of objectives and the functional-structural view of organizations provide the grounds for developing a conceptual framework for Information Systems design. The combination of these elements constitutes the basis of the theoretical approach that supports the great majority of current applications. This topic is discussed further in section 3.2.

The impact of systems thinking on Management Science is still very important, although the value of teleology is sometimes questioned. For example Checkland's works on methodology stands in a rather special way to most of systems engineering methodologies, for it questions the requirement of defining or finding out organization's objectives, shifting attention towards individuals' views of the organization and its purposes.

This impact of Systems Thinking has been particularly felt in the area of Operational Research. According to Ackoff -an early promoter of the use of scientific method to management- the holistic nature of managerial problematique demands the application of a synthesis oriented method, rather than a method that is based in the analytical partition of the system into separate parts (1974).

Systems ideas in management, are quite relevant to Information System design. The notion of human organizations as a set of interrelated parts -integrated by the presence of objectives hierarchically related- provide the basic rationale to further methodological approaches.

Most of Information Systems design methodologies currently available demands from the designers an early recognition of the system's goals and purposes, both in relation to the total system and with respect to the inmediate part of concern.

In Data Processing, systems approach has made an important contribution, since it provided a method to reduce confussion and duplication of efforts that piecemal computarization of clerical work had created. Unfortunately the same approach helped to create the illusion of the Totally Integrated Information System that later was going to cause much frustration and scepticism among systems designer (Dearden 1972).

Next section contains a further discussion on the basic rationale underlying current approaches. This constitutes an analysis of the prevailing consensual system.

2.4.- Elements of the Basic Rationale for Information Systems Design. A Way of Looking at the Consensual System.

Last section was devoted to give a brief account of what can be considered prevalent ideas on managemnt. This section aims to ilustrate how these and others ideas combine themselves to provide the basic rationale to Information System design that is currently found in text books and current literature.

2.4.1.- Purposiveness and Profit Making.

For example the idea that organizations have purposes easily merges with the premise that companies are to maximize profits. This is neatily ilustrated by Kelly's book when defines as the final objective of an Information System that of improving profitability (Kelly 1970).

De Newfville and Stafford make it quite clear: "Systems Analysis, at its core consists of the application of classical microeconomics concepts to the problem of resource allocation. At its simplest, it could be a quantitative study of the possible ways to achieve certain goals or to use available resources, ... it generally involves the use of a number of analytical tools, such as: production functions to represent combinations of supplies, marginal analysis concepts and optimization techniques to determine preferable alternatives ..." (Newfille and Stafford 1971).

In general, systems design methodologies give much attention to cost-benefit justifications, which is of course a very reasonable approach. However, the above quotation does illustrate how ideas coming from different fields combine themselves to provide new versions of old theories.

Emphasis on cost-benefit analysis mirrors the prevalent cultural values rather than the preminence of a theoretical outlook. Manager scientists -consultants in particular- are compelled to sell their skill in a market where the main consideration is the monetary profit, in this context they must convince managers of the economic advantages that the implementation of their projects provides.

This consideration is important because it establishes how Management

Scientists' options are constrained to the few that are compatible with the criteria of profit maximization.

Management Science has developed its methods and techniques under no explicit theory about the nature of social systems and their dynamic, its advance as scientific discipline has been -probably more than any other single area of knowledge- constrained to the prevailing theories of economics and sociology. From its inception it has been closely linked to business studies to the extreme of being usually taken as a synonym.

2.4.2.- Purposiveness and Hierarchies.

Teleological connotation of Systems Theory within a scientificly minded academic community where analytical methods are regarded as the proper way of finding out the inner nature of phenomena, plus the idea of the possibility of an objective observer, provide the grounds to the formulation and acceptance of a structural-functionalist view of management.

This view sees management as a purposive process, and organizations as functionally arranged assemblies of parts engaged engaged in the achievement of mamanagement purposes. Although the approach does not rule out conflict nor it establishes that the objective can be easily translated into the mathematical language of an objective function, it suggests the presence of some absolute objective that can be found out through a process of enquiry. That objective is said to provide the basis for an internal arrangement of functions and hierarchies (Morasky 1977).

Hierarchy and hierarchical relations are most pervasive topics of discussion in Management and Organizational Theory. They are such ubiquitous features that their presences is many time times considered as natural phenomenon.

As Mesarovic et. al. put it "Existence of hierarchies in nature has been discussed by too many, too often, adding too little to what was already known: namely, that hierarchical arrangement does exist" (1970). In their view, hierarchies are recognised to be present at every level of description or abstraction, at the level of complexity of decision making or problem solving and at the level of organizational arrangement.

This natural presence of hierarchies is some times associated with some necessity of Nature, more explicitly to the necessity of establishing authority relations. As in Emery's views (1969), hierarchical organization is regarded as a synonym of authority, although he accepts that its presence may stem from deeper roots, namely from the necessity to reduce the apparent complexity of a system. In the last analysis however Emery sees authority and hierarchies as closely related phenomena. "... Since the success of any organizational unit meeting its assigned responsibilities depends on the composite performance of its sub-units, the higher level must have some authority to direct the behaviour of the lower level units. Typically, this authority vests in higher level managers the power to specify lower levels goals, to allocate resources and on occasions, to change its organisational structure".

Concepts like hierarchy, authority, delegation and unity of command has been raised to the category of principles in traditional management, although the ethical aspect on the right to manage and to set goals to other people are seldom discussed.

Emery's position somehow illustrates the extent up to which management scientists tend to regard the existence of a higher management level vested with the power of specifying lower levels' goals as a natural and unquestionable fact. Although he sees the way that power is used and authoritarianism as important aspect of management, he regards the issue as matter of style rather than a question of ethic.

A quite different approach to the origin of hierarachy in organisations is that of Jaques (1978), in his view there is no evidence to support the idea that various lines of stratification in the social and physical world naturally exist. Alternatively he suggests that the origin of hierarchies in organizations is due to human nature.

Taking human abilities -in terms of work capacity- as the key factor in the development of hierarchies, Jaques alleges that "... if all men were equal in work capacity, the bureaucratic hierarchy would be impossible in social systems. It would have never been discovered. Men would have worked together in leaderless groups or in partnerships, or in any other type of small face to face size associations, but a bureaucratic hierarchy never!!".

According to this view, functional explanation to hierarchic organizations is at best incomplete, since task differentiation -being a human creation- can not account for the explanation of the phenomenon. The pervasiveness of this organizational feature is entirely attributed to the idea that hierarchy is attuned to human nature; thus the regularity of hierarchical arrangements is said to correspond to an equivalent stratification of abilities in human populations.

Jaque's theory establishes a hierarchically stratified taxonomy on the basis of people's different work capacity; the defining element being that of ability to deal with abstract situations. Resorting to discontinuity theory he argues that it is possible to group human population into five discrete categories which are hierarchically stratified.

The levels of abstraction are in their turn defined by the time span of the task that the individuals perform in the organization, for example the lowest level of abstraction is featured by the roles with time span less than three months, for instance sales assistants, machine operators and typist. The highest and fifth level has a time span between five and ten years, namely the jobs of chief executives, head of services, managers of enterprises and army division officers.

The prevailing view in management considers hierarchy in organizations as a matter of fact. This is epitomized, for instance in Anthony's influential work on Planning and Control Systems (1965).

In this view, there are three basic types of activities related to the processes of planning and control. In the first place it is Strategic Planning involving the activities of policy formulation, goal setting and top management planning. These tasks being typical of the highest hierarchical level.

In the second place it is Management Control dealing with activities related to the ongoing administration of the organization. It is performed by the middle management.

A third level is that of Operational Control which deals with assuring that specific tasks are effectively carried out. It is said to be performed by individuals of the lowest level of the hierarchy.

This framework has proved to be most influential to Information Systems design; its main appeal seems to be its coherence and its clarity for anlysis of business organizations.

An underlying assumption in Anthony's approach is the consideration that organizations not only have objectives but also that these objectives are decided in the process of strategic planning by the top management. It assumes that organizations are to achieve goals that are set by the individuals that occupy the highest positions in the hierarchy.

Anthony claims no originality to this approach, he sees that Simon's distinction between programmable and not programmable decisions (Simon 1960, 1977) corresponds to his concepts of Mangement Control and Strategic Planning respectively. He also accepts that his distinction are in general equivalent to those commonly found in management text-books labeled policy formulation and policy execution.

Simon describes organizations as three layered cakes. At the bottom there is the process that procures row materials, manufactures the physical products and deliver them. In the middle layer there is the process that governs day-to-day operations of manufacturing and distribution, this is the level of programmed decisions where problems are repetitive enough to determine definite procedures to solve them in such a way that it unnecesary to treat them again and again every time that they occur.

The top of the layer deals with what Simon calls non programmable decision making, at this level problems are said to be non-repetitive, novel and un-structured. In response to this problematique, the organization can not developed standard policies and every problem is said to require insight and intelligence.

He predicted that automation of decision making would not change the three layered structure, and that at most it could result in a more explicit formal description of the entire system, making the relation among the layers clearer and more explicit.

The hierarchical arrangement is regarded by Simon as not being peculiar to to human organizations but as a characteristic shared with the biological world. To the question of pervasiveness of hierarchical arrangement in Nature, Simon suggests several possible answers.

A first reason is that natural selection favours hierarchic rather than non-hierarchic systems, because the components of a hierarchy are themselves stable systems; a second reason is that hierarchical systems require less information transmission among the parts, and finally because the complexity of a hierarchical system -as seen by an observer- becomes almost independent of its size.

Simon's view is that those arguments do not constitute a complete account of the problem, but he does think that reasons for hierarchies go far beyond the need for unity of command or other considerations related to authority.

Teleology and a hierarchical view of organizations complement each other and provide a foundation to the functionalist approach to Management.

The degree of freedom to set its own objectives given to each link of a hierarchical organization, determines the degree of centralization present in a particular structure.

The problem of centralization versus de centralization is a recurrent topic of discussion in management, it is highly sensitive because its close relation to the problem of power and politics, consequently to that of individual freedom.

On the other hand mangerial effectiveness is often associated with the issue of degree of centralization.

According to Mesarovic et. al., in a hierarchical structure several decision making units have sometimes different and conflicting objectives, but in the last resort the objective's unity must be kept. "It is in the very nature of the multilevel, multigoal system that higher level units conditions but do not completely control the goal seeking activities of lower level units ... it is essential for the effective usage of the multilevel structure that the decision units be given freedom of action."(1970).

This quotation is of interest because, although the authors do not discuss the issue, they perceive the need of balancing freedom of action and conditioning from above. The dichotomy centralization versus de centralization is certainly an important and sensitive issue in management.

Research carried out in the United States reveals that people at different levels of the hierarchical rank experience different degrees of motivation, involvement and interest in their jobs; their identification with organizationally established objectives appears very much as a function of their own position within the hierarchy (Tannembaum et. al. 1974).

This work suggests that hierarchical position is closely related to the way that political and economic power is distributed. If on the other hand hierarchy is regarded as natural fact it could be argued that social inequality is an inevitable fact. To this point the discussion gets a stage where is no longer possible to continue without reference to ethics.

This discussion on what is recognized as prevailing ideas in management has introduced what is considered the Consensual System under which Information Systems designs are carried out.

The basis of the consensual system of Information Systems design are in general provided by the prevailing ideas on management as expressed in text-books, syllabuses and current practice.

The most fundamental feature of the consensual system is its underlying economic rationality whose origins can be traced back to the beginings of management as subject of scientific enquiry.

The emphasis on teleology of early Systems Theory and the rationality of profit maximization provide a theoretical base and the initial criteria for Information Systems design and implementation.

Information Systems are created to support the activities of organiztaions that are hierarchically and functionally integrated by a systematic decomposition of the final objective.

The hierarchical outlook, on the other hand, provides the basis for a taxonomy of decisions which in turn defines the information requirements to support activities which are said to be typical of the different hierarchical levels.

The practice of Information Systems design as a body of knowledge appears as a specific aspect of management Working Science. The purpose of next chapter is to make explicit the ideas on design that define the actual practice and which are generated under the influence of the prevailing paradigm.

CHAPTER III

INFORMATION SYSTEMS DESIGN AS WORKING SCIENCE WITHIN THE CONSENSUAL SYSTEM OF MANAGEMENT

As the use of computers in business and public services grew, so did the necessity for a conceptual reference for the design and implementation of computer based information systems. Initially, the main concern was with the search for an understanding of the information flows within organizations and with developing a methodology to tackle these tasks.

3.1.- Theoretical Frameworks for Design

One of the early attempts to provide a rationale to the process of planning Information Systems developments was Blumenthal's (1969). He then saw the need for systematic planning to overcome the organizational problems being created by the then rapidly expanding use of computers in business institutions.

He observed that "islands of mechanization" were not fitting properly within the rest of the organization. His framework for development was meant to avoid the overlapping of important elements such as files and programs, to ensure uniform criteria for subsequent information systems developments in order to reduce costs of integration of related systems and to provided basis for coordinated development and easy adaptation to business change and growth.

In his own terms "... Information Systems planning is important enough to be formalized and not left to emerge namely from the interplay of interests that are narrower than those of the business as a whole, although this interplay will remain an important regulating mechanism".

This framework for planning consists of two major elements; one is a theoretical construction of the process of decision making derived from the synthesis of Forrester's feed-back loop conception of the decision process, Simon's distinction between programmable and non-programmable decisions, and Anthony's characterization of organizations as three hierarchical levels of managerial activities.

The second element consists of a set of criteria to make an orderly and coherent classification of the basic components of a business system.

The first element is used to define with which level of the management hierarchy is a particular information system to do. In this respect it is important to poin out that Blumenthal ruled out the possibility of designing information systems for the top level of the hierarchy on the grounds that is unknown how to encapsulate its necessary information "... in the kind of data bank we know to construct today." (Blumenthal 1969).

He argued that as strategic decisions are based in something else than historical records, it is not possible at that state of the art to design systems to support decisions of this kind. Management Control, however -that is to say Anthony's second level of hierarchy- finds its source of data in the Operational Control level.

Being the relationship between these two levels defined by one being the source of data of the other ; and the latter being the source of command of the former, he argues that both are the constituents of what he calls Management Control Systems, and states that is to this layer of the hierarchy to which information systems belong.

The layer itself is horizontaly composed of a number of Management Control units or modules each of which embodies a particular information subsystem, as described in figure 3.1.

In the figure, Management Information Systems appears providing the basic information to a Management Control Centre that deals with programmed decisions which are directly affected by the operations of functional units.

The dotted rectangle labeled Operational Control Information System is defined as the core of Management Information System in the sense that constitutes its operational functions.

The mentioned set of criteria is aimed to provide basis for identifying and classifying the component modules of an Information System, in this sense are considered elements to be identified and properly classified within a business operation.

An adequate taxonomy of modules is aimed to avoid overlapped

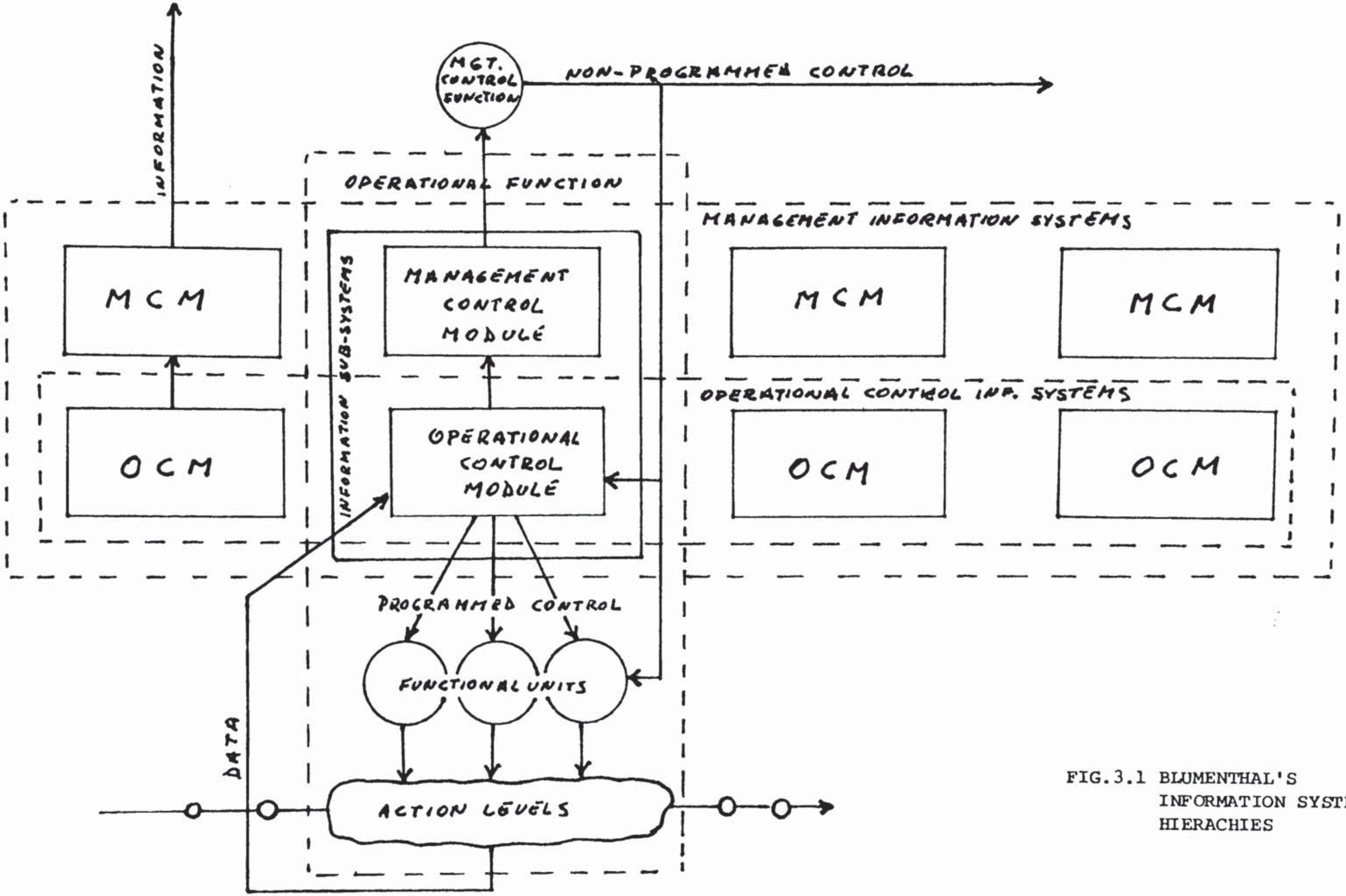


FIG.3.1 BLUMENTHAL'S INFORMATION SYSTEMS HIERACHIES

developments and subsequent redundant operations, and to define interfaces between sub-systems in a way that further integration is facilitated.

For the purposes of classifications, two primary criteria are offered. The first one relates the size of the module to economic considerations, for example if a module is too small to be economic then its development should be postponed or integrated with a major one; this decision should be made on empirical basis. A module, therefore should encompass an economicaly large number of actions.

The second criteria is that of module's robustness to organizational re-arrangements, that is to say modules should group those actions which are to be carried out independently of formal organizational structure.

The boundaries of the modules are defined in the last event by the data set itself, for instance working files, master files, directories and others.

The data sets in their turn provide the basis for the interface between the modules and the real world management needs. This interface is mainly provided by special purposes working files as in the case of a file of finished goods shipments derived, for instance from an order processing module.

A most fundamental base for modules' robustness is provided by the empirical fact that "... not all information process are equally strongly tied together in the company". (Blumenthal 1969).

According to the degree of relateness of operations Blumenthal arrives at a taxonomy that distinguishes two basic branches. One deals with the aspects of Physical Operations, whereas the second is to do with what he calls Administrative Operations.

Within the first group there are two sub-groups (fig. 3.2) one dealing with the logistic side of physical operations, that is raw materials, production process and saleable product; and the other dealing with fixed physical assests, i. e. facilities, equipment and capital projects.

The Administrative Operational group is in its turn divided into two sub-groups, the first is said to do with the financial side and the second dealing with problems of manpower.

There are at least two important facts worth noticing in this framework. One is that the term Management Information System is used to refer to the formalized aspects of management control, leaving out the strategic or non-programmable level of decisions.

A second point to notice is that it aims to be a holistic approximation, for in addition to hierarchical classification and to horizontal functional grouping of activities, it adds a third dimension in the form of modules that cross over the boundaries of organizational divisions. As Blumenthal puts it, the purpose is to provide a framework which is not derived from "... traditional pictures of a firm such as the organization chart, in order to rationalize the information network into its component systems". (1969).

The proposal can be regarded as systemic for the perspective is, in his own words "... to create an evolvable model of Information Network in the business".

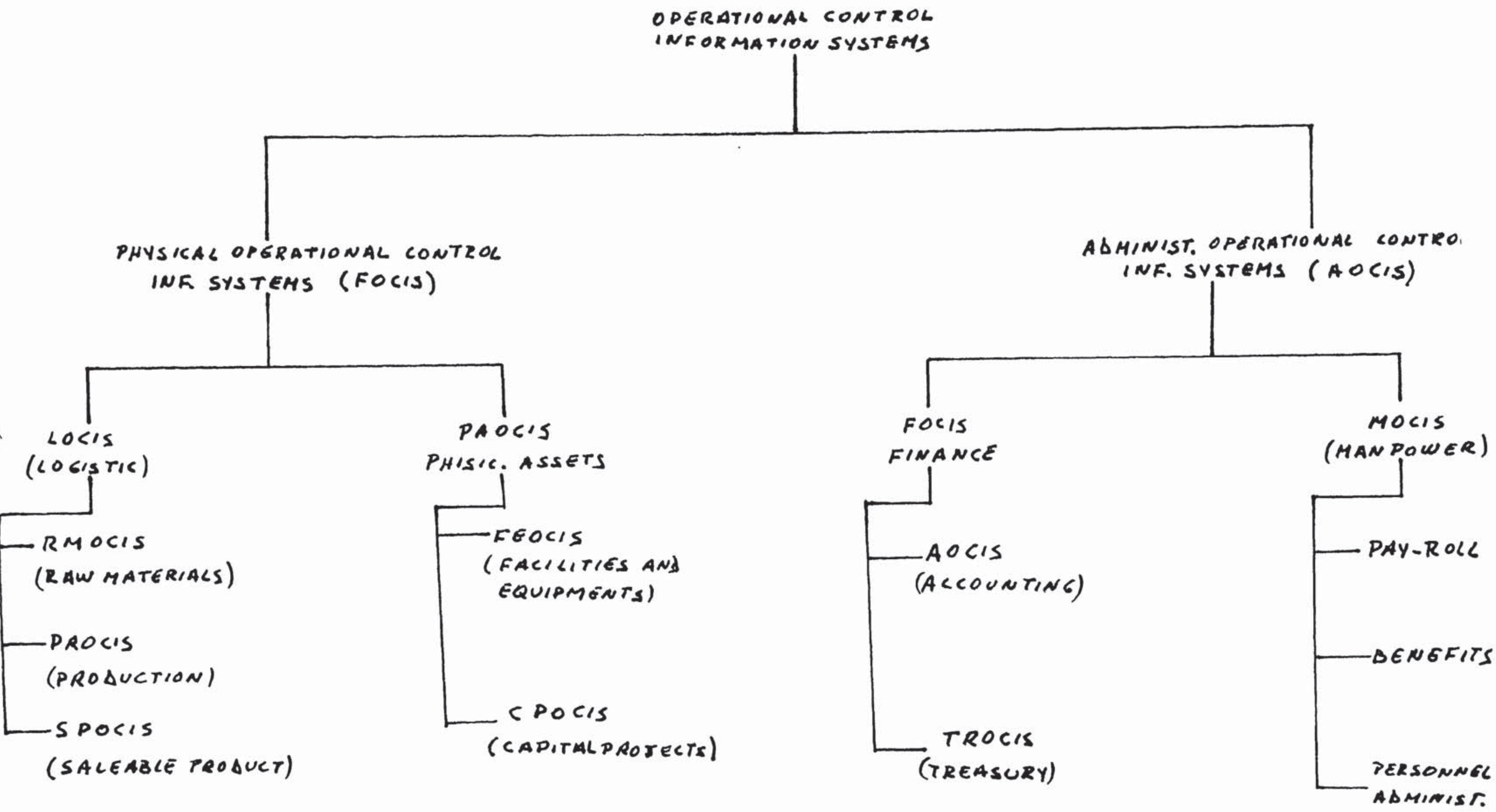


FIG.3.2 A TAXONOMY OF INFORMATION SYSTEMS

Blumenthal's work is an interesting and ilustrative example of synthesis between currently believed organizational and managerial theories and systems thinking. Into this evolvable model of informational networks comes together ideas from systems dynamics, decision theory, functionalist organizational theory and sytems theory.

The framework is conceived as a starting point for 'buttom up' development, it is expected that with this understanding the designer is able to work within a conceptual context and on clear basis to delimit the boundaries of the system to be designed.

By leaving out strategic decision making, the approach is constrained to internal informational flows without considering the problem of information for longer term decision making.

Following Blumenthal's work, many other interesting developments appeared, for instance that of Gorry and Scott-Morton (1971).

Although based on very similar conceptions, the authors introduce some new elements specialy in relation to the peculiarities of decision making at different levels of the hierarchy.

The authors' starting point is their concern for the fact that few implemented information systems have had a significant impact on the way as Management makes decisions; they argue that such a situation is the result of limiting the scope of the designs to the realm of structured decision systems.

To fit best Simon and Anthony's views this approach introduces an intermediate type of decisions called semi-strucured and combine them as in figure 3.3.

It is argued that current practice of information systems design had been based on the "total system" approach which had already proved to fail to represent the appropriate information requirements for Management Control and Strategic Planning, and that the efforts, so far had been mainly concerned with the upper part of the diagram; particularly with the Operational Control bit.

As a new analytical element they stress the need of using their framework to make more efficient allocation of resources in the area information system design. Figure 3.3 should help to identify those areas that present the best economical potentialities for further developments.

With this criteria in mind, the importance of decisions at different hierarchical levels should be ranked in order to define priorities for developments, since many important decisions are relatively unstructured. A case is made to give more attention to modelling the decision making process.

In this way, the authors explicitly expand the scope of Information System design to deal with problems that are less dependent on internal factors and the idea of model building is promoted. Gorry et. al. stress that the designer requires greater managerial skills to elicit from top management itself its views of the business and the environment.

A new and special role is given to managers, for they are expected to work together with the analyst to jointly develop a model. The authors

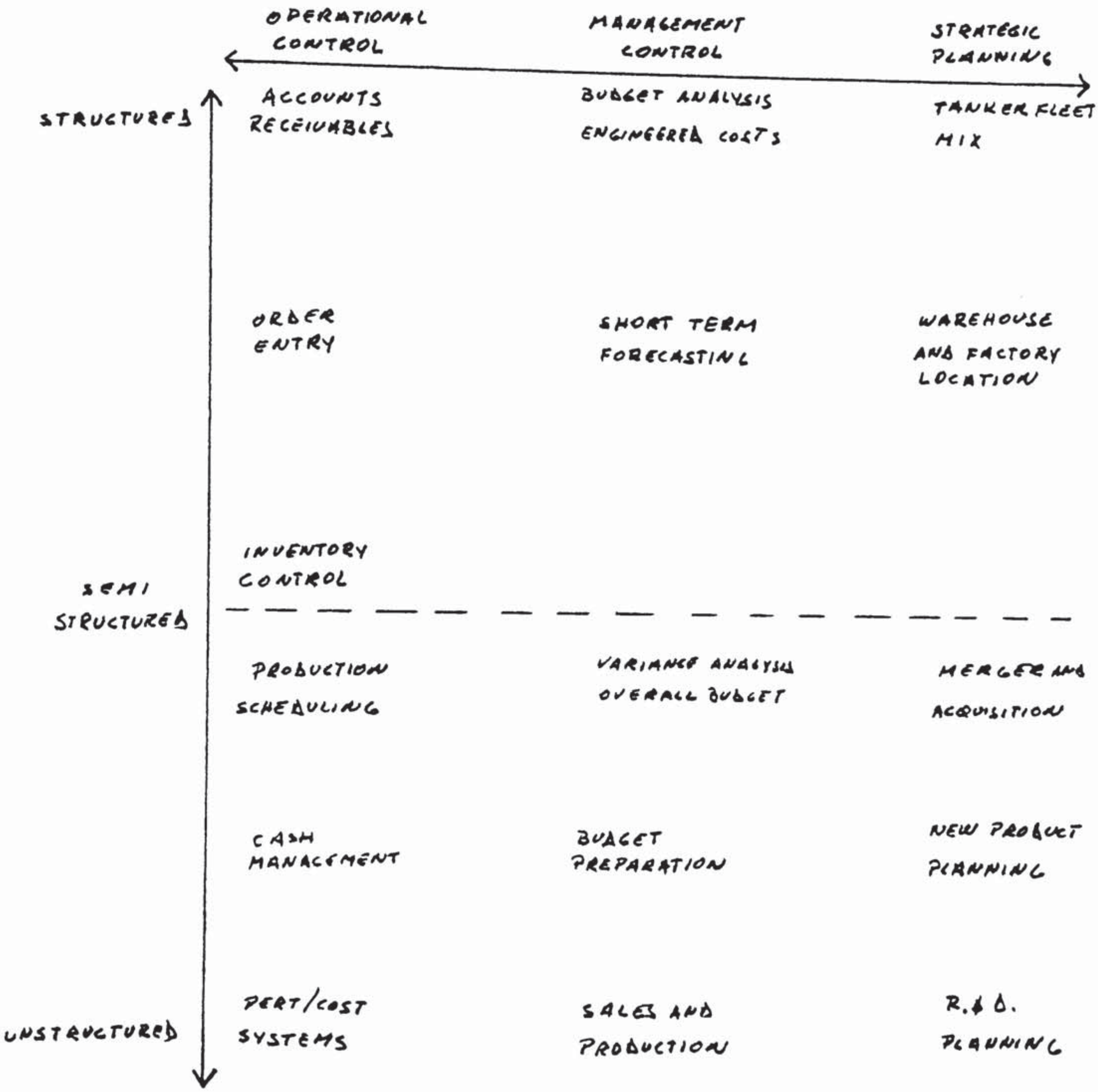


Fig.3.3 Organizational Hierarchy and Type of Decision

sustain that most of information systems developments had only dealt with the areas above the dotted line in figure 3.3, but as time was passing by and with the development of new technology and experience the line was evolving downwards.

Gorry et. al. emphasize that the nature of decision making at different levels of the hierarchy differs in some fundamental way and that Information Systems for strategic decision making was not necesarily going to require the use of data base.

Under the heading of "Blue print for M. I. S.", Zani puts forward a very similar platform for Information Systems design and development (1970).

On the same conceptual basis as Blumenthal, Zani argues that most of the currently implemented designs "... had spun off as by-products of the process of automating or improving existing systems within a company", and that it was necesary for effective design to make a rational planning of the process of implementation in a way that the organization is looked top-down instead of the "current" practice of looking at the company "buttom-up".

Zani's comments on the "top-down" approach and the recurrence of this type of argumentation in text books and current literature, illustrates the way as how within a particular paradigm, there may be many variations on the same theme that contribute very little to enhance knowledge about a particular topic or problem.

Zani's main purpose is to provide top management with a set of criteria to deal with the whole question of developing new management information sytems in a way that the tasks are tackled according to their informational value.

The framework, at its most global level is built up starting from the view that the strategy of an organization is the result of external forces and internal resources. Accordingly, the resulting strategy determines, in turn the organizational structure and the way as the strategy itself evolves via long and short term planning.

The idea is that every information system development is conditioned to strategic considerations, that manifest themselves in terms of an organizational structure. To deal with this structure, Zani adopts Anthony's framework and states that a decision analysis should be carried out for each level of the hierarchy in order to answer the following questions:

- "What decisions are made?"
- "What decisions need to be made?"
- "What factors are important in making these decisions?"
- "How and when should these decisions be made?"
- "What information is useful in making these decisions?"

The answer to these questions would define the information requirements for each level of management, while the overall objective defined by the global strategy is kept in mind. An important outcome of the decision analysis should be the specification of tasks and their interrelations in the context of the organizational structure and their effect on the "key success factors" such as opportunities, risks and competitors.

Zani emphasizes that the differences, unveiled by a decision analysis between the three levels of of organization must be carefully taken into account, since failing to understand them results in a poor understanding of the system which in ends up in a bad quality design.

This three frameworks dicussed so far show how the prevailing views on management determine a particular way of tackling organizational problems. This is more clearly ilustrated by the fact that each author uses Anthony-Simon's conceptions of organizations and management.

This approach to organizations is pervasive in current literature on Management Information Systems and widely found in text books and research programs for instance Mason and Mitroff (1973), Davis (1974), Prowse (1980).

For this reason it is reasonable to state that this type of theoretical approach constitutes a scientific development within management consensual system, in the sense of chapter I.

There is also a second pervasive element in Information Systems literature that complements the frameworks already discussed, this is that of methodologies for design and implementation. A discussion on this aspect follows in next section.

3.2.- Methodologies for Information Systems Design.

As it has already been mentioned, holism and teleology have come to Information Systems design providing basis for methodological developments.

In management information systems textbooks, methodologies usually appear in the form of check-lists that specify the task to be carried out step by step in a process of design and implementation. A most influential approach to design in this respect, has been the methods of Systems Engineering, for example Hall's (1962), Newfville and Stafford's (1971), and Optner (1975).

The impact of Systems engineering methodologies is mirrored for example in modalities some times called sequential or linear approach to design. See for example Davis (1974) and Burch and Strater (1974).

The majority of these approaches establish as the starting point the determination of systems objectives and the identification of user's specific information requirements. Current literature is continuosly producing variations on more or less the same conceptual basis.

In a thorough article on systems productivity Brewer (1979) distinguishes five major method for design. In 1975 Roscoe et.al. developed a method based on gaming, whereas Bally et. al. having identified three main approaches produced a fourth one (1977), some of these methodologies are described in this chapter.

According to Britten (1980) the linear methodology is based on the assumption that in project development one activity logically follows from its predecessor so that each stage is completed before the begining of the next. It is said to define the following stages of development:

1.- Project Proposal Stage.
2.- Preliminary Study Stage.
3.- Full Study Stage.
4.- System Specification Stage.

5.- System Construction Stage.

6.- Implementation Impact Stage.

7.- Final Implementation Stage.

8.- Project Closure Stage.

Britten sustains that the main short coming of this approach is that more often than not, the project's initial requirements are vague or fail to meet the real need in a way that the assumption of each step following the completion of the previous step is impracticable.

The practical result of applying this approach is the iteration of each step as many times as is necesary till the design fullfills actual necesities. This iterative method is some times called "loopy linear" Bally et. al. (1977).

Bally et. al., as an alternative to these methods develop what they call "The Prototype Approach". The idea is that "... an initial and usually highly simplified prototype version of the system is designed, implemented, tested and brought into operation. Based on the experience gained in the operation of the first prototype, a revised requirement is established, and a second prototype design and implemented. The cycle is repeated as often as necesary to achieve a satisfactory operational system, bearing in mind the possibly escalating costs of each subsequent cycle; it may well be that only one prototype is necesary before producing the final system." (1977).

A more comprehensive approach has been developed by Ross and Schaman (1976) under the label of S.A.D.T. -Structured Analysis and Design Technique-. The method includes three elements: a) A graphical language for the description of the system, b) A method for developing the graphics. and c) Management rules for controlling the development of the model.

The idea is that the analyst enhances his understanding of the system by developing these representations.

It is based on the functional decomposition of the system following "top down" criterion, building graphic representations of each component. These representations -built by the analyst- are presented to an expert on the system in question, who must write his comments on the fidelity of the diagrams. The analyst in turn must reply to the expert in writing, in a way that each diagram is cross-checked with the views that people in the system have.

The diagraming of the system follows specific rules. It is emphasized that these diagrams should not be confussed with flowcharts for in the former boxes represent data class and arrows activities that generate or use the data.

This methodology accounts for two types of diagrams, one type -Activity Diagrams- describes the systems operations, whereas the second type -Data Diagrams- describes the data processsing activities which are necesary to support the activities as the defined by the Activity Diagrams

Developing Activity and Data models follows specific project management rules, for example it establishes that the most general level of activities three to six boxes must be used for the global description of the system. It is suggested that this stage may take several man-month to be completed.

The following step is a further decomposition of each of the boxes into three to six boxes again, and so forth until the whole system has been fully described.

After the Activity Model has been completed, the Data Model is built. This includes the list of data requirement pertinent to the activities, for example it defines files and reports that are necesary to support the activities.

It is argued that this methodology is not purely descriptive and that true structured analysis is not about drawing diagrams but drawing diagrams to support organizational analysis. According to "E.D.P. Analyzer" (1979), "The decomposition may involve the analyst in questions of organizational changes, re-assignment of responsibilities, possibly enlarging the scope of the system beyond what was originally thought, and so on."

Another approach reported in literature E.D.P. Analyzer (1979), is that of Information Analysis (I.A.) developed at the University of Stockholm. it establishes five stages:

1.- Change Analysis.
2.- Activity Studies.
3.- Information Analysis.
4.- Data System Design.
5.- Equipment Adoption.

At the first stage, underlying managerial and organizational problems should be identified, the idea is that when a new Information System is being considered, that part of the organization concerned with it should be looked at as a source of problems whose solution requires a design. At this stage then, analysis may reveal that some changes are needed in the operational system that handles physical materials as well as the information.

In this way, the information system design may turn out to be for an enterily new operational system that is modified as a consequence of the Change Analysis.

In the Activity Study stage the process of analysis of the first stage is continued in greater detail. It involves the use of boxes that "bound" the system description to a well defined set of activities, this set must be made up of three to six activities, each set configurates a function.

The Information Analysis stage follows similar rules to the second one, but only information processing aspects are considered. This analysis results in the identification of the information that must be available in order to perform the physical activities.

A further decomposition of the Information Analysis outcome defines in detail the data processing requirements and operations.

The novelty of this approach consists of the fact that considers the system as problem area whose performance may be improved by the actual modification of the process and/or by an adequate information system design. It delays the detailed design, but provides firmer basis for ulterior development.

It is difficult to establish how many methodologies have been made available in current literature, and probably impossible to know what has been their impact in practice. The proliferation of methodological approaches can be interpreted as a responding to a continuous dissatisfaction with the quality of the implemented systems. For the purposes of this discussion only three other methodologies are to be discussed.

Roscoe and Taylor (1975) developed an approach based on gaming, arguing that the lack of people involvement and poor planning are the key causes for implementations failures, they put forward the idea that using simulation game during the development of the system it is possible to ensure and promote users participation and interaction.

As starting point, they identify four main phases through which the systems design progresses from initial conception to actual operation. These phases are:

1.- Conceptual Phase

2.- Definition Phase

3.- Development Phase

4.- Operational Phase.

The first one involves the definition of the problem and consideration of alternative solutions, their evaluation in terms of costs and time; and the selection of the most appealing one.

The Definition stage involves a detailed planing of activities and the general specification of the system. The following stage these plans and specifications are transformed into computer programs, files and systems procedures; including users training.

Finally in the Operational phase the system is put into operation, this includes further testing and a trial period.

The author stresses that enhancing the probability of success requires to identify and resolve problems at an early stage, they say that there are two problems that often occur during the conceptualization phase; first the manager often has a preconceived idea of a problem area and how the problem should be solved, and second the analyst is often biased to a particular type of solution or techniques.

The idea is to employ a game during the conceptualization phase to minimize these problems, and on the other hand to get people actually involved in the problem of system definition. To conduct the game based system design Roscoe et. al. propose the methodology described in figure 3.4.

The initial step in this framework is the identification of the systems objectives in terms of sought results, such as increased productivity, reduce inventories and in general improve performance. This step is carried out in parallel by abstract game development and the definition of the current system.

The Abstract Game Development embodies an idealized system solution which is used as a reference for the users to gain an understanding of the problem area from different points of view. This solution is then confronted with the Current System Operation for a comparative analysis; the users -in a game environment- are then expected to gain greater understanding of the overall aspects of the system by focussing attention on the differences between the ideal solution and actual current situation.

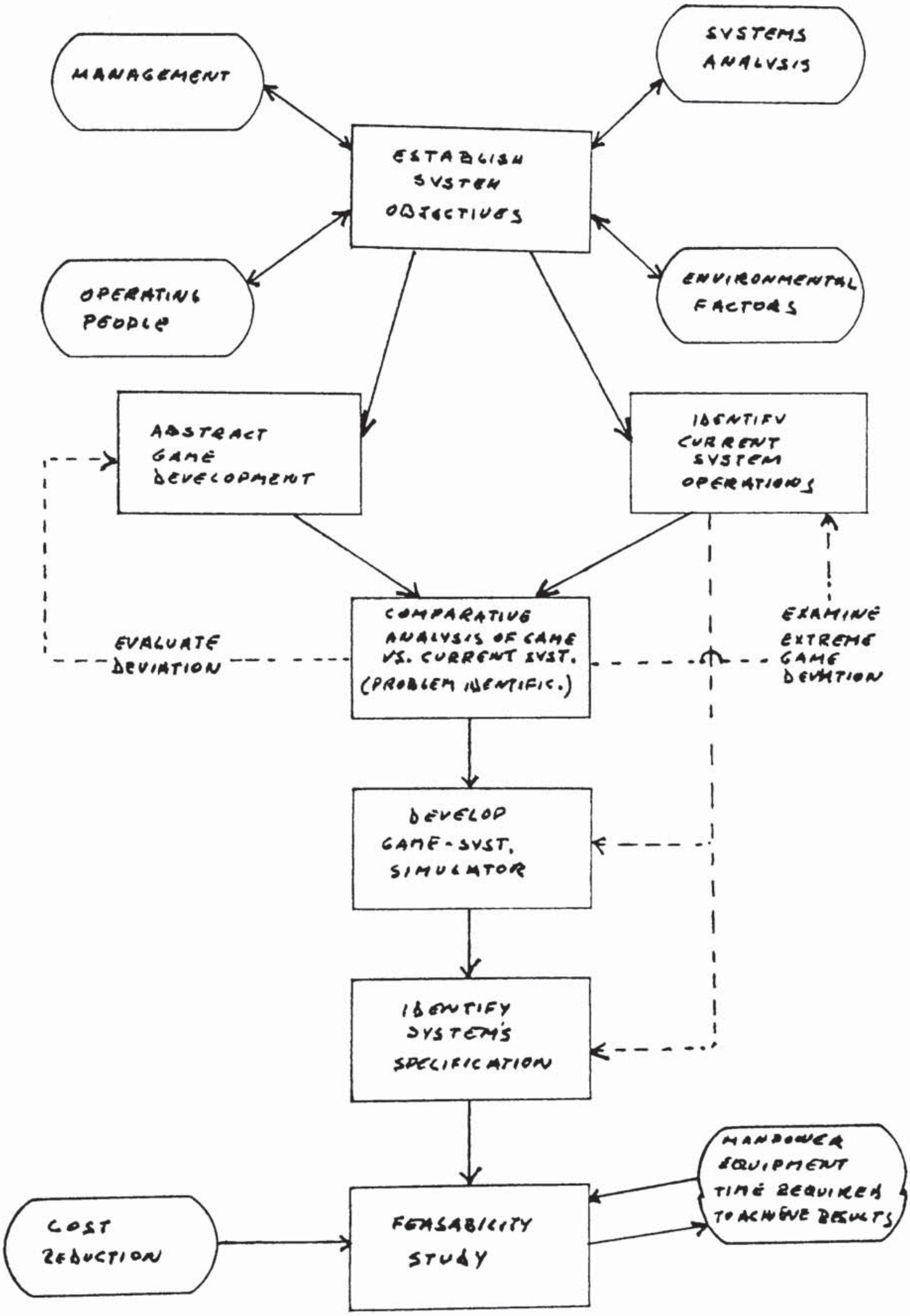


Fig.3.4 Game Approach to Systems Design

Users are provided with questionaires and are stimulated to write their views on the problem.

Only once the users have gained a global understanding the rest of activities proceed. The activities are aimed to simulate the problem area in conjunction with the solution approach. As the game proceeds, much of the activity of the definition phase takes place, for instance the identification of particular elements like data and users requirements.

The simulation process itself provides the means for the System Specification. The specification arises as a necessary activity that must take place in order to pass from the simulated system to the operational one.

The authors state that the system as specified by the game process will be a feasible one, but that economic feasibility should alway be carried out before implementation.

Professor Checkland's methodology for problem solving is reported as being used for Information System design (Brewer 1979). The most important stage of this method is that of "Root Definition" because it emphasizes that participants in a problem situation entertain different world views and that those differences must be recognized and considered when the improvement of a complex organizational system is sought.

In relation to Information System design, this approach can be particularly useful to gain an initial understanding of the system as perceived by the users, hence improving the possibility of developing a good communication with and among them. This should facilitate the process of achieving a design that satisfies conflicting expectations.

Tate has developed a methodology for problem solving on similar basis, he argues that a crucial moment in the solution of an organizational problem is the identification of the "Client Set". That is the list of individuals affected or having to do with the problem area. The next step is to list each of the clients objectives and find out -through analysis- how they conflict and define constrains to the possible solutions. (Tate 1977).

This proposition, although simple, proves to be very useful for without major complications provides the analyst with clear basis to proceed the investigation.

This brief review of methodologies suggests that the proliferation of approaches is somehow due to designers' uncertainty respect to the effectiveness of final designs and that, on the other hand little real improvement is being made. According to Brewer (1979) "Most of new methodologies are based on the traditional stage approach to system development". Variations correspond to change of emphasis rather than to actual change of outlook.

For instance, Checkland and Tate's methodologies emphasize the natural difference of perception that is encountered among individuals that play different roles in an organization. The gaming approach stresses the necessity of taking account of user's involvement, but in every other respect establishes the same steps as the stage by stage approach.

The Prototype approach in turn, emphasizes the way as iterations in step by step method should take place. It really suggests that a global conception of the system should be borne in mind at every step of the project.

S.A.D.T. stresses the necessity of understanding the way that organizations actulally work, whereas the Information Analysis outlook, emphasizes the presence of organizational problems.

There can be little doubt that, that it is still possible to work out many other "approaches" to design, but it is doubtful that an ideal one is to be found.

3.3.- The Use of Corporate Models.

An alternative approach to the problem of Information System for Corporate Management has been developing Corporate Planning Models to support strategic decision making. Higgins (1976) maintains that the use of corporate models to support planning activities is the result of applying the concept of Information Systems to corporate management.

The use and effectiveness of this approach have been investigated by various authors.

Since 1969 a number of surveys and researches have been carried out in order to answer questions like, how prevalent are corporate planning models?, which are their main applications and how much are they utilized? (Ramirez 1977). In 1969 Gershefki conducted a survey on a sample of 323 companies that answered a questionaire; 62 of them reported to be already using models while another 39 indicated the intention of developing models by the following year.

By 1973 Grinyer and Woller found that 9% of the largest companies in the U.K. already had or were developing corporate models in a variety of industries, another 12% said that modelling -other than corporate- were taking place in the organization.

In september 1974 Naylor and Schouland conducted a survey on 1,881 companies based on the U.S.A. and Europe, which were thought to be using corporate planning models. Out of them 73% was either using or developing a model while another 15% was planning to do the same.

The authors compare the results of their survey with those obtained by Gershefki in 1969 to conclude that corporate modelling was a growing activity. In rigour, however it is not possible to draw conclusions from the comparison of these figures, since bias in in the samples and the limitations that the use questionaires implies do not allow acceptance of the surveys' results without questioning.

There are, however some factors that may be interpreted as sign of an icreasing use of Corporate Models, the most important perhaps the falling costs of computer resources.

These studies have revealed that corporate models are more frequently used to provide financial projections and to facilitate the long term financial planning. This view is illustrated by the type of reports that the models usually produce. Grinyer and Woller's work shows that profit and loss reports are the output of 98% of corporate models in use, 79% produces Balance Sheets, 68% financial ratio analysis, whereas only a 34% reports marketing operations and 9% manpower plans.

Grinyer et.al. concluded that in the U.K. Corporate Models tended to be mathematicaly simple and using accounting routines. In a detailed study by Grinyer and Batt (1975) it was found that the companies in question had deterministic, case study simulation models mapping accounting relatioships.

The use of this models in management is said to have a number of advantages and limitations (Grinyer and Woller 1975), for instance:

Models provide rapid answers at relatively low cost. Once the model has been developed it allows experimentation with a variety of forecastings, without extra expenses in manpower.

Models are comprehensive and cosider the effect of interrelated accounts. Thus if one factor is changed it is possible to study the effect on the entire company.

Models help to define management's need for information and provide communication links in the organization

Models enable the assessment of long term impact of short term decisions.

Models only deals with quantitative aspects, leaving out an important dimension of strategic decision making.

Models do only what they have been designed to do. Thus a model representing accounting procedures casts no light on sales behaviour after a change in price conditions for example.

Models' outputs are highly sensitive to changes in fed in by users. Thus errors in data may lead to serious errors in the results produced by the model.

Models cannot create alternatives, they only help to evaluate them. Thus ultimate quality of strategies still depend on the managers abilities.

They leave out the political aspects of strategic decision making.

Comparing limitations against advantages of the use of Corporate Models, Naylor (1976) considers that on the whole the benefits fully justify their implementation and use. An study by Hall (1977), however states that managers were not finding them useful.

Hayes and Nolan (1974) report that among the models implemented between 1959 and 1969 it was difficult if not impossible to find experiences that were not "disasters", although they observed that the situation was improving steadily as a result of a change of approach in development form top-down and bottom-up to inside -out.

A discussion on the reasons for the failure of Corporate Models to make a significant impact in actual decision making is contained in next Chapter. For the moment it is convenient to point out that the majority of development has been made under the assumptions of the prevailing paradigm. Naylor and Mansfied for instance (1977) puts forward a conceptual framework based on a number of assumptions about a "typical Company", it can be showed that this approach is quite functional to the prevailing theories about management and organizations; similarly Precious and Wood (1975) provide an illustration in a case study that reports several years of experience producing a model for a Company.

Among the many reported uses of corporate models, special mention deserves those works based on Systems Dynamics, for instance Coyle's (1978) and the recently reported by Allenstein and Probert (1980). Beer's work on an Information System for an Economic System keeps a special relation to this Thesis which will become apparent in part III.

CHAPTER IV

DISSATISFACTION WITH MANAGEMENT INFORMATION SYSTEMS AS SYMPTOMS OF INSTABILITY IN THE CONSENSUAL SYSTEM.

The last two Chapters have been devoted to discuss the basic elements of the framework for analysis described in figure 1.5 -Consensual System and Working Science-. The hypothesis that management knowledge is tested in the social practice of administration is the subject of discussion in this chapter, with particular emphasis on what is regarded as the expression of destabilizing social effects.

The argument can be summarized in the idea that Working Science -as reported in text-books, syllabuses, and professional bodies prescriptions- is put to test in the practical solution of current problems. The effect of this confrontation has a twofold character.

On the one hand, social practice tends to retain those theoretical contributions that are functional to the prevailing standards of efficiency and effectiveness socially accepted within the conventional wisdom. This type of knowledge remains socially valid and has the effect of reinforcing the prevailing consensual system.

What is disfunctional -on the other hand- tends to disapear as useless knowledge, resembling failures in a process of adaptation by trial and error. Errors, however may sometimes end up opening possibilities to the solution of related problems; several illustrations are found in Kuhn's work (1970) for instance his discussion on the fluid theory of electricity and summarized in his quotation of Bacon's dictum on methodology: "Truth emrges more readily from error than from confusion".

The area of Information Systems also provides examples, consider for instance the notions of Data Base and that of fully Integrated System as discussed by Dearden (1972). Developments on the basis of those concepts although not successful in terms of practical results, have contributed to a better understanding of the problems of Information Systems design.

It happens however that some type of disfunctional social knowledge cannot be rejected on the pure basis of efficiency and effectiveness according to the prevailing standards. This type of knowledge questions the standards themselves and demands a reconsideration of the problems from an alternative point of view, it also tends to remain, but in conflict with the Consensual System. For instance marxist economic theory and in management the ecologically oriented views of Beer.

Disfunctional knowledge to be able to remain has to be supported by some evidence of dissatisfaction with current paradigms that can be understood by the community, including the supporters of the prevailing paradigm. This is what in figure 1.5 is labeled de-stabilizing social effects, they express themselves in the form of recognized complaints about the ability of current state of knowledge to achieve an acceptable degree of effectiveness in the solution of practical problems.

Next sections contain a discussion on these complaints as perceived by some members of the Management Science community, which in the last event justify the effort of approaching the problem from a different epistemological base. It will be noticed that some authors explicitly suggest that it is necesary to work in this direction starting from different presuppositions about the nature of organizations and individuals.

4.1.- Critics to the Asumptions Currently Used in Systems Design.

One of the earliest criticisms to the conventional understanding of the concept of Management Information System was written by Ackoff in an already classic paper in 1967. In his review of the state of knowledge, he centres the critique on what he calls fallacious assumptions in relation to managers' behaviour and requirements.

Ackoff argues that ideas like that the managers need more information to improve the quality of decision making was conflicting with his belief that managers rather than suffer from lack of information suffered fro over-abundance of irrelevant data. Therefore more than additional information he concluded that what managers need is elimination of irrelevant data by the means of filtration and condensation of reports; being these two ideas hardly ever considered in current specialized literature.

A second fallacy -he argues- was the assumption that to know what information managers need the analyst had only to ask them.

The problem in this case is caused by the belief that managers know what information they need and want. Resorting to a simple principle of scientific economy Ackoff claims that the more an individual understand a phenomenon the more information he feels he need, this tend to provoke a sort of schismogenetic situation demanding for an ever increasing amount of information.

The problem probably arises because no proper definition of information needs is posible without an explanatory model of the dynamics of the decision making process. In part III it is argued that management as every other efficient regulatory process requires a model of the system to be regulated.

A third fallacy identified by Ackoff, is the assumption that once the manager has the needed information he will automaticaly make the right decisions. The assumption is questioned on the grounds that Operational Research practice shows that many good results obtained by rigourous modellation are counter-intuitive to managers' judgement and that in addition to having the right information managers should learn about the dynamics of the process that they are supposed to administrate.

This observation again points out the necessity of explanatory models for an adequate understanding of them by the managers.

In the fourth place, Ackoff says that the common-place belief that more communication results in a better performance is not only false, but that greater communication between different units tend to make inter-departmental coordination more difficult. This observation, possibly counter-intuitive to many designers can be rigorously demonstrated on the principles of cybernetics. Ashby has showed that too rich interaction among the component parts of an organization make the adaptation process more difficult and altogether impossible (Ashby 1976). This is explicitly discussed in Part IV.

Finally it is argued that the assumption of managers not having to understand how Information Systems work to be able to use them, it also plays against an adequate use of their outputs. The fact that designers try to produce systems that can be easily used without managers having to understand them ends up leaving managers ignorant about the way the system works.

The end result is mangers unable to evaluate Information Systems performance and being too embarrased to publicly show their ignorance on the matter. Ackoff adds that managers tend to leave too much of the design process to Analysts whom lack managerial skills and understanding of their problems; one of the consequences of this delegation has been the aquisition of expensive systems that operate many times less efficiently than the old ones.

To overcome the difficulties created by the false assumptions, Ackoff suggests a procedure for design based on decision analysis and establishes as an important pre-requisite for proper design managers direct participation in the process.

Ackoff's criticism is important because points out directly to systems designers' assumptions and questions believes that are usually taken as truthful. He, however does little to cast light on an alternative approach nor make a major contribution to define a line of research in the area.

The observation that managers and specialists should work together during the design process when acted upon by theoreticians and practicioners has not resulted in a major break-through in Information Systems design (Argyris 1977).

4.2.- Critics to the Assumption of Rationality in Human and Organizational Behaviour.

Since the early 1970's a great deal of attention has been given to the problem human factors in systems design. The concern has ranged from the concrete aspects of ergonomics to the less specific ones of human capacities as information processors and individuals attitudes towards organizational change.

4.2.1.- Rational Behaviour versus Emotionality.

An iteresting contribution to the discussion on human factors in systems design comes from Argyris (1971). Confessing little knowledge on the technicalities of information technology, Professor Argyris questions the value of Information Systems on the grounds that their conception rests on the assumption that individuals and organizations behave rationally.

Argyris' view is that the problem of failures to implement effective Information Systems stems from the re-newed call for rationality embedded in the methods for design and the emotional resistance that rationality generates in individuals. He states that "New developments for rational decision making often produce intense resentment in men who ordinarily view themselves as realistic, flexible, definitively emotional".

With respect to Information Systems, he sees valid basis for people to resist changes or at least to be skeptic about the willingness of people to accept their introduction. The main reason for this feeling is provided by managers' fears about every important necessary change of their styles, thoughts and behaviours.

Argyris contends that understanding this problem requires thinking about the nature of human organizations and about the ways as man introduces and internalizes new forms of work. Within this aspect of the problematique he places the whole problem of effective Management Information systems design.

It is sustained that managerial culture rests on pyramidal organizational structure, where authority resides at the top and where every operation is meant to be carried out under the terms of rationality.

This prevailing outlook makes people in the lower positions dependent and submissive to their superiors, this in turn tends to develop disfunctional behaviour in the form of apathy, indifference and absentism.

At the top level the effects of this outlook is said to show in a different manner: "At the upper levels the formal design tends to requires executives who need to manage and intended rational world, to direct, control, reward and penalize others and supress their own and others emotionality" (Argyris 1971).

Executives in this organizational ambient, tend to be ineffective in creating and mantaining good interpersonal relationships, their supression of emotionality makes them fear it in a way that makes them incapable of obtaining from employe s genuine commitment to organizational goals.

The result of increasing rationality -Argyris maintains- is to have executives that have "more conformity, mistrust, antagonism, defensiveness and closeness than individuality, trust, concern and openess". As informal procedures are replaced by formalized rational decision making techniques or machines, information becomes increasingly under control of higher management while the lower level feel their freedom becomes increasily reduced resulting in psychological withdrawal.

Other possible implication of increasing rationality in organizations is the creation of an unattractive world for decision makers where goals and the actions to achieve them are externally specified, delimiting in this way their level of aspirations. Such a situation -it is argued- can only lead to feelings of failures and dissatisfaction.

Argyri's observations on the possible effects on people are of the utmost importance. In his work -it is worth noticing- the main preocupation is not with the necessity of implementing effective information systems, but with the effects on human nature of forcing more and more rationality in organizations. He argues that managers are likely to get into a double bind situation, for as they follow the new rationality they will succeed as managers and fail as human beings: "He is damned if he refuses to obey, and he is damned if he does obey" (Argyris 1971).

The conclusion is that the organizational dilemma created by introducing Management Information Systems cannot be overcome by treating them as purely technological problems; in his view the crucial problem of disfunctional behaviour in organizations is the presence of over-defensive attitudes which are unveiled by the introduction of an increasing rationality to managerial activities. No solution can be achieved without considering the fact that "Emotional problems within organizations do not simply disappear when they are not faced; instead they remain to obstruct continually the implementation of rational plans" (1971).

This contribution is important from many point of views, particularly perhaps because besides identifying a set of possible dilemmas created by increasing rationality, he shows that the problem of resistance -open or concealed- cannot be tackle as a technical difficulty of Information System design. The main problem, in the end are the emotional reactions triggered by the feelings of constrained freedom within organizations.

4.2.2.- Dysfunctional Behaviour and Systems Design.

This problem of resistance to implementation and disfunctional behaviour in organizations has also been discussed by Dickson and Simmons (1970). They justify their studies on the grounds of the evident failure of computer systems to increase economic returns and the contention that the underlying reason for failure is essentially behavioural.

Examining the effects of Information Systems in various levels of the organization, the authors suggest means to minimize dysfunctional behaviour to implementation. They hypothesize that resistance to organizational change is a natural human attitude, but that it is possible to overcome it by finding adequate methods to introduce changes.

Under this hypothesis it is possible to arrive to recomendations about the way as new systems should be introduced.

Dickson et. al. distinguish three types of dysfunctional behaviour -Agressive, Projective and Avoiding- and establish that each of them is more or less typical to different groups within the organization.

Agressive behaviour aims to damage the object that brings innovation, this being typical of Operating personnel whose jobs are more directly threatened by elimination or change of processes.

Projective disfunctionality is expressed in the form of blaming the new system for problems originated in entirely different causes. This type of reaction is said to be typical of Managers whose job content is modified by newly introduced methods.

Avoidance, as defensive attitude is characterized by indifference and withdrawal, this is said to be typical of top level management.

The authors consider that the first requisite to minimize dysfunctional behaviour is to be aware that resistance is likely to occur. They say that there is not a single solution to this problem and that each situation should be evaluated in particular. However they prescribe some general rules to reduce the possibility of resistance.

For instance, as Systems Analysts visualize significant problems of resistance they should attempt to create a favourable atmosphere to the project. In behavioural terms, they should precondition the organization to a positive attitude towards change.

Preconditioning demands in the first place effective participation of those who will be affected by the new system; particularly from managers whom should take part through the whole process of design and implementation, making sure that people are able to see attainable goals throughout the whole exercise.

As a second requirement they establish that nature and details of the system should be as clear as possible to eveyone who is going to be affected by the changes. For this purpose it is important to minimize initial systems errors, since frequent mistakes creates conditions to undermine further acceptançe.

In summary, Dickson and Simmons state that dysfunctional behaviour always takes place and that it can be minimized by ensuring greater involvement from managers and everybody who is affected by changes. The final message for the system designer is that in his work he should consider behavioural elements as much as computer technology.

4.3.- Feelings of Failure Due to Over-expectations Created by the Computer Industry.

Feelings of disatisfaction reported in current literature have a variety of origins. Expectations generated by the Computer Industry marketing activities and the myth generated around computers deserve some consideration.

Computer industry has proved to be one of the most dynamic sectors in the world economy during the past 25 years. Its growth, no doubt is the result of large demand for its products mainly due to the increasing introduction of computers to business and public organizations.

A superficial consideration of these facts may lead to the conclusion that such a receptivity of computer technology demonstrates the successful contribution of computers to management and decision making. A careful consideration, however is likely to show that such a conclusion is not accurate in various senses.

There is little doubt that computer applications to massive data processing activities and to automation of clerical work -according to conventional management standards- has been highly successful.

When considering their contribution to decision making at a corporate level, however successful applications are notoriously scarce, and many of them are actually reported as outright disasters (Hayes and Nolan 1974). Despite of this, the aquisition of computers and their related technology has been kept at a high rate.

Rothery (1971) suggests that marketing efforts of computer manufacturers have created a myth around the computers capabilities and that such a myth has been believed by managers, the myth is reported as having created over-expectations about their contributions.

These over-expectations have come as the result of very effective publicity campaings developed by the computer industry. The main effect of this is said to be the association of ideas like efficiency, increased savings, leadership in management, and advantages over competitors; to concepts like M.I.S. , Corporate Modelling, E.D.P., Real Time Systems and the like.

Rothery states that those marketing efforts have been accompanied by the development of a most remarkable network of publications, conferences, courses on Information Systems for managers and plain commercial propaganda.

The mythology this way created around computer industry greatly contributed to overstate the case of Information Systems technology. It developed false images about efficiency and improvement and on the way that managerial practice was going to be affected.

Rothery contends that all this mythology contributed to generate feelings of failures in Systems people whose effect was to change their innovative style into an over-defensive attitude about their work and to produce self-actualizing practices that contributes to increase their isolation from current management practice. "The first judgement of computer people is their adulation of computer technology to the point of ignoring the real need for information systems design" (1971).

4.4.- Dissatisfaction with Corporate Models Performance

Dissatisfaction with Information Systems performance is also found in literature dealing with Corporate Planning Models. This situation like the others so far discussed can also be interpreted as an additional symptom of instabilty of the prevailing paradigm.

Hall (1973) considers that Corporate Models are actually of very little use to decision making. The main reason he sees is the lack of involvement of senior managers in the process of model building. This is said to be due to model builders little effort to involve and educate top managers about the use of models in the planning process.

A second reson he sees is the over-simplified character of models and lack of relevant data to run adequate simulations. He also strongly questions the assumption of managers' rational behaviour arguing that being decision makers irrational people they will never use a planning model which is based on principles that are logical and rational.

Besides all that, Hall contends that the real problem of building models to support strategic decision making is subtle, and on the whole rests on the following main causes:

> i.- The theoretical basis -promoted in academic circles- on which the planning process has been constructed are wrong.
>
> Discussing Emery's conception of the planning process (Emery 1969), it is argued that such a framework does not correspond to the way as strategic decisions are actually realized in practice, where the planning process is bottom-up with projects being pushed up through the organization.
>
> Top mangers' role is considered as one of approving or rejecting projects, rather than selecting among a set of well quantified alternative courses of action. This sole reason accounts for his belief that managers will never use real time decision models.
>
> ii.- The planning process, he argues is heavily biased by the personal commitment of individuals and groups to a single choice. This fact lessens the relevance of every other systematic consideration of the rest of the alternatives.
>
> Commitment, however is somewhat balanced by the fact that managers are evaluated on the results of their decisions rather

than on the quality of their decision analysis. In this context it is likely that a model will be used to elude responsibility instead of as analytical tool to improve decisions.

Besides these causes, Hall states that the function of model building within the managerial process is poorly understood and at best incompletely defined. For example, the implementation of modelling exercises is usually said to provide a decision tool for quick and accurate evaluation and selection of alternatives, whereas the functions of improving the planning process and the implicit learning experience for managers and and model builders are forgotten or completly ignored when the model performance is evaluated. Additional interaction between managers and model builders helps to develop a common decision framework within the organization, whose value cannot be expressed in terms of money.

Finaly, it is argued that an oversimplified view of causal relationships results in models of doubtful validity, and that the use of historic data for validation become less and less relevant in world that experiences rapid change.

On similar lines of reasoning, Higgins and Finn (1976) -discussing the lack of use of models by managers- study the several different roles that managers play within the organization.

Supported by Mintzber's studies on the role of managers (Mintzberg 1975), the authors conclude that, considering the variety of functions that they perform, it is unlikely that managers use of models and other decision tools will occupy an important part of their time.

Mintzberg distinguishes seven basic roles, they are: i) Figure head, ii) Negotiator, iii) Liaison, iv) Information processor, v) Disturbance handler, vi) Management control, and vii) Strategic planner.

Higgins and Finn's view is that roles i and ii are not directly affected by the introduction of Corporate Models, although the second one could be certainly affected by an adequate use of models. In their opinion the roles of liaison and information processors are only marginally affected by the use of this type of tools.

With respect to the managers' role as corporate planners, the authors consider it is unlikely that top managers will use the models directly, even if they have the skills; because in this role they are usually dealing with several projects simultaneously having little time to go into the detailed evaluation of each of them. The evaluation process takes place at a lower level, thus models will only be significantly used by middle managers.

Top managers' role in Management Control and Strategic Planning is much more related to motivating subordinates, acting as referees in resource allocations, monitoring exixting projects and promoting innovation, than to analytical considerations of alternative projects.

4.5- Institution of Information Systems and the Problems of Organizational Learning.

A more recent paper by Argyris (1977) relates the problems of Information Systems implementation to the more fundamental and subtle problem of organizational learning.

Argyris establishes that current literature on Information Systems design problems usually links failures to the following main reasons:

Lack of understanding of Management Information Systems by managers.

Top Management not being sufficiently commited to promoting the use of Information Systems within the organizations.

Adequate Information Systems being too difficult and too expensive to built and use.

Designers and managers having been unable to reach an adequate level of mutual understanding about the job requirements and potentialities.

Designers having ignored managers' cognitive styles.

The implementation process has been too narrowly conceived, and

There has been dehumanization in the conception of Management Information systems. (Argyris 1977).

Argyris' view is that apart of currently believed reasons for implementation failures there are deeper and different causes, and that any solution derived from this conventional explanations is likely to contain inner contradictions that may result in counterproductive consequences.

Along those lines, Argyris contends that getting into the core of those contradictions requires considering Management Information Systems in terms of the more general problem of organizational learning. To do this it is necesary to start from the premise that organizations requires individuals who posses and develop a determined type of skills; these skills are acquired by a learning process.

Because of human limitations as information processors, individuals must ruthlessly generalize and store the rules that define and describe those skills, in order to leave some free information capacity to deal with the rest of environmental complexity.

For this reason, the programs -policies and rules of behaviour that define the activities- tend to be implicit and hidden behind the complexity of the task. In order to keep capacity available for the rest of complexity, individuals stick to the programs in a way that the latter are made rigid and not easily alterable.

As a result of this tendency, managers are confronted to the task of having to monitor subordinate's actions whose programs are stored and held 'tenaciously', preventing this way the possibility of correcting errors that have origin in the already internalized rules of behaviour.

Argyris suggests that this process is transmitted upwards in the pyramidal organizational structure, resulting in an expanded organizational problem.

Uncertainty generated -at every level- by individuals' limited information processing capacity is usually dealt with by the means of simplifying tasks as much as possible, for instance by successive division of labour and by the use of management by exception.

As long as managers are supposed to monitor performance of many subordinates -and also have uncertainty derived from their own information capacity limitations- they need data about individuals' performance that is both comprehensible and manageable. Argyris conclusion is that this information must necesarily be abstract.

The resulting effect is summarized by Argyris in this way:

> "So now we have workers with tacit programs ruthlessly generalized that are difficult to control directly, managed by superiors who use information that is abstracted from the unique situation for which they are held responsible. The superiors, in turn, must be managed, and the problems of tacitness, incompleteteness and abstractness become replicated" (1977).

Thus, the necessity for abstract information defines the existence of two basic types of Information Systems, one dealing with concrete descriptions of solutions to singular situations, and other containing abstract, quantitative descriptions of key performance indicators. Argyris calls local Information Systems to the first one, and Distant Information System to the second.

One of the many interesting coclussions of Argyris' work is that managers cannot use Local Information Systems without having to be unjust with their subordinates, and that what managers realy need are Distant Information Systems containing abstract information about overall performance rather than about the way as the tasks are being carried out. The type of Information Systems that managers require is one that:

i) Contain abstract, quantitative descriptions of key performance indicators.

ii) Represents stable variance.

iii) Represents the results or outputs of complex processes, and not the processes themselves.

iv) Contains explicitly rational logic in that they attempt to satisfy the logical systematic rules for defining categories, making inferences, and confirming or disconfirming evaluations publicaly.

v) Excludes as much as possible tacit knowledge and tacit processes.

In Argyris's analysis, the meaning of the term justice is defined by whether individuals' performance -effectiveness, responsibility, competentness- is confronted with the adequate Information System or not.

Individuals who deal with the processes themselves -hence using Local information Systems- tend to consider most valuable to think in concrete terms about the immediate results of the processes rather than in abstract terms about their nature. Similarly they tend to infer causality from information which is strictly linked to the contingent causal mechanisms rather than from information which is specific to the mechanisms themselves.

Therefore, as long as their performance is evaluated in terms of capacity for abstraction and ability to discourse about mechanisms rather the mechanism, they are likely going to feel victimized by unjust demands.

These considerations on Information Systems and types of information, show how it is possible to associate the concepts of effectiveness, resposibility and competence to individuals' sense of justice within human organizations.

As a summary it is concluded that management must carried out with incomplete information, leaving to lower levels the full responsability for their bit and leaving the top to intervene only when standards are not met. Effective management at each level must use a M.I.S. that has significantly different properties.

This Thesis somehow responds to Argyris demands, for the design put forward in part III is sufficiently general to be adequate to everey level of an organization and it essentially deals with what Argyris calls Abstract Information.

The taxonomy of changes discussed in this thesis helps to emphasizes the necessity of making these distinctions from the point of view of the designer.

The method used in this work does not require the use of notions like employee, subordinate, boss or top level. It will be noticed that makes use of more abstract and precise terms like change, state, stability, adaptation, survival and organization.

Argyris' contribution is most valuable and relevant to this Thesis, it will be later noticed that several of his distinctions are clearly linked to the theoretical basis of this Thesis and to some of its main conclussions.

Perhaps the most important sole contribution of Argyris' work to the area of Information Systems is the identification of important positive loop structures in organizations, that tend to prevent successful implemetations. It also important to this Thesis and surely to further work his remark that recomendations for improvement currently found in literature may turn to be not only inadequate but also counterproductive.

Complaints about Information Systems' contributions to effective admistration is a recurrent topic in literature. In a recent article Lines (1981) sustains that after 25 years of experience in the use of computers in management it is still possible to find examples where a fine piece of equipment has been so mishandled as to be virtually useless to operational management and even more so at the more global level.

Again, the causes for the failures are attributed to systems designers lack of knowledge of management, mangers lack of understanding of computer technology and incapacity to operate more effective procedures.

In this article, hopes for improvement are placed on computer technology, particularly in the popularization of computer techniques brought about by microcomputers and a more widely spread teaching of the subject in schools and technical colleges.

As matter of conclusion it is argued in this thesis that Information Systems -and probably management sciences as a whole- as an area of knowledge and social practice shows symptoms of instability. The argument is supported on the empirical fact that there is a sustained reporting of dissatisfaction with implementations, a proliferation of "new" methodological approaches to design and implementation, and the explicit questinoning of the assumptions on which most of current developments and methodologies are supported.

PART TWO

INTRODUCTION

The purpose of this part is to provide the reader with the basic concepts and definitions on which the developments of parts III and IV are based.

Chapter V starts with a brief discussion on Cybernetics as a general science of information and with a description of some of the fundamental presuppositions that support the cybernetic explanation. It then proceeds with definitions of fundamental concepts like state, change, system, and stability; and concludes with a first look to management as an informational process.

Chapter VI is devoted to show the relevance of Regulation Theory to Management, presenting a taxonomy of regulatory processes whose importance is fully appreciated in Parts III and IV.; it contains a discussion on the limits to regulatory processes and concludes with a discussion on the concept of survival and the consequences of regarding organizations as viable systems.

CHAPTER V

INITIAL METHODOLOGICAL CONSIDERATIONS AND DEFINITIONS

The view embraced in this Thesis is that human organizations are viable systems (Beer 1974, 1979), as such their basic concern is with developing the ability to survive under whatever conditions.

An organization that is able to survive must be necessarily endowed with the ability to distinguish from a variety of changes those that may threaten the preservation of what defines its identity.

The whole business of part III is about designing an Information System that enhances the natural ability of organizations to cope with perturbations.

The quality of any design is heavily dependent upon the soundness of the the theoretical principles that supports its conception. The principles used in this Thesis are those of cybernetics and this chapter is devoted to introduce them and some of the basic presuppositions that are implied in the cybernetics explanation.

Cybernetics was originally defined by Wiener "as the science of control and communication in the animal and the machine". The communicational connotation of this definition suggests that it may provide the theoretical base to information systems design.

More recently, Beer (1981) has re-defined it as the science of effective organization. The difference between these two definitions is subtle and denotes an important change of emphasis.

For the initial part of this work, Wiener's definition is sufficiently complete, but in the discussion that follows in part IV the meaning of Beer's definition becomes clear and its relation to Wiener's is established.

According to Bateson (1978), the subject matter of cybernetics is information, the latter being regarded as different to the events and things that can be perceived in nature. In this sense cybernetics covers the whole realm of phenomenology, but its restricts its scope to the communicational aspects.

The universality of information is what endows cybernetics with its multidisciplinary value. As a science its deals -across the frontiers of conventional disciplines- with "the information 'carried' by events and objects", Bateson (1978).

This distinction between information on one hand and objects and events on the other gives content to the idea that cybernetics deals with what organizations do rather than with what they are. it deals not with the physical components -people, money, machinery- but with the ways that these elements relate to each other and with the form as organizations behave.

Cybernetics stands to reality as a logical-mathematical framework to deal with perception of difference. In Bateson's view it is "A branch of mathematics dealing with problems of control, recursiveness and information" (1980).

As a theory of machines, "It takes as a subject-matter the domain of 'all possible machines' and is only secondarily interested if informed that some of them have not yet been made, either by man or Nature. What cybernetics offers is a framework on which all individual machines may be ordered, related and understood" (Ashby 1976).

The mathematical character of cybernetics deprives it of all empirical requirement, it depends in no way on the properties of matter. It only provides basis for an observer to describe, classify, and formulate hypotheses on the communicational phenomena.

5.1.- Initial Methodological Considerations.

The above statement about an observer formulating hypotheses on the nature of a sequence of events conveys the idea that, despite of the changes that are taking place in the subject of observation there must be something invariant in it. The resulting hypotheses are usually explicit descriptions of some invariant.

5.1.1.- Constraint and Invariance.

For an observer to be able to formulate hypotheses other than that the subject changes at random it is necessary to assume that the sequence in question is in some way constrained to follow some pattern. The presence of a constraint in a sequence of events implies the idea that the likelihood of each event taking place at a particular moment is uneven.

The concepts of invariant and constraint are closely related, in general the presence of a constraint in a sequence of events implies an invariant. The relation between constraint, invariant and predictability is therefore evident.

In reality -for instance in the complexity of human organizations- events follow each other according to certain patterns. An individual in the organization that wants something in particular to happen, for instance to dispatch an order on time can be considered as an observer predicting a particular event; his ability to achieve the expected result depends upon his capacity to understand the invariant underlying the sequence of events. From this point of view, the search for what is invariant in a given process it is an important task in the manager's job.

Although the manager or cybernetician's task can be described in simple terms, the task itself can not be said to be a simple one. The main difficulty is the observer's limited capacity to process information, this limitation imposes upon the observer a definite amount of uncertainty.

In many managerial situations the complexity of the source of events surpasses managers information processing capacity. Cybernetics as science provides methods to remove uncertainty, as such it can be regarded as a science to deal with complexity and consequently relevant to management.

Thus when dealing with behaviours of complex entities, a necesary methodological step is to formulate hypotheses about the nature of the invariant.

When looking for invariance, the scientist or manager has several alternatives at his disposal, for instance the black box method and modelling.

The use of the black box method implies that the researcher resigns to examine the process in its total dimension -this decision is usually made for practical reasons-, alternatively the scientist limits his efforts to a careful observation and recording of the sequence of the events and surrounding conditions.

Once there is a sufficient number of records, he proceeds to examine his notes in order to establish a pattern that allows predictions about the actual behaviour of the subject.

On many ocasions however, the use of this method is impracticable, for instance when events take place over too long periods of time. It also have the disadvantage that the conclusions established by the pattern may be invalidated by the observation of new events that contradict the former explanation.

The necessity of model building for Information Systems design is discussed with more detail in part III, for the moment it is convenient to indicate that -particularly when dealing with social processes- it is also possible that a single new event invalidates a model. The design discussed in part III requires modelling but it also establishes as an integral part of it a means to indicate whether a reformulation is needed.

5.1.2.- Parts and Distinctions.

Whenever an observer hypothesizes about the behaviour of an entity, he must necessarily divide the universe into at least two parts: the entity and the environment. Frequently it is convenient and sometimes necessary to split these parts further and further. What is important for methodological purposes is to consider that the process of analytical partition does not entirely depend on the observer's convenience.

The hypothesis is then that those divisions and sub-divisions are constrained by inherent properties of the entity and the environment in question. According to Bateson "The division of the perceived universe into parts and wholes is convenient and may be necessary, but no necessity determines how it shall be done" (1979).

5.1.3.- Feed Back Loop Structures.

When the explanation of organizational behaviours is sought, the identification of functional components is usually imperative; the description of causal relations among components invariably yields a network of interactions that take the form of feed-back loops.

The consequences of these observations can be summarized in the idea that whenever in a system of dynamically related variables the value of one of them is changed at random by an external disturbance, after a time the same variable will undergo a change -due to the same disturbance- that is not random. The nature of the latter change being somehow determined by the characteristics of the circuit that connects the variables.

Feed-back loop structures are pervasive in communicational phenomena, and certainly an important feature in the human activity of decision making as it is described in the illustration of figure 5.2.

"Evidently, the universe is characterized by an uneven distribution of causal and other types of linkages between its parts; that is, there are regions of dense linkage separated from each other by regions of less dense linkage. It may be that there are necessarily and inevitably processes which are responsive to the density of interactions so that density is increased or sparcity is made more sparse. In such a case, the universe would necesarily present an appearance in which wholes would be bounded by the relative sparseness of their interconections" (Bateson 1979).

Thus the identification of those dense regions of linkages is a crucial step in the methods of cybernetics. The preservation of the integrity of the regions is a necesary condition for an adequate understanding of phenomena. In the design put forward in part III, the process of unveiling the nature of the linkages takes the form of building a dynamic model of the relationships that exist between organization and environment as a unique region of dense linkage.

5.1.4.- Information and Context.

From the point of view of method, it is also necessary to bear in mind that informational processes occur within contexts. Phenomena take place within combinations of other phenomena; usually the understanding of one of them requires the understanding of their relations. The relevance of this consideration to a system that somehow classifies changes can be summarized in the rule that no explanation can dispense with the relationship context-content.

Bateson's view on the subject is that the "Hierarchy of contexts within contexts is universal for the communicational (or 'emic') aspect of phenomena and drives the scientist always to seek for explantion in the even larger units. It may (perhaps) be true in physics that the explanation of the macroscopic is to be sought in the microscopic. The opposite is usually true in cybernetics: without context there is no communication" (1978).

When dealing with managerial phenomena, the risk of ignoring the context of a phenomena is always present. It stems from two facts.

Firstly, because common sense tends to take context for granted since it is not always necessary to make it explicit, when dealing with situations that are familiar.

In the second place there is the methodological influence from physical sciences that tend to explain phenomena in a context which is over-simplified or altogether ignored.

5.1.5.- Energy and Behaviour.

Bateson maintains that although behaviours are triggered by difference and that differences are not energy, informational processes requires collateral energy (Bateson 1979).

In other words, for an entity to be able to display behaviour -hence to cause communicational phenomena- it is necessary to have an inflow of energy from some source. Whether this energy is "stored" within the entity or not is irrelevant, but the source must exist.

A way of looking at organisms is to regard them as entities engaged in the process of gathering energy. The design of part III is based on the premise that securing a safe energy source is a vital activity for a viable system. The topic is discussed further in chapter VI.

In order to look at management as an informational process and to provide the initial conceptual base to what follows in part III it is necessary to discuss now the meaning of some other fundamental concepts concepts.

5.2.- State, Difference and Change.

The term observer has been introduced without definition, it is convenient now to indicate what is the essential feature of an entity that observes.

By observer it is understood any sort of embodiment that can generate behaviour from its perception of something being different. That is to say it is an entity endowed with ability to make distinctions about its surrounding conditions and about itself.

Of the many possible taxonomies of difference that can be established only one is particularly relevent to this thesis. This is the one that is defined in relation to time.

A static difference is that which is established between things with no relation to time, for example the statement "one kilo is different to one pound" is timeless, and although it may trigger behaviour it is not particularly relevant to this work.

A dynamic difference is established in relation to time, the statement "you are not a boy any longer" implies a difference over the time. It is this type of difference that define the concept of change, its relation to time must be borne in mind.

An important consideration to make when talking about differences over the time is that the paradox of the same being distinct is likely to arise. To avoid that risk it is necesary to bear in mind that change conveys the idea of difference between descriptions or representations, "...If this is ignored, paradoxes arise" (Von Foester 1972).

Therefore, the sole idea of change always implies something in the object of change remaining unchanged.

Those descriptions or representations are called states. A formal definition of state is given by Ashby as "... any well defined condition or property that can be recognized if occurs again" (1976).

A state is usually described by the values that a set of variables takes at a moment in particular. For instance the Balance Sheet of a company can be regarded as an state defined by the value that variables like liquidity, investment in assets and liabilities take at a particular moment.

It is important to notice that in Ashby's definition, the expression 'that can be recognized' reveals that states are somehow observer dependent. Therefore, a state -and the whole consequences of its definition- is not a property inherent to the subject of description alone. The description although observer dependent can not be arbitrarily established by it.

An adequate description always says something that is inherent to the thing, but it is established as a relation between the observer and the object of observation.

5.3.- Systems and Stability.

The term system requires futher attention, so far it has been used in a rather vague manner, it is now convenient to clarify its meaning.

Current literature contains many definitions for the term system, for example this: "A system is a set of interrelated elements. Thus a system is an entity which is composed of at least two elements and a relation that holds between each of its elements and at least one other element in the set. Each of a systems elements is connected to every other element, directly or indirectly. Furthermore no subset of elements is unrrelated to any other subset" (Ackoff 1972).

This type of definition -useful for many purposes- has no place in this thesis, because it equates the concept of system to that of entity.

The term system in this work is reserved for any of the many possible descriptions of the elements distinguishable from an entity that define observable patterns of behaviour. A system therefore is a description of elements and relations that explain some aspect of an entity's behaviour.

Formally speaking, a system is defined by a set of states and a rule of change or transformation. In general in this Thesis, the term system refers to those states and transformation -known or unknown- , including of course, the set of variables that defines the statates and their relations.

There is a further consideration to make with respect to the relation between transformation and states. Normally the researcher starts with an incomplete definition of the variables and the transformation to arrive -once the investigation is completed- to a coherent explanation of the behaviour.

A system that provides complete knowledge about some aspect of an entity's behaviour is said to have closure, whereas the initial definition is said to lack it. The term system in this thesis is used for both -the context specifies the type-.

What is important to specify here is that system -with closure or not- is not the same as the object of observation. Words like "thing", "entity", "organization", "embodiment" and "company" are used for the latter.

The concept of stability is also used in a rather vague manner. Terms like social stability for example means very different things to different people.

For the purposes of this work a clear definition is needed, in general stability is a property of a state of a system; more precisely of a state of equilibrium.

A state of equilibrium is one that experiences no change after a transformation has operated on it. By definition, an equilibrial state is one whose transformed is the same state, i.e.

$\underline{a}$ is a state of equilibrium if only if $T(a) = a$

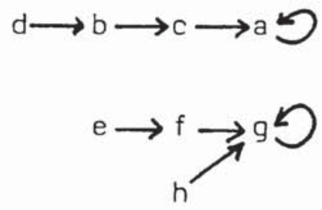
For practical reasons, sometimes it is important to know how resistant is an equilibrial state to some source of change that is circumstantial and external to the system. The concept that relates an equilibrial state to that of external source of change -perturbation- is that of stability; the example of figure 5.1 illustrates the issue.

In the example, the state $\underline{a}$ is re-established after the second step.

A system T is defined by the set of states a, b, c, d, e, f, g, h, with transformation:

T:↓	a	b	c	d	e	f	g	h
	a	c	a	b	f	g	g	g

Its kinematic graphic is:



The system has two equilibrial states, a and g. Defining a disturbance D such as D(a) = d and applying it to the system while at a, and letting the system to its own dynamics the result is:

$$
\begin{aligned}
D(a) &= d \\
T\,D(a) &= b \\
T'D(a) &= c \\
T''D(a) &= a \\
T'''D(a) &= a \\
&\vdots \\
T^{n}\,D(a) &= a
\end{aligned}
$$

The same system under other disturbance say P(a) = e the result is:

$$
\begin{aligned}
P(a) &= e \\
T\,P(a) &= f \\
T'P(a) &= g \\
T''P(a) &= g \\
&\vdots \\
T^{n}\,P(a) &= g
\end{aligned}
$$

Fig. 5.1. Equilibrium and Stability

Therefore, the equilibrial state a of the system T is stable under disturbance D.

Under disturbance P however, the system can not return to state a it sticks to g undefinitely.

The example shows that a is not stable under disturbance P, because the transformation T can not re-establish a as its equilibrial state. In general it is said that "the state of equilibrium a in the system with transformation T is stable under displacement D if and only if

$$\lim_{n \to \infty} T^n D(a) = a$$

(Ashby 1976)."

Therefore, the term stability always denotes the property of a state of equilibrium in relation to a set of disturbances. The use of this concept requires cares because of the risk of attributing this property to the embodiment itself rather than to one of its descriptions.

On the other hand, although stability is a condition for survival it has no ethical connotation per se. Its desirability can only be assessed in the context of an observer's scale of values. For instance the stability of a particular political regimen can be considered desirable or otherwise, depending on the preferences of the observer.

The idea of stability of a state can be easily extended to cover wider classes of distinctions, for example it is possible to talk of the stability of a trajectory or line of behaviour, the stability of a field in a phase space, and the stability of a system.

5.4.- Management as an Informational Process.

With this initial elements in mind, it is convenient now to look at management as a process of informational exchange.

In the first place it is possible to look at the organization as a source of messages. That is to say, -according to the premise of a constrainted reality- as undergoing non-random changes that define certain patterns of behaviour.

A manager on the other hand can be looked at as an observer (internal or external) that wants to have some knowledge about the organization's behaviour, i.e. to formulate hypotheses.

An organization as any other subject of observation contains an infinity of aspects, therefore it may give origin to an undetermined number of descriptions.

The nature of the hypotheses is going to depend -to some extent- upon the observer's intentions. On the other hand, the presence of invariants also conditions the hypotheses, for they should unveil the invariants themselves.

Although the aspect to be considered is to some extent matter of the observer's choice, his choices are also somehow constrained to some set, since they are dependent upon his place in the social context and the means of observation at his disposal.

From the point of view of acquisition of knowledge the whole task of the manager can be considered as that of formulating hypotheses about aspects of complex entities.

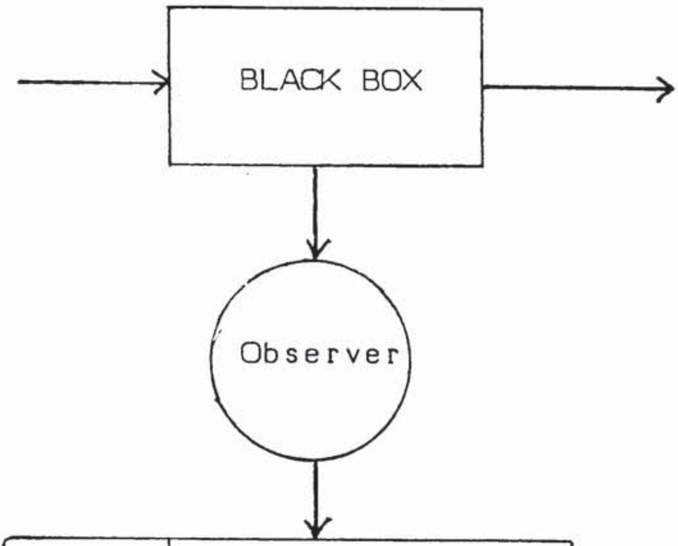
The formulation of hypotheses about an organization's behaviour requires two important considerations:

> i.- The hypotheses are about some aspect of the organization's behaviour and in no way can give a full account of the complexity of the embodiment.
>
> ii.- The hypotheses define a model of some actual relationships between surrounding conditions, context or inputs, and the observed sequence of states.

Figure 5.2 describes a simple process of model formulation, in this example the observer is depicted as making use of the Black Box method. The observer records the organization's states and surrounding conditions until he has a reasonable number of notes. With these elements in hand he proceeds to look for regularities in the sequence of surrounding conditions and states of the system; if a regularity is found the observer codes the sequence into a general formulation (canonical representation) of the system.

Provided that the canonical representation of the system is useful to predict the behaviour of the box, the observer has experienced a change from a state of ignorance to one of knowledge. This way the observer is changed by the process of enquiry.

The search for hypotheses that explain an actual behaviour is usually difficult. It does not necessarily end in satisfactory explanation; if the observer fails to find the pattern in the sequence of inputs-outputs, he may



Time	Protocol: Inputs	Protocol: Outputs
1	A	c
2	A	a
3	B	a
4	B	a
5	A	b
6	C	b
7	C	b
8	A	c
9	C	a
10	C	b
11	A	c
12	A	a
13	B	a
14	A	b
15	B	b
16	A	c
17	B	b
18	B	b
19	A	c
20	A	a
21	B	a

Canonical Representation

↓	a	b	c
A	b	c	a
B	a	b	b
C	b	b	a

Fig. 5.2 Black Box Method of Model Formulation

abandon the attempt altogether and regard the process as chaotic, or alternatively he can reformulate the observation by redefining the descriptions i.e. change the set of variables that defines the states and/or modify the periodicity of observation.

Knowledge obtained by using this method must be used with care because its validity is strictly limited to the protocol. It is always possible that the actual system provides a state that contradicts the predicted value given by the canonical represenation.

"All knowledge obtainable from a Black Box (or given input and output) is such as can be obtained by recording the protocol; all that, and nothing more" (Ashby 1976).

Figure 5.2 describes the process of gaining understanding of an organization's behaviour by passive observation of its trajectory.

A manager, however is usually interested in gaining knowledge about the system's dynamics in order to intervene it in such a way that describes a trajectory of his choice.

An observer in this position is one that aims to exercise control on the behaviour by coupling itself with the system, manipulating the systems inputs in order to restrict the system's states to a particular sub-set. Unless he concludes that the sequence is random, he needs a rule to manipulate the inputs effectively.

Figure 5.3 represents a manager coupled to a system engaged in the process of achieving a goal.

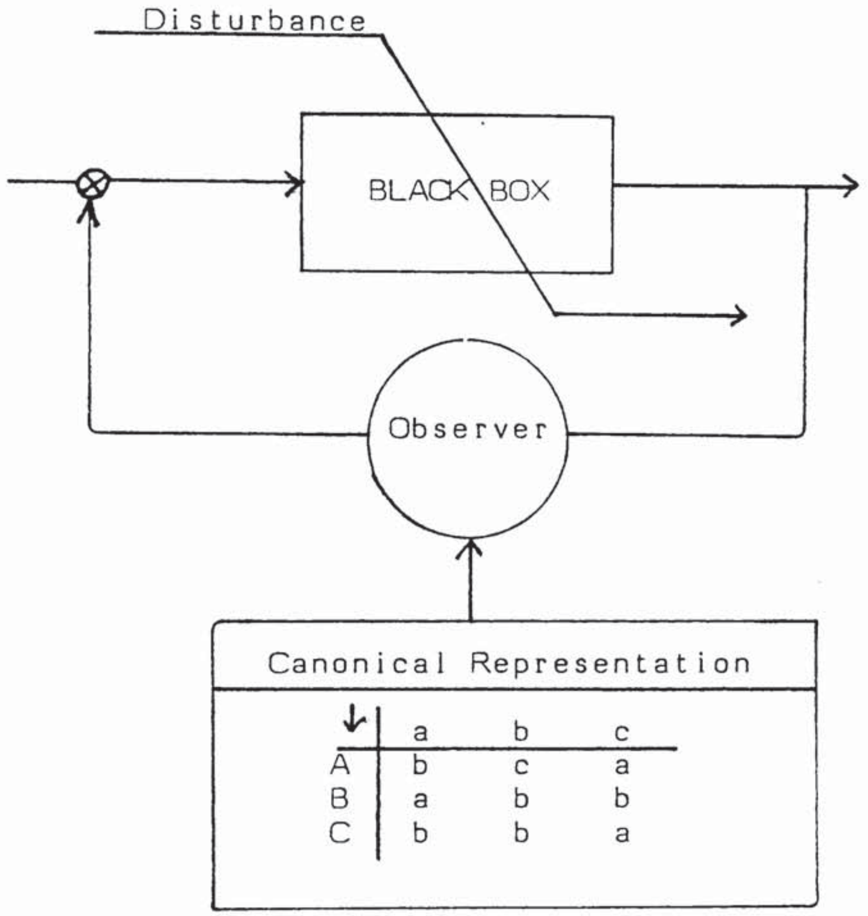
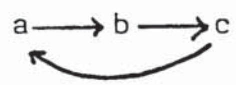


Fig. 5.3 The Use of a Model for Decison Making

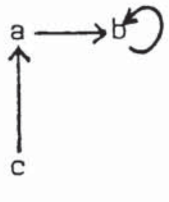
For the purposes of illustration assumes that the goal is to make the system to display the behaviour a a a a a ... a, and that he is provided with an hypothesis of the system behaviour (rule for manipulation of inputs).

A disturbance, as previously defined may operate on the system. It is indicated by the broken arrow and by definition is external to the coupling.

For the manager or observer to be able to carry out the task of keeping a as constant output, the first thing to do is to look at the output value and compare it with the value defined as target; whenever a difference is spotted, he has to manipulate the inputs in a way that the target is re-established. The system kinematic graph shows that a is equilibrial only under conditions B,a i.e.

A: 

B: 

C: 

In principle this manager has two general strategies to follow if a disturbance takes the system out of target, one is to manipulate the inputs at random until a combination B,a is achieved. The second possibility is to study the system's dynamics, record the protocol and find out the invariance.

A prior it is not possible to say which strategy is best, from the point of view of economics it would dependend on the cost of working out the invariance in relation to the cost of delaying regulation by using trial and error. From the point of view of regulation, however it it is clearly more convenient to use the canonical representation, since in the long range it re-establishes the target quicker and time taken for adaptation is crucial when disturbances tend to appear frequently.

It is worth noticing that the validity of the latter argument is subject to the premise of the existence of contraints in nature, otherwise random moves would be as efficient as any other method.

The examples given in figures 5.2 and 5.3 are simple but sufficiently general to provide some important clues to an Information Systems designer. It suggests for instance that random trial and error can be a very inefficient method in a context where perturbations tend follow each other quickly.

It also suggests that the design of Information Systems for management requires developing theories about the nature of the organization's behaviour, otherwise the information obtainable from a comparator has very limited value. Consider for example the following situations.

SITUATION A

a) At time 0, the system described in figure 5.3 is in target *a* under input B, that is to say in position B,a.

b) At time 1 disturbance D takes place making:

$$DB(a) = c$$

c) The system's dynamics shows that in this case if the manager respond to disturbance by moving parameters at random he will never succeed to make output a constant. In this case unless he has an explanation of the organization's dynamics, knowing that a perturbation has taken the organization out of target makes no difference for the purposes of regulation.

SITUATION B

The same example provides another important clue to design. As it has been discussed in section 5.1.3, random disturbances affecting a system generate non-random changes in the system at later stages, this feature must be taken into account when a design is in question. Consider the following case:

a) At time 0, the system is in target in the position B,a.

b) At time 1 a disturbance D takes place such as:

$$DB(a) = c$$

c) A manager taking action, according to an adequate explanation of the system, changes it to input A at step 2, then to B at step 3, and keeps it at B indefinitely. Thus the system follows this trajectory:

Time	
0	$B(a) = a$
1	$DB(a) = c$
2	$ADB(a) = a$
3	$BADB(a) = a$
.	
.	
.	
n	$B^{n-2}\ ADB(a) = a$

In this example the manager makes use of its knowledge of the system's constraint, at step two he temporarily applies input A in order to speed up regulation. This is the best of several possible alternatives.

SITUATION C

A final important clue is to do with the feed-back loop structure of the managerial process and the delay time of informational flows. The importance of this relation has been extensively discussed by Beer (1974, 1979, 1981), Forrester (1960, 1961, 1968) and Coyle (1978). The authors stress that if management takes no account of the relations between the timing of corrective action and and the opportunity of information, corrective action may lead to explosive osciletion and collapse.

The following illustration gives an example of the possible consequences of information being out of phase with the system's dynamics.

a) Assume that the manager knows how to deal with disturbance D. i.e. do the same as in situation B.

b) At time 0 the system is in target in the position B,a.

c) At time 1 disturbance D takes place, thus:

$$DB(a) = c$$

d) Information about the output being at c gets to the manager at time 3, instead of time 2.

e) Following what he knows about the system, but unaware he is one step late:

Time	
0	B(a) = a
1	DB(a) = c
2	BDB(a) = b
3	ABDB(a) = c

4 $BABDB(a) = b$

.

.

.

n $B^{n-4}ABDB(a) = b$

At time 3 the manager receives the information of disturbances taking the system to c, he applies corrective policy but at the wrong moment, stabilizing the output b.

Similar examples can be given of loss of stability due to too quick reaction to disturbances. It occurs for example if a perturbance take the system out of target to a values that is within the stabilizing trajectory and the manager instead of leaving the system to relax itself, makes change of inputs, as happens when there is over reaction to a transient change.

In summary what the managers need is opportune information, this conclusion is certainly not new, in it is found in every management book, the meaning of the condition of opportunity, however it is very rarely discussed.

In Information Systems text-books for instance, opportunity is usually associated to the idea of real time. The use of this term also deserves some care; in D.P. and M.I.S. literature is equated to the view that management should be plugged into the computer facilities on minute to minute basis interrogating the machine about every sort of event, disregarding the time scale at which the process take place (Dearden 1966). This view, which is prevailing in current literature has deprived the term of its theoretical value.

In the context of this Thesis, the term real time information has no absolute meaning until the size of the time intervals at which is appropriate to carry out control has been defined. The size of the intervals is a property of the inner structure of the system, the time unit can in no way be arbitrarily defined by the designer.

Real time information, therefore refers to the one that reaches the manager within the unit of time defined by the dynamics of the specific managerial process in question.

As discussed in Part I, the majority of current designs almost exclusively deals with the technicalities of data gathering and processing, relegating to a second plane the problem of the dynamics of managerial processes.

Those relatively few attempts to use modelling techniques have -in the majority of the cases- mimicked the accountancy operations with little reference to the organization's behaviour. The use of dynamic modelling can be considered as an exception to the general rule, but most of the emphasis has fallen on simulation.

The design worked out in part III, supported on regulation theory integrates information processing and dynamic modelling into a coherent framework. So far the concepts of regulation and control have been used in a rather vague manner, next chapter contains more precise definitions and provides other theoretical elements which are necesary to the discussions of parts III and IV.

CHAPTER VI

MANAGEMENT AS REGULATORY PROCESS

In this chapter the essentials of a Theory of Regulation are discussed and its relevance to Management is outlined. The necessity for this discussion will be apparent in part III, where the requirements for an Information System are established.

A taxonomy of regulation is presented together with several examples that show the pervasiveness of regulatory processes in organizations. The classification if followed by comments on the necessity for a designer to be aware of the actual limitations to which every regulatory process is subject.

Finally, it establishes relations between the concepts of stability and survival and how this relation stands with respect to regulation in general.

6.1.- Regulation in Management.

For the purposes of clarifying the concept of regulation and to observe its relation to management, it is convenient to look again to the process described in figure 5.3 from a slightly different point of view.

A first possibility is to regard the manager as being engaged in the process of making the output a stable with respect to disturbances. Thus, from this perspective management is a stabilizing process.

A second possibility is to regard the manager as engaged in the process of reducing the total variety of the outputs to a minimum -from three to one in that example-. Therefore, conceptually speaking, the operations of achieving a goal, stabilizing an output, and reducing variety are equivalent.

By regulation, is therefore understood any process that prevents variety transmitted from some source from reaching and increasing variety of a variable, set of variables or system.

The manager of figure 5.3 can also be looked at as preventing variety from a source of disturbances from reaching the target a. It follows that the terms stability, meeting a target or achieving goals, and regulation are closely related.

The illustration shows that between regulation and management there are commonalities that legitimate the approach of designing Information Systems based on a theory of regulation.

In every regulatory process there are four basic elements, as it can be noticed in figure 5.3; they are a source of disturbances, a reguland -the black box in the example-, a regulator -the mananger-, and a target.

The way variety flows through these elements provides the basis for the taxonomy that is discussed in next section, this classification is supported by Connant's work (1968)

6.1.1.- Passive Regulation.

This is the most elementary type of regulation, it occurs whenever an actual object blocks transmission of variety from a source of disturbances to a given target. It acts independently of whether variety is being transmitted or not. It is illustrated in figure 6.1.

Despite of its elementarity, it is widely found in nature and human organizations, it naturally occurs in shielded animals. In human organizations it is found at every level, for instance in the form of safety helmet in the shop floor, as a safe-box in the financial department -preventing the variable cash from being affected by a disturbance 'thieves'; and as double glazed windows, peventing urban noise from affecting a given level of quieteness in the Board room.

More interesting cases of regulation are those where the regulator has some effect on the reguland in a way that the target is met. A regulator that acts on the reguland when disturbances affect or are to affect the target must necessarily receive information about the presence of disturbances by some means.

A regulator with non-random response to a given disturbance is a mechanism that makes choices according to the nature of disturbances. Sensing, making distinctions and selecting adequate trajectories are the elementary activities of a managerial process.

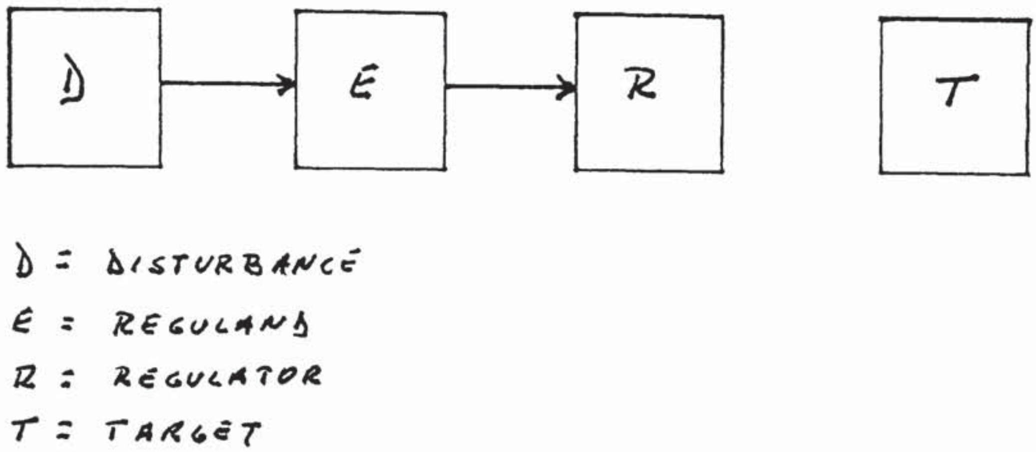


Fig.6.1 Passive Regulation

Since management is about making adequate choices it can be said that is a process of displaying intelligent behaviour. The expression right or adequate choices deserves some attention for it usually involves an important ethical issue.

For many practical purposes it may be sufficient to regard adequacy of response as the effectiveness with which a target is met. But this sort of statements say nothing about the way as the target comes about.

In management the target is usually set by some authority, for instance the Board of Directors may decide that the company should sell 10,000 units per year.

Whether the target is 'right' or not is a question of a different logical level and requires considerations beyond the purely functional aspects of regulation.

The setting of the target has not been included as an element of regulation, its inclusion in fact leads to the definition of control.

Whenever an individual or entity -provided with some regulator- sets a target and meets it, that individual or entity is in control of the outcome. Therefore the term control involves the setting and achievement of a goal whereas regulation involves the process of achieving a given goal.

In principle it is not possible to state in an absolute way what it is a correct target and what is not, it is to a great extent a matter of the observer's value system. The view adopted in this thesis is that the observer's options are limited to a set that is not conflicting with the viability of the eco-system.

6.1.2.- Regulation by Error.

This type of regulation takes place when the regulator recognizes the presence of disturbances by comparing the target value with the actual value of the outputs. That is to say when the Regulator spots a disturbance by observing the regulated system rather than the source of disturbances, figure 6.2 describes the essentials of this type of regulation.

The figure says that whenever the system's output differs from the target T, the regulator R selects a behaviour to act upon the reguland E in order to bring the output value back into target. Notice that this type of regulation is of the same sort as the one described in figure 5.3.

Each of the four boxes in figure 6.2 are functional representations of different aspects of reality, the distinctions are made for purely analytical reasons.

The functional character of the boxes suggests that defining what is their content is to a large extent up to the observer and his intentions. This methodological consideration is important because the association of a functional diagram with actual embodiments and to the names used for the embodiment requires care and clarity.

For instance the reguland E is functionally regarded as that part of the system external to whatever it has been defined as the regulator. The E for reguland may also stand for Environment -as it is used in part III- there is no problem in doing so provided that the functionality of the term

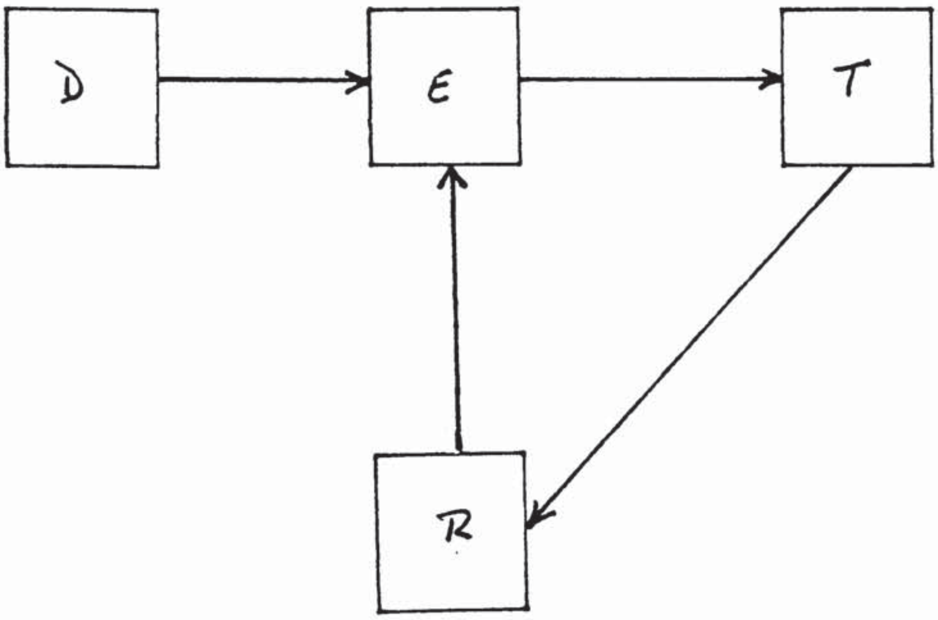


Fig.6.2 Regulation by Error

is kept in mind.

The ordinary use of terms like environment, organization, and company usually suggests some physical location that brings confusion to the analysis resulting in pointless discussions on whether the system's boundaries lie here or there, or whether such and such element is or not part of the system. For the purposes of this thesis those distinctions are purely functional.

The term target in its turn describes a desired property or condition, it refers to nothing physical. The regulator R is the mechanism that computes the values of the discrepancies between target and output and responds to re-establish target T. By source of disturbance D is meant whatever event or set of events that causes or may cause discrepancies between the actual state of the system and the target T.

Figure 6.2 shows several interesting features of this type of regulation, for example it shows that R gets information about disturbances through the path D→E→T, the reguland can not react directly to D, it can only respond to the event deviating from target. It follows that regulation by error can only be partially successful for it can not block all variety from the D.

Therfore it is of use only when T is defined by a set of continuous variables whose values range from within target to grossly out of target, in a way that safety limits can be established in order to trigger responses on time. The point is further discussed in part III.

Although imperfect, this form of regulation is widely used. Its importance stems from the fact that a regulator may always fail to get information from other sources.

It is also used at every level of the organization, for instance in the quality control activities where the decision to scrap a certain lot of items is taken after verifying that a certain number in the sample has been found to be defective. A similar situation is found when a liquidity level falls beyond certain limits and management react by getting a loan from a financial institution.

6.1.3.- Feed-forward Regulation.

This case of regulation is more interesting from the point of view of efficiency for in principle it gives the possibility of reducing the variety in the outcome further. Figure 6.3 shows the functional arrangement of the parts.

It occurs when the regulator obtains information on the presence of disturbances by observing the states of the reguland and it is able to respond in a way that T is not affected.

It requires that the effect of D on T is delayed for some time in a way that the regulator is able to get information, select appropriate responses and act on the reguland before the output is taken out of target.

This type of regulation deserves at least two important considerations for the purposes of actual design. The first one is that speeding up the flow of information about the state of E can effectively contribute to improve regulation.

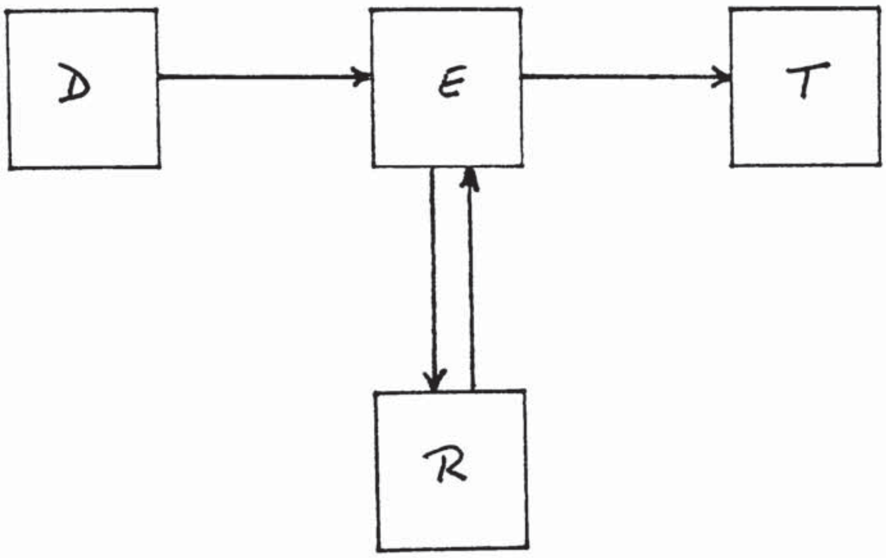


Fig.6.3 Feed-forward Regulation

The second consideration is that there must be some constraint in E's behaviour since effective anticipatory regulation requires some correlation between the past, present and next states of the environment.

In management this type of regulation takes place for example when a company decides to modify its product line because leading companies in the industry are doing it, and before there has been any reasonable effect on achievement of sales targets.

6.1.4.- Regulation by Cause or Parallel Regulation.

In this case the regulator does not wait until the presence of a disturbance manifests itself through the environment, but gets information directly from the source. In this situation, the regulator anticipates the effects on the environment in a way that by simultaneous countermove it forces the outcome to be within the target. A description of this type of regulation is in firgure 6.4.

Bearing in mind this formulation, the regulator's task can be seen as one of coordinating its behaviour with the reguland's in a way that T is unaffected by D. Coordination in this sense aims to block information coming from D to T.

The most outstanding feature of this type of regulation is that in principle it may be perfect in the sense that the entropy in T can be reduced to zero. A case of prefect regulation can be attained when the regulator's behaviour is isomorphic with that of the environment Connant (1968).

This type of regulation occurs for instance when a company recognizes

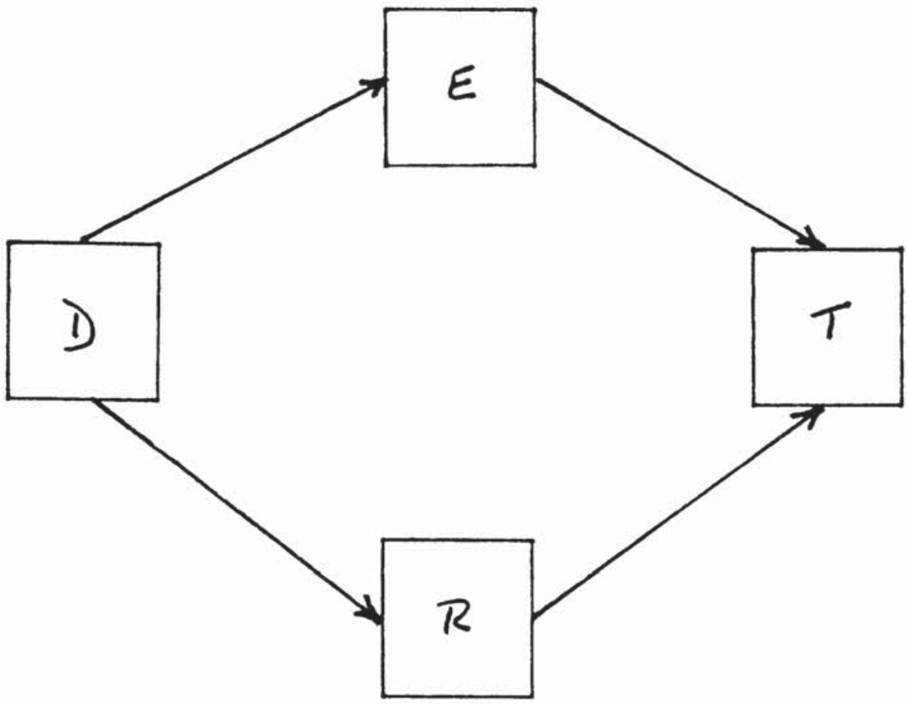


Fig.6.4 Regulation by Cause

trends in technological developments that may make its operational methods obsolete; engages itself in technological development and incorporates the new technology into its operational methods.

In general, research and development units, and up to some extent marketing departments are actual mechanisms to promote this type of regulation.

6.2.- Limits to Regulation.

The four basic types of regulation described above, are comprehensive enough to illustrate in global terms the most salient features of the possible relations between Disturbances, Reguland, Regulator and Target.

Familiar examples show that each type frequently occurs in management, the classification is useful to provide clues for the design of an information system for corporate management.

To put managerial problematique in terms of regulation and to make good use of the theory, it is convenient to take into account the limitations that every regulatory process has and see -if possible- how these limitations can be overcome. It is important that the designer has a realistic view on what is actually possible to achieve, in a way that he does not set objectives which are impossible.

The most fundamental limitation encountered by any regulator is given by the Requisite Variety Law (Ashby 1976). The law or theorem establishes that the varieties in D, R and T are related in such a way that the latter cannot be reduced beyond the quotient between D's variety and R's variety.

$$V_T \geq V_D / V_R$$

logarithmically $$V_T \geq V_D - V_R$$

The theorem establishes that the variety in the target T -given certain variety at D- can only be reduced by increasing the variety in R. In Ashby's own terms "only variety can destroy variety".

The importance of this law to regulation can not be over-emphasized, the law say that given a regulator with fixed or finite variety, the amount of regulation that can achieve is bound to that amount.

In relation to organizations the law simply says that the ability of the organization to achieve some goal is bound to its capacity to increase its variety by a similar amount to the increment of the environment's.

The law as discussed here, assumes the variety of disturbances equal to that of the reguland. Ashby has shown that if $V_D > V_E$, the law equally applies, namely that <u>only</u> an increment in V_R may <u>actually</u> diminish the variety of the target.

This consideration is important because it refers to the situation where the variety of the Disturbances is actually less than what at first sight might have been estimated. $V_D > V_E$ represents a situation where 'different' disturbances have the same effect on the reguland; this is clearly the situation when the variety of the disturbance shows a constraint.

The finding of a constraint in the set of disturbance makes it possible to reformulate the problem of regulation in a way that some of the original disturbances can be disregarded as such. The finding has an important regulatory value in the sense that may make regulation possible in a situation originally regarded as hopeless.

The implications of Ashby's law to regulation and organization are discussed at a greater extent in part IV , for the moment it indicates that adaptive organizations in complex environment must amplify variety, one possibility to do it is to find constraints in the sources of disturbances.

Ashby (1976) has suggested that an organism in a complex environment faces two types of variety; one that threatens its viability, which must be blocked at any cost; the other type comes in the form of information in the sense that the organism can code and store it in order to use it later to block the effect of the harmful one. That is to say, provided it that the environment is constrained in some way information of the regularities can be used at later times to block harmful variety.

The flow of variety through the components of a regulatory process poses problems no yet considered. In the example of figure 5.3 the manager is described as receiving a clean signal from the comparator. That of course is seldom the case in actual management; very frequently the signals from the comparator are noisy.

The problem of massive variety flows generated by complex managerial processes has been traditionally faced by developing computer systems that are capable to deal quickly with large amounts of data. The problem however is far beyond present and future computer technology capacity. Ashby has shown (1972) that according to Bremerman's limit even very simple regulatory processes involving no more than 400 binary element may generate such an amount of variety that no imaginable computer can cope with it.

On the other hand, Beer (1974) has pointed out that the intensive use of computers in management has rendered greater proliferation of variety, making valuable signals more and more noisy. The result being an increasing gap between the amount of information received by managers and their limited capacity to process it.

Change and variety are closely related concepts, the design put forward in this thesis aims to provide criteria to distinguish changes that are meaningful to survival.

The problem of identifying changes that are important to the organization's survival requires to establish criteria to determine which changes requires monitoring and to define how much difference constitutes a change.

For instance, of the many changes taking place in the environment, it is necessary to identify which are worth monitoring and then to find out how much variation in the value of the variable makes a difference in terms of viability. Often in management people discuss these issues with no clarity of priorities and significance.

The amount of discussion and confusion that this type of problem produces illustrates the relevance of the topic, this discussion complicates further when concepts like policy and organization change are introduced.

The relevance of change to any viable system is only partially observer dependent, nature itself pre-defines to some extent what is relevant and what is not. Next section contains a discussion on an initial criterion to distinguish between changes that matter from those that do not.

6.3.- Survival and Viability.

The consideration that provides the basic criterion to establish the importance of different types of change is the hypothesis that organizations' essential characteristc is that of survival.

Therefore a careful discussion on the meaning of the term survival is necessary. The characterization of organizations as viable systems has been developed by Beer (1966).

He established that a viable system has several characteristics. "Viable systems have the ability to make a response to a stimulus which was not included in the list of anticipated stimuli when the system was designed. They can learn from repeated experience what is the optimal response to that stimuli. Viable systems grow. They renew themselves by for example self-reproduction. They are robust against internal break-down and error. Above all, they continually adapt to a changing environment and by this means survive quite possibly in conditions which had not been entirely foreseen by their designers" (1966).

More recently (1981) he has emphasized that viablity is the ability to survive by maintaining a separate existence.

The concept of survival encapsulates the most fundamental features of a viable system, and its meaning can be put in direct relation to the concepts of stability and regulation.

Following Ashby's views consider a living system like a mouse, which as every dynamic system can be described by the set $S_1, S_2, S_3 \dots S_n$ of possible states that it may take.

From that set there is a subset $S_1, S_2 \dots S_k$ that correspond to the mouse being alive, these states are those in which ceratain <u>essential variables</u> are kept within physiological limits. Therefore a living mouse can be represented by the transformation $M(S_i) = S'_i$, $i \leq k$; whereas a dying mouse can be represented by the transformation $D(S_i) = S_j$ $i \leq k$ and $j > k$.

The mouse has survived the presence of a disturbance C -for cat- if its essential variables are kept within physiological limits, that is to say if after the perturbation the mouse's state is within the set S_i. If the mouse has survived, then it has folowed the behaviour:

$$CM(S_i) = S'_i$$

$$MCM(S_i) = S'_i$$

$$M\ CM(S_i) = S'_i$$

$$\vdots$$

$$M^n\ CM(S_i) = S'_i$$

It should be noticed that the description of this behaviour is identical to the definition of stability in Chapter V. Ashby has shown that the concepts of survival and stability can be put in an exact relationship, in a way that facts and theorems about any of them can be used for the other, provided that exactness is sustained.

The practical importance of this observation is that makes possible to deal with problems of survival and stability in a clear and precise manner. It allows the designer to use the mathematical elements that are useful to tackle problems of stability and and control.

For the purposes of implementing a system like the one put forward in this thesis the concepts from Management Systems Dynamics are particularly relevant, this discipline is a basic component of the approach developed here. According to Coyle (1979) "Systems Dynamics is that branch of control theory which deals with socio-economic systems, and that branch of Management Sciences which deals with problems of controlability".

A living organism is one that keeps -under whatever conditions- certain variables within physiological limits. That is to say it assures that its essential variables are kept stable.

The process of survival can also be looked from the point of view of regulation, in this respect a viable system is one engaged in the process of preventing that variety coming from the environment reaching the essential variables. A living organism is therefore a regulator.

It is however important to keep in mind that although the relation between stability and survival is rigorous, the actual interaction between a prey and a hunter is far more complex than the above illustration suggests. In part III the survival process is studied in greater detail and the properties of ultra-stability are used to derive the requirement for an information system design.

The concept of stability as discussed here is sufficient to show that the enhancement of viability requires in the first place to spot any significant change in the value of the essential variables. This and other related topics are discussed further in part III, for the moment it is convenient to pay some more attention to the problem of what defines the essential variables and the unit of survival.

The first methodological problem encountered when trying to identify changes that are meaningful to viability is to establish or find out what is to be considered the essential variables. In management it is difficult and perhaps impossible to satisfy every body's expectations.

Ashby payed no attention to the practical problem of establishing or finding out the essential variables in social organizations. He was mostly concerned with the processes of adaptation and learning in animals and their relations to a general theory of mechaninsms. "The book is not a treatise on all cerebral mechanisms but a proposed solution of a specific problem: the origin of nervous system's unique ability to produce adaptive behaviour. The work has as a basis the fact that the nervous system behaves adaptively and the hypothesis that is essentially mechanistic; it proceeds on the assumption that these two data are not irreconciliable" (Ashby 1976b).

In Ashby's work the problem of finding out the essential variables and their physiological limits is something that can be easily solved experimentally, since in animals the variables and their limits have been fixed in the process of evolution.

The method he suggests to determine the essential variables is summarized in this quotation: "Given a species, we observe what follows when members of the species are started from a variety of initial states. We shall find that large initial changes in some variables are followed in the system by merely transient deviations, while large initial changes in others are followed by deviations that become ever greater till the 'machine' changes to something very different from what it was originally. The result of these primary operations will thus distinguish, quite objectvely the essential variables from the others." (1976).

The essential variables determined by this means are shown not to be equally important in terms of the urgency in relation to lethality; thus it is in principle possible to rank them according to their relative importance. The relevance of this observation is discussed furtherin section 12.5.

The method, although rigourous and precise it is of little use to find out the essential variables of social institutions such as business organizations. What follows next is a discussion on a primary criterion for social organizations.

The starting point is the empirical fact that survival, in animals and organizations alike depends -in the last event- on the availability of a source of collateral energy. It can be easily verified that the lack of this source sooner or later ends up in the organism's death.

The point is illustrated further by the fact that organisms -animals and organizations- spend a large proportion of their time gathering food. For practical purposes then, a rate of energy gathering and a level of energy reserves may provide the initial set of essential variables.

In the context of human organizations, the energy source is usually expresed as a source of finance, and measured in monetary units. It is then reasonable to represent the energy inflow as a rate of profit and the availability of resources as a level of liquidity.

In this way it is possible to link, without ambiguity the problem of regulating the essential variables with that of economics; it can be easily verified that when the value of the variables rate of profits and/or level of liquidity go beyond certain limits, the organization almost certainly collapses.

The fact that some organizations fail for other reasons does not invalidate the above observation, it only shows that there may be other essential variables in addition to the financial ones. The theme of essential variables recurrs in this Thesis and further consideration is given in parts III and IV, for the moment it is convenient to discuss further the implications of considering financial variables as essential.

The purpose of profit making is some times questioned on ethical grounds. A look to industrial relations, is generally sufficient to show that profit making by some people tend to conflict with some other peoples purposes' within the same organization. There can be no question about that.

This discussion on the ethic of profit making many times leads to argumentations on whether or not the company's purpose is or not to maximize profits. Some people maintains that the company's purposes are not to make a profit, but to provide a service, whereas others would argue that they provide a service to make a profit.

In other occasions the arguments go like this: The company's purposes are not to make a profit, but to increase its market share or become a leader in its area, or to create jobs, bring new technology and progress. The counter-argument is that companies want to do all that to increase their profits at a later stage.

Some organizations declare as their purpose to serve the community and they make large contributions to charity, promote social welfare support research programs, etc., but again each of these actions may be interpreted as manouvres to increase profitability.

To this work, such a discussion is void of content and irrelevant. The approach adopted here is that there must be no question about the necessity of a financial source -expressing in economic terms the source of collateral energy- and that profit rate and liquidity level as measured in current business operations are good enough indicators for a design to identify changes that are relevant to Corporate Management.

Since organizations can not survive without a source of collateral energy, there is no problem to consider the energy available as an essential variable. Once this view is understood, it is simple to conceive organizations as regulators, blocking variety to keep these variables stable.

It can also be shown that the value of the variable energy available depends upon the nature of the dynamic interaction between the organization and the environment.

There is certainly the problem of how much energy 'should' an organization gather, whether to maximize it or not. At first sight it seems obvious that the more reserves an organization accumulates the better for its survival, but the present scale of economic activities seems to be getting levels that can have serious ecological consequences.

To this discussion it is useful to consider again the example of the mouse under the disturbance cat, but this time from the more emotional point of view of an observer that sees the cat as looking for its source of energy and the mouse as trying to survive. The question is then what is going to survive?.

From the human point of view it may be concluded that the survival of the cat is preferable since mice are pest, from another point of view it may be suggested that the one that should survive is the fittest. The problem of survival in general is becoming an issue of increasing concern to the contemporary society. None of these criteria seems to be appropiate.

Bateson (1978) has pointed out that an adequate identification of the unit of survival is vitally necesary for the present society to survive; he says: "It is now empirically clear that Darwinian evolutionary theory contained a very great error in its identification of the unit of survival under natural selection. The unit which was believed to be crucial and around which the theory was set up was either the breeding individual or the familiy line or the sub-species or some similar homogeneous set of conspecific. Now I suggest that the last hundred years have demonstrated empirically that if an organism or aggregate of organisms sets to work with a focus on its own survival and thinks that that is the way to select its adaptive moves, its 'progress' ends up with a destroyed environment. If the organism ends up destroying its environment, it has in fact destroyed itself".

Bateson's observations deserves a great deal of attention, particularly in the situation where socio-economic development depends so heavily in the exploitation and super-exploitation of the environment.

It is for these reasons that in this thesis, the use of the expression 'organization's viability' always includes the survival of the physical environment; the unit of survival is the organization in its environment.

Therfore, the use of the variables rate of profit and level of liquidity is convenient for they relate to the energy source and are measurable in monetary units with which most of people are familiar. But in no way can it be related to the ideas of classic economics where the aim of profit maximization is regarded as the element that provides of stability to the whole economic system.

This redefinition of the unit of survival places current mangement in an important dilemma.

In market oriented economies management can not afford to think of the survival of the environment; if managers do care about it, their companies survival is endangered for those that survive are the ones that make the greatest profits. Thus even if managers as individuals are conscious of the necessity of preserving the environment, the objective conditions in which they work prevent them from developing policies which are not environmentally harmful. Current management finds itself in a perfect double bind situation.

It is not matter of this thesis to discuss a way out to this schismogenetic situation, an approach to this problem is found in Beer's book "Platform for Change".

In summary, the use of the expression Essential Variables in this Thesis is related to the idea of a safe source of energy, considering that the organization and its environment constitute an indivisible unit.

A great deal of organizations' behaviour is to do with the process of gathering energy, but certainly not all. This situation is obviously related to the fact that companies not only make profits, but also contribute to charity and postpone profits in order to develop technologies.

The view adopted in this thesis is that an organizations' primary need is that of being able to display behaviour, to which energy inputs are vital. For this reason energy gathering is regarded as the primary focus of attention. Only when this necessity is satisfied an organization can engage into some other type of behaviour.

Organizations can be seen as experiencing different types of necessities, at every given moment there must be a dominant need that becomes the foreground of attention; while this is so every other necessity recedes -at least temporarily- into the background.

This dynamic of attention suggests that at times, company's main concern may not be liquidity and rate of profits. The design of Part III is deduced considering profits and liquidity as the focuss of attention, but this is only because the energy source is considered to be the most vital necessity.

The principles of regulation are sufficiently general to make the design applicable to perhaps any conceivable target. This thesis' approach to design may in principle be applicable to any set of targets that is in the organization's foreground. The topic is discussed further in section 12.5.

PART THREE

INTRODUCTION

In this part the requirements for the design of a system to identify changes that are significant to organizational viability are deduced.

The basic method consists of the use of the Ultra-stable system and its adaptive properties to establish the informational requirements to enhance survival capacity.

Chapter VII is devoted to describe the Ultra-stable system's components and relations. It starts from the premise that one way of dealing with organizational complexity is to resort to some theoretical mechanism that although simple, it retains the essential properties of adaptive organisms.

Chapter VIII summarizes the initial requirements for Information Systems design that the necessary and sufficient conditions for adaptation demand. It states that those conclusions are rigorous but incomplete in the sense that the Ultra-stable system as described in Chapter VII can not account for the features of foresight and learning so pervasive in higher organisms.

Chapter IX discusses the modifications that the basic formulation of the Ultra-stable system requires to cater for the properties of foresight and learning and introduces modelling as an essential requirement for Information Systems design for Corporate Management.

Chapter X concludes with the basic components of a system for change identification considering the requirements for learning and foresight; and develops an approach to the problem of actual design and implementation.

CHAPTER VII

THE ULTRA-STABLE SYSTEM AS UNIT OF ANALYSIS AND ITS PROPERTIES

The purpose of this part is to unveil the basic components of a system that identifies changes that are meaningful to Corporate Management. This development is based on the fundamental assumption that human organizations display adaptive behaviour in order to preserve their integrity.

The idea of looking at organizations as viable systems discussed in chapter VI is here developed further and the informational requirements are considered in a much greater detail.

This chapter in particular, discusses a method to go about the task of deducing the basic components of a design. It starts from the empirical fact that human organizations are very complex entities that develop specific means to cope with perturbations coming from the environment.

The method consists of resorting to a mechanism that being simple enough to be understood, it retains the necessary and sufficient conditions to display adaptive behaviour.

The mechanism in question is Ashby's ultra-stable system, its properties are described first and then used to derive what a design to enhance adaptability should contain. Before describing the ultra-stable system it is convenient to justify further this strategy.

7.1.- Complexity, Organizations and Management.

The idea that organizations are very complex entities and that management is somehow dealing with complexity has been discussed by Beer (1979). In this Thesis, this idea is used with the specific aim of working out an information system that improve survival abilities.

The system for identification of change can be regarded as a tool to deal with managerial complexity, since its final purpose is to provide coherent information on the state of the organization and its environment.

The terms complexity and dealing with complexity are for this reason central to this development; it is therefore convenient to look at them and establish some criteria to recognize success or failure in the task of dealing with complexity.

7.1.1.- The Meaning of Complexity.

A basic consideration to be made when considering the complexty of some entity is to be aware that the property of being complex belongs to some level of description and not to some absolute property of the thing.

Following Waddington's ideas (1977), complexity is to do with the number of elements that can be distinguished in an entity and with the number of relations that exists among the elements.

The degree of complexity is therefore somewhat a function of the number of identifiable elements, the number of interrelations that exist among them and the way as they interact.

Complexity increases as the number of elements does, but it grows much faster as the number of interrelations increases. For this reason, an effecient way of dealing with complexity is to prevent the development of interrelations; to get to know a complex entity is sometimes useful to ignore the interrelations and explain it in terms of the properties of the parts. In this Thesis this method is not used.

With these elements in mind, it is possible to give a more precise meaning to idea that organizations are complex entities and that management is about dealing with complexity.

The number of elements and interrelations that can be identified in an organizations is large enough to make impossible any complete enumeration, for instance people, jobs, industrial relations, managers, markets, competitors, customers, profits, liquidity, and so on and on. By the same token , the relations among those elements are multiple, for example between profits and industrial relations, and between the latter and productivity, and between this and profit again, etcetera.

For these reasons management as decision making or problem solving process can be regarded as the activity of dealing with the complexity generated by those elements and their interrelations.

A consideration that must be borne in mind every time that a design to improve management is under consideration is the fact that as the number of distinctions grows the complexity generated this way rapidly surpasses all human and material possibility to deal with it. Every attempt to deal with managerial complexity therfore must include a clear delimitation of the number of distinctions to be made, if the number is too large the chances of success may be altogether impossible.

The idea that the number of distinctions is delimitable by the observer suggests that the resulting complexity is up to some extend matter of arbitrary choice, since the number of distinctions is observer dependent.

For this reason it is appropiate to reserve the term complexity as name for a relationship established between an observer and a subject of observation. The idea of dealing with the whole complexity of an organization must be discarded from the begining for that is impossible.

The expression "dealing with complexity" must be necessarily referred only to some aspect of the entity. The aspect in question is defined by the observer's intentions, in this Thesis it is assumed that the observer wants in the first place to predict -with some degree of certainty- events.

This assumption is entirely defensible on empirical grounds, for instance the manager that makes the decision of closing down a line of production in order to increase profits or to maintain a certain level of liquidity is clearly engaged in a predictive exercise. In a similar positions is the one that decides to explore new markets abroad or to launch a marketing campaign.

The assumption can be summarized in the idea that the observer -managers in this case- is always trying to understand how states follow each other.

Dealing with complexity, therefore is developing an understanding about how a source of complexity, say an organization behaves and about how a behaviour can be directed in some particular way.

7.1.2.- Measuring Complexity.

The relations that exist between the concepts of state, element and interaction provide the basis to approximate a measure for complexity. Beer (1979) suggests that the complexity of a system can be measured by its variety, which is defined "...as the number of possible states of whatever it is whose complexity we want to measure".

Since the number of states depends upon the observer's intentions, so does the amount of complexity measured in this way. It follows that this form measuring says nothing about the inherent complexity of the entity -in fact it has no sense to try to measure it- it only provide a measure according to a specific description of the entity.

Knowing that a system has a complexity of say 2^{400} does not help to understand its dynamics, however it may give to the designer important clues respect to the feasibility of his work and the plausibility of his methods.

The fact that the complexity of an entity -defined in this manner- depends to some extent on the observer's distinctions should not lead to the belief that he defines it completely. The distinctions that an observer can draw are only partially arbitrary.

Once an observer has made an initial set of distinctions, he then must find out the relations that may exist among the distinguished elements. These relations belong to the domain of the entity and can not be arbitrarily established. A coherent explanation of a dynamic process often requires to find out missing elements -new distinctions- and to establish actual relations.

It is important to bear in mind that Beer's measurement of complexity refers to the maximum number of states that an entity may take. Self-organizing systems however, by definition fail to display their total variety and their actual variety is usually well below the maximum.

That is the case of a constrained situation where some law, which is inherent to the entity's dynamics, is present. Dealing with complexity can certainly be interpreted as finding out the invariant. As soon as this is found, the behaviour of the system can be anticipated and complexity fades away.

7.2.- The Need for Rigorous Simplification.

Since organizations are sources of complexity, their effective management and the study of their behaviour require methods to deal with the complex in a rigorous manner.

There are several possible methods to gain an understanding of complex entities. Two of them are particularly relevant to this Thesis.

The first one consists of using an abstract mechanism that embodies the essential properties of all the other members of the class to which it belongs, for instance the ultra-stable system mentioned in the introduction of this chapter; the idea is to use a simple description which is sufficiently complete to learn about adaptive behaviour in general in order to apply its general principles to the design of human orgnizations. All that is required is a mechanism whose properties can be directly observed without interference from what is accidental and apparent.

As a unit of analysis, the ultra-stable system is purely abstract and it is used as a surrogate of any other adaptive entity like for example the Homeostat or an organism. A full description follows in next sections.

A second method consists of the use of dynamic modelling in order to understand the ways as a particular adaptive entity behaves. It is worth noticing the difference between the two methods, while the first one is used to learn about the nature of adaptive entities in general, the second is used to learn about the adaptation process of a particular entity. The importance of dynamic modelling becomes fully apparent in chapter IX.

7.3.- The Ultra-stable System.

The strategy that has been chosen demands a description of the ultra-stable mechanism to show in which way it encapsulates the essentials of adaptive behaviour. Of particular interest is the study of the mechanism's communication channels and information flows that are necessary for adaptive behaviour to take place.

As the discussion develops it will become clear that the use of this method provides the basis for a taxonomy of change in organizations.

7.3.1.- The Essentials of the Ultra-stable System.

The starting point of Ashby's formulation is the most fundamental fact that given a determinate dynamic system which is properly isolated, as the time passes the system inevitably goes to some form of equilibrium (1962).

A system that describes a trajectory towards an equilibrial state can conveniently be looked at as it were behaving selectively, rejecting non equilibrial states and sticking to the equilibrial ones for as long as the conditions of isolation remain.

The principle can be illustrated using the same notation of chapter V, for intance consider a system defined as in figure 7.1.

Given a system T with states a b c d and with tranformation:

T:	a	b	c	d
	a	c	a	b

The system's trajectory if properly isolated is:

$$d \longrightarrow b \longrightarrow c \longrightarrow a \circlearrowleft$$

Figure 7.1 An Isolated System.

The system as defined here looks almost trivially simple and probably useless to describe managerial situations. But at this point simplicity is wanted, this representation however can convey a great deal of complexity if required.

Each state for example may correspond to a complex description, and the transformation although simple may be the result of a difficult investigation. Thus, when a marketing manager says that product X has a life cycle defined by: development ⟶ introducton ⟶ acceptance ⟶ saturation ⟶ obsolescence ↺ , he is not defining in detail what goes on at each stage at a lower level of abstraction, but predicting the trajectory at a global level.

A marketing analyst in turn may observe the organization at a lower level and distinguish other states, for instance: market research ⟶ goal market determination ⟶ marketing channels identification ⟶ promotion campaign ↺ and so on.

The condition of isol.tion, on the other hand is not as artificial as a first look may suggest, it is also related to the level of abstraction. The idea that management takes place in a highly changing environment, does not invalidates the assumption; this type of statesment usually lacks accuracy in relation to what it is meant by disturbances and change of environment. The problem of isolation and interaction is discussed further in part IV, for the moment the observation of the fact that independence and equilibrium are highly common in nature and in management suffices.

Management takes place in a context where change and equilibrium abound and alternate, the system for identification of change aims, not the least to establish criteria to distinguish from a multitude of change those which are important to maintain over the time certain equilibrial states unchanged.

Figure 7.1 is a convenient starting point and has no other purpose than describing the property of selective behaviour of systems in isolation.

A further complication is required at this stage, in particular a feature to account for the property of equifinalty as defined by Bertalanffy (1973).

What is wanted is a system that shows the ability to reach the same final state even if it is started from a variety of initial conditions.

This can be easily achieved by introducing in the definition of the system several transformations instead of only one. Each transformation operating on the states according to the specific surrounding conditions prevailing at a given time. A simple description of a mechanism with this property is Ashby's Machine with Inputs.

7.3.1.1.- The Machine with Inputs as a Dynamic System.

Figure 7.2 contains an example of a machine with inputs, several possible trajectories are defined. Each of them acting on the states according to what surrounding conditions prevail.

The system of figure 7.2 describes a dynamic process in a variety of n contexts. Whenever there is a change in the surrounding conditions, for instance $T_1 \longrightarrow T_4$ the field defined by the set of possible trajectories also changes.

That this representation can show the property of equifinality can be grasped at a glance if observed the trajectories defined , for instance by initial conditions (T_1, d), (T_5, d), and (T_3, b). An observer that can only see the embodiment's behaviours, ignoring the transformations would find that the entity shows some preference for state a and would also

T	a	b	c	d
T_1	a	c	a	b
T_2	c	c	a	b
T_3	a	c	a	a
T_4	b	b	c	b
T_5	a	a	a	a
.				
.				
.				
T_n	b	c	a	d

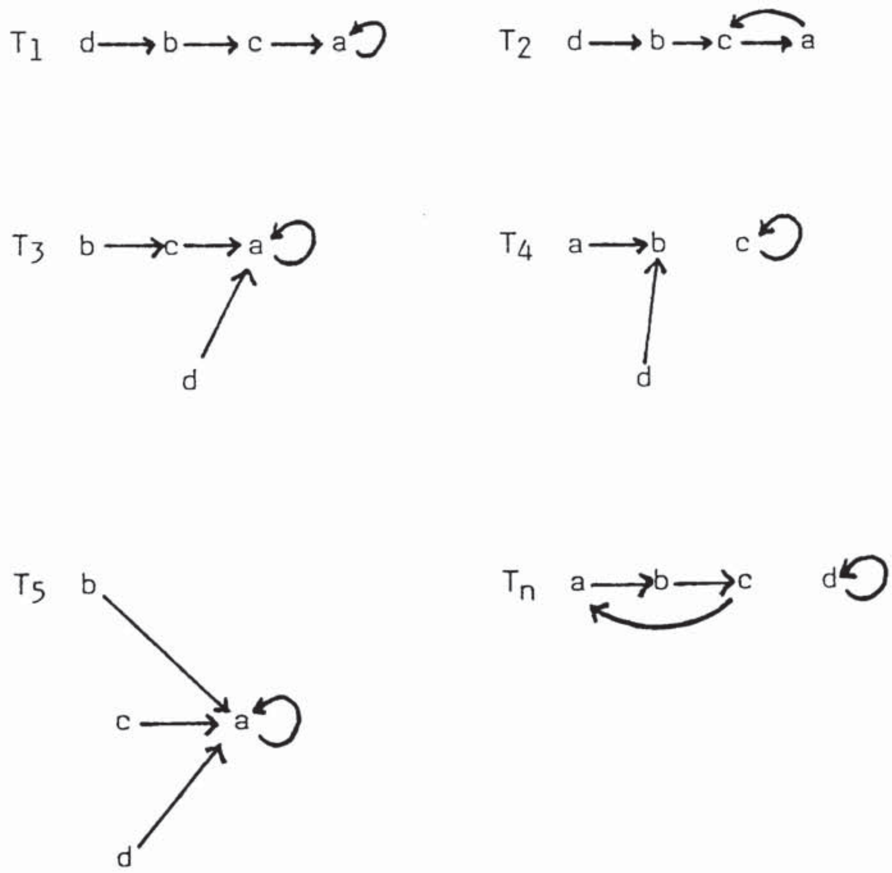


Fig. 7.2 The Machine with Inputs.

notice that it can get at it through several paths; sometimes it will take one unit of time to go from d to a, whereas in other ocasions it will take up to three units to get at a.

The machine with inputs can be used to define and illustrate the meaning of several important concepts. For instance it provides the basis to develop a rigorous taxonomy of change in organizations.

Two types of change can be identified in this representation, the first occurs when the system simply goes from one state to the next, for example from c to a; this change happens within a trajectory or when there is a particular surrounding condition prevailing at a given moment.

The second type occurs when the system's inputs change from one surrounding condition to the next, for example $T_1 \longrightarrow T_3$. The first type correspond to a change within a behaviour, whereas the second one correspond to a change of behaviour. They belong to different logical levels.

The distinction is not trivial, and its relevance to the design for identification of changes is paramount. Some examples will clarify it.

Consider for instance a company that decides to open a new branch to operate in area X. This system can be represented as describing a trajectory from the state of not having a branch to the one of having it. Of a different logical order is the sequence of states that describes the system as : locating a place ⟶ hiring a constructor ⟶ having the place ready ⟶ moving to the place ⟶ operating the new branch ↺ .

It is obvious that the information to support the decision of having or not having a new branch is logically different to that to support of hiring constructor A, B, or C. The machine with input although simple it provides unambiguous basis to establish these distinctions.

So far no suggestion has been made about the way the parameters change one after the other. To illustrate one possibility consider the presence of an observer capable of changing the parameters T_i at his entire will. Assuming that for some reason the observer prefers state a to any other and that he knows nothing about the machine tranformation except that it has six parameters to be manipulated.

If disturbances appear such as the system is moved away from a, the observer would need to do something in order to re-establish a. Assuming that the system is under condition T_1 and that disturbance D operates D(a) = d. If he does nothing he will notice that after three units of time his purpose is met again, thus if he wants to re-establish a in shorter period, he must do something, for instance to change the parameters at random, say from T_1 to T_4.

The result of such a move is to get the system stuck to b, so he must do something again. As the observer proceeds by trial and error, he will sometime get T_5 and then realize that keeping the parameters at T_5 is the most effective strategy, since it always re-establishes a after one unit of time.

The machine with inputs when coupled to some purposeful observer can be used to illustrate the meaning and relations of the concepts of learning and adaptation.

In this example, whenever the observer, after a disturbance -deliberately or not- forces the machine to go T_i T_5 he is diplaying his adaptation to the disturbance. Whenever the observer changes his behavour from moving the parameters at random to the behaviour defined by the tranformation R:

↓	T_1	T_2	T_3	T_4	T_n
	T_5	T_5	T_5	T_5	T_5

the observer has <u>learnt</u> to cope with disturbances in general.

Learning therefore is the process of acquiring adaptive behaviours towards disturbances, whereas adaptation is the process of making adaptive behaviour to occur given the presence of disturbances.

The distinction between parameters and states is subtle. To establish what variables stand as parameters is largely dependent on the method of observation and on the intrinsic nature of the dynamics at issue.

In a machine with inputs parameters and states may be defined as vectors of variables. The fundamental difference is given by the time scale at which they experience change.

The relation between parameters and states is time dependent , in the sense that the units of time taken to define the trajectory within a behaviour are considerably shorter than those that define transitions from parameter to parameter.

7.3.1.2.- <u>Behaviour of Coupled Dynamic Systems.</u>

Ultra-stability as a concept and phenomenon only makes sense when two dynamic systems -organization and environment- interact. For this reason it is necessary to have a look to the behaviour of coupled dynamic systems, it will be noticed that a peculiarity of coupled systems provides a necessary condition for ultra-stability to take place.

Discussion in the previous section included an example of a dynamic system interacting with an observer. A purpose was assumed to exist on the side of the observer, whereas an invariant set of transformations defined the system with parameters T.

In this section, however the assumption of the existence of a purposeful observer is lifted, since it is unnecessary to explain ultra-stability and adaptation. Whenever the term purpose is used in this thesis it can be regarded as a convenient short-hand for the fact that dynamic systems when left to their own forces go to some 'preferred' terminal state.

Two systems are said to be coupled when the values of the parameters of one of them is a function of the value that the states of the other take, and vice versa.

Coupling preserves intact the machines' configurations since it requires no modification of the transformations; but the way as the parts are coupled does determine their joint behaviour.

In the illustration of figure 7.3 two machines are coupled according to the transformations Q and S, in a way that they provide the whole W.

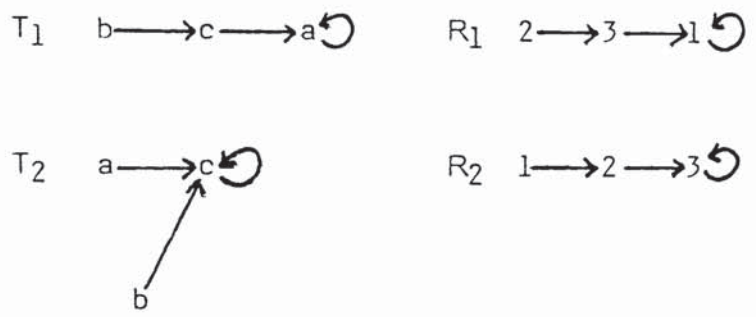
It can be noticed that when T and R are considered as two separate systems, there are four possible equlibrial states, namely a, c, 1, and 3;

T

T	a	b	c
T_1	a	c	a
t_2	c	c	c

R

T	1	2	3
R_1	1	3	1
R_2	2	3	3



Q

↓	a	b	c
	R_1	R_2	R_1

S

↓	1	2	3
	T_1	T_1	T_2

W

↓	(a,1)	(a,2)	(a,3)	(b,1)	(b,2)	(b,3)	(c,1)	(c,2)	(c,3)
	(a,1)	(a,3)	(c,1)	(c,2)	(c,3)	(c,3)	(a,1)	(a,3)	(c,1)

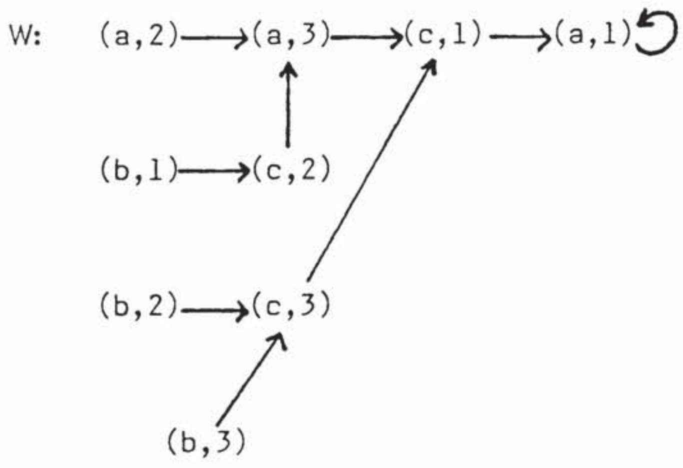


Fig. 7.3 Coupling of Dynamic Systems

whereas when coupled according to Q and S, the only possible equilibrial states for the parts are a and 1.

The crucial fact to observe in this example is that whichever are the whole W's equilibrial states, they must be such that its parts T and R must also be in equilibrium.

The remarked fact is the expression of Ashby's veto theorem (1976) which establishes that for the whole to be in equilibrium is necessary and sufficient that each part should be in equilibrium in conditions provided by the other parts. The importance of this theorem to this discussion is that parts when coupled act even more selectively towards states that provide equilibrium to the whole.

In the example of last section selectivity was determined by an observer's preference for state a. Vetoing theorem establishes that parts act selectively without resorting to the notions of end or purpose. Somebody watching the trajectories of R and T while coupled, could come to think that they were coordinating their behaviour in order to provide equilibrium to the whole. The topic of coordination is discussed further in part IV.

The example of figure 7.3 also shows that the behaviour of the whole also depends on the way the interactions are defined, according to Q and S in that case. The concept of coupling clearly shows that the behaviour of the whole depends on the nature of the parts as much as on the way as they interact.

7.3.2.- Ultra-stability and Adaptation.

In this section, the concepts of dynamic system, coupling with feed-back and the veto theorem are put together in such a way that the ultra-stable system as developed by Ashby is fully described.

The hypothesis that human organizations display adaptive behaviour assumes that they and their environment interact dynamically. From this it follows the fundamental fact that their interaction is subject to the general principles applicable to the coupling of dynamic systems.

7.3.2.1- Organization and Environment as Coupled Dynamic Systems.

Following Ashby's discussion on ultra-stability, the starting point is to draw a distinction between two dynamic systems. These systems can be described by sets of variables whose values over the time define sequences of states or trajectories; and their coupling is indicated in figure 7.4 by two arrows.

The arrows can be conveniently considered as representing a sensor and motor channel with which the organism or organization acts and reacts with its environment. This level of interaction plays its part within each behaviour as defined in section 7.3.1.1. it threrefore accounts for 'small' changes that generate 'minor' responses.

The type of interaction of interest is that which defines the organism's ability to survive. According to the definition of chapter V, a system that survives is one that keeps within pre-established limits the value of its set of Essential Variables. These values in turn may be changed by the presence of disturbances coming through the environment.

For the purpose of analysis it is therefore necessary to distinguish from

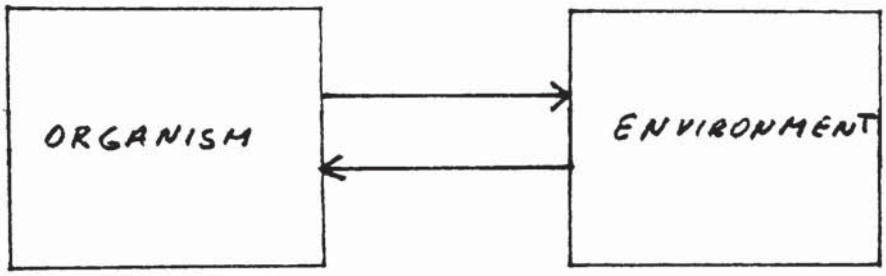


Fig.7.4 Organism-environment Coupling

the set of variables that defines the organism, a sub-set which contains the essential ones. In figure 7.5 this distinction is made explicit; the Essential Variables are taken apart from the original box and placed in a way that their exposure to the environment can be fully appreciated.

Figure7.5 does not show any immediate effect from organism to essential variables, a direct channel is in fact not necessary to explain adaptation. In chapter X however the possibility of the organization acting upon that set is discussed further.

The organism of figure 7.5 can be looked at as it were trying to keep its essential variables within limits by manipulating the environment. If the organism knows nothing about the way this relates to the essential variables, then its only possibility of survival is to try to keep them within limits manipulating the environment by trial and error; as it proceeds in this way it can be regarded as gathering information about the way as the environment relates to the essential variables by the black box method.

This type of situation in not very frequent in management, since in the majority of the cases managers know something about the way as these relations work. Nontheless sometimes management must face situation of high uncertainty, for instance when an entirely new problem crops up.

In those cases is not rare to see managers trying a little bit with one choice and watching what happens later in order to reach a conclussion on the way as the environment affects the organization. In this case the trial and error process can be regarded as one of gathering information to develop adaptive responses. Some degree of trial and error seems to be

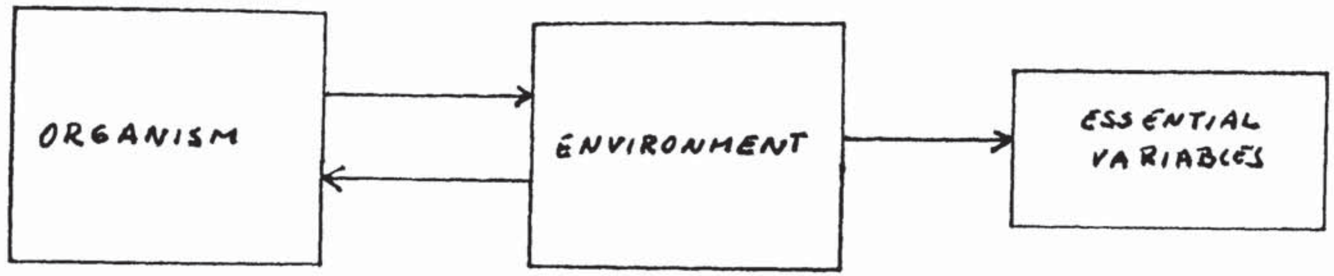


FIG.7.5 ORGANISM, ENVIRONMENT AND ESSENTIAL VARIABLES

inevitable when an organization is confronted to a complex environment. If only for this reason the process deserves the attention of the management scientist.

7.3.2.2.- The Necessity of a Second Feed-back Loop.

An organism that keeps its essential variables within physiological limits by reacting to the environment, requires to be informed of the state of them because two basic reasons.

In the first place it needs to know whether their values are being taken out of limits in order to react or not; and secondly to know whether the results of its effects on the environment have been successful or not.

If the essential variables have no effect on the environment, the existence of a second channel from essential variables to the rest of the organism is necessary, since there is no other way of gathering information. This second feed-back loop is described in figure 7.6.

It is now convenient to focus attention on the organism and look at it as it were a machine with inputs. That is to say as a dynamic system that can display a number of trajectories or behaviours.

The organism therefore can be looked at as having a repertoire of behaviours at its disposal which can be displayed and changed according to the value that the essential variables take. In figure 7.7 the set of parameters determining the the organism's behaviour is introduced as having an effect on it, and being directly affected by the essential variables.

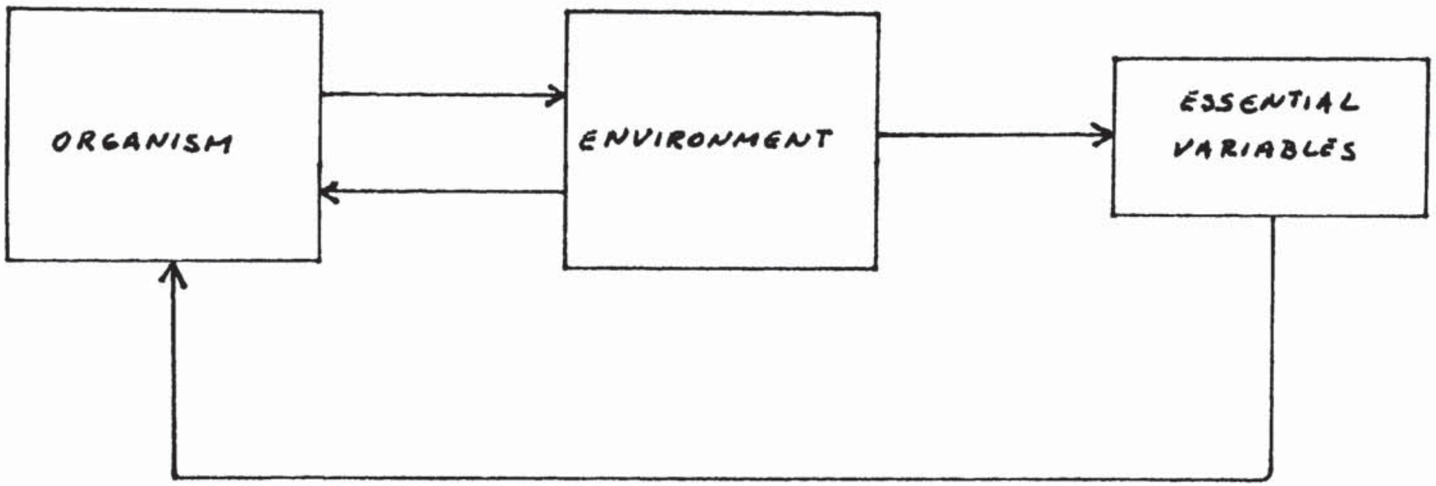


FIG.7.6 THE EFFECT OF THE ESSENTIAL VARIABLES ON THE ORGANISM

This second loop determines which behaviour takes place. It commands changes of behaviour whereas the first feed-back loop accounts for changes within a behaviour.

At this stage some clarification of the nature of the distinctions in figure 7.7 is necessary. In the first place the starting point has been to distinguish two sets of variables describing in a general way the coupling between organizataion and environment. Then from the organism description a sub-set of variables (essentials) was again distinguished, and finally a second sub-set of parameters as defined in section 7.3.1.1 was indicated.

Secondly, it should be noticed that the diagram and its distinctions are purely functional, in no way they indicate anatomical features. For instance the essential variables usually located inside the organism appear in the diagram outside the box organism; similarly the set of parameters appear to be acting on the organism from the 'outside'. The important thing to notice is that organism and environment form an inseparable unit on which some convenient distinctions are made.

Thirdly, the para meters P account for the surrounding conditions of the organism only, not for the whole coupling. P is therefore a significant sub-set of the total surrounding conditions containing the parameters that are directly affected by the essential variables and that have an effect on the organization's behaviour. In chapter VIII a second subset of parameters is introduced to discuss the possibility of learning, for the moment that set is not necessary to explain the occurence of adaptation.

7.3.2.3.- Adaptation and the Veto Theorem.

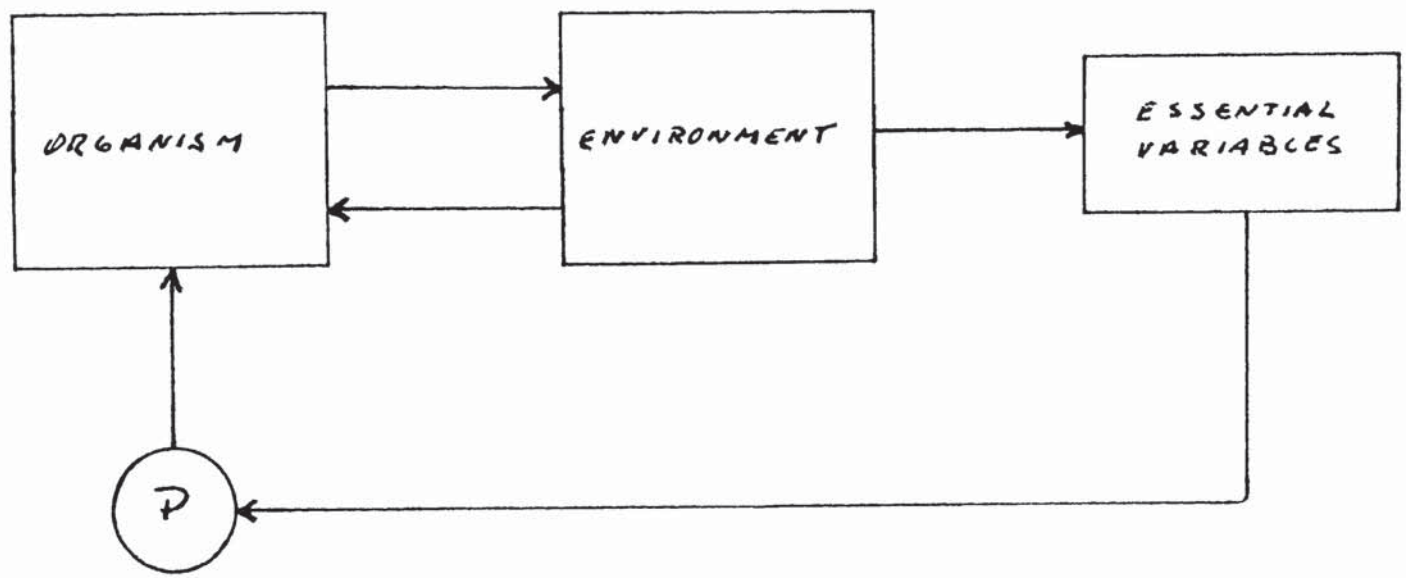


FIG.7.7 THE ULTRA-STABLE SYSTEM

The discussion on adaptation has demanded that two dynamic systems are coupled through a sensing and motor channel and that there is a second feed-back loop from the environment to the organism through the essential variables and the repertoire of behaviours P.

When to a system of couplings as the one described in figure is added the condition that P is at equilibrium only when the essential variables are within pre-established limits; and the veto theorem is applied,"...it follows that all possible states of equilibria of the whole have essential variables within given limits. So if the whole is started at some state and goes along the corresponding line of behaviour, then if it goes to an equilibrium, **the equilibrium will always be found to be an adapted one"** (Ashby 1976b).

The veto theorem establishes that whenever the whole is started from some initial condition -if it goes to some state of equilibrium- that must be one where the essential variables are within pre-established limits. If they are not within limits, P keeps changing -the organism will continue trying behaviours- and will do so until the essential variables are brought back to physiological limits.

Every equilibrial state of the whole is an adapted one in the sense that the Essential Variables are kept within limits.

In summary, for adaptive behaviour to be displayed is necessary -apart from the first loop- the existence of a second feed-back loop that carries information from the essential variables to the repertoire of behaviours. And it is sufficient if in the coupling organism-environment, the value of P does not change when essential variables are within pre-established limits, otherwise always change.

It is now possible to draw without ambiguity a distinction between the concept of stability as defined in chapter V and the meaning of ultra-stability as the property of a system of coupling like the one of figure 7.7 plus the conditions of linkages discussed in this section.

In the first case, a disturbance displaces the equilibrial state and the system returns to the same state without changing any surrounding condition. Ultra-stability occurs when after a disturbance displacing the equilibrial state the system responds by changing some conditions until the same equilibrial state is re-established.

The mechanism and related concepts as discussed so far can provide initial clues for the design of information Systems for identification of changes . This possibility is realized in chapter VIII.

CHAPTER VIII

INITIAL IMPLICATIONS TO DESIGN

The Ultra-stable system as described in the last chapter, already contains some important clues for design of Information Systems. The clues can be better understood if some of the implicit conditions for ultra-stability are made explicit and related to managerial situations. Next sections discussed the conditions and their implications.

8.1.- Implicit Conditions for Ultra-stability.

The last chapter's definition of ultra-stable system assumes that the variables that define the organism and the environment -including the essential ones- vary continuously, whilst the parameters P change discretely over the time.

Those assumptions give simplicity to the mechanism and make easier its use as theoretical unit of analysis, but apart of that practical consideration, the hypothesis that in actual organism-environment interaction the variables vary continuously seems to be fully defensible.

An example drawn from a practical managerial situation and some discussion on the topic of continuity may shed light on the suitability of the assumption.

For instance an organization that is facing financial problems can be looked at as an organism whose essential variable liquidity is approaching its physiological limits. The value of this variables is probably being monitored on daily basis, if it goes out of limits the organization will have to do something, namely to display a behaviour which may fall into one of the following hypothetical situations: going public, selling part of its assets, borrowing money from the goverment or re-negotiating its liabilities.

If for example the organization decides for the first alternative, the decision defines a discrete change of behaviour from not being public to going public. This change unchains a sequence of minor changes through the organization and environment until -if successful- they lead to the re-establishment of a safe liquidity level.

These minor changes occur continuously in relation to the change of behaviour which 'jumps' from not being public to being public.

A similar example can be taken from the observation of the adaptive moves of organisms, for instance a hunter that goes from resting to hunting. This single change -probably triggered by an essential variable reaching a critical value- determines that the organism and environment's variables undergo a sequence of minor changes that stand as continuous when compared with the change of behaviour.

In relation to the example of a company with cash problems, the assumption of liquidity being a continuous variable may be questioned on the grounds that cash flows into the organization by discrete sums of money. A management accountant in charge of the short term financial planning may well develop the idea that liquidity varies continuously.

A discussion on whether such and such variable is continuous or discrete is of no use to this Thesis, for most of practical purposes variables are observed and changes are noted discretely.

To say that the variables in the organism and in the environment change continuously is just to say that when compared with change of parameters, the former take place at considerably shorter periods. The topic has been somehow discussed in section 7.3.1.1.

The assumption of continuity in the essential variables -as defined here- is necessary for the working of the Ultra-stable system. The fact is that an organism that survives must have its essential variables moving at small steps within physiological limits and approaching their critical values little by little.

It is convenient to distinguish three mutually exclusive sets of values that the essential variables may take. The first set includes the 'normal' values in the sense that they do not trigger change of behaviour; the second set includes the values that do provoke changes in the parameters values, this are called the critical values; and the third type are those that are incompatible with the process of survival and that defines the lethal area.

The distinction between change in the value of variables and change of parameter can be conveniently translated to the managerial jargon by identifying change of parameter with change of policy, and change in the value of the variables as changes occurring as the result of implementing a particular policy. From now on, change of policy and change of parameters are considered synonyms.

The assumption of policies changing at discrete steps is obviously compatible with the example of a company with cash problems. It is clear to every manager that once the decision of going public is made, time must be allowed to elapse to see the effects on the variable liquidity. No doubt a policy must always be kept invariant for some specific period of time.

In a more general sense, for a system to display adaptive behaviour it is necessary once a parameter changes to some value, this should be kept to that value for some time. At each trial, time must be allowed to elapse in a way that the trajectory can be observed to know whether that particular policy has been successful or not to bring the essential variables back to their physiological limits.

In principle the duration of each trial -that is to say the period of time that the parameter must be kept unchanged- is related to the time taken by the information to go from change of parameter, through the organism, the environment and the essential variables, to complete the cycle at the parameters' position again.

The amount of time taken to complete the cycle is crucial to successful adaptation, since too much time means losing the opportunity to try other policies; and too little may prevent the system from sticking to an adequate policy. Both extremes diminish survival chances.

It is therefore crucial, from the point of view of survival that organizations are able to recognize the necessary length of the period for change of behaviours. A design for identification of change should provide an indication of these lengths.

The importance of time to survival can also be illustrated considering the relation that must exist between time for adaptation and the frequency with which disturbances upset the essential variables. It is evident that if perturbations come to the organization with a periodicity that is shorter than the time taken for adaptation the survival possibilities tend to vanish.

Time for adaptation relates to an organism viability as an essential variable itself, it has an upper and lower limit. The topic is discussed again in Chapters XI and XII.

Finally, it is worth noticing that the ultra-stable system as described in chapter VII makes no demand about the ways as changes in P follow each other. The mechanism as originally developed ba Ashby assumes that changes in P occur at random; constraint in the behaviour of the parameters are not necessary for adaptive behaviour to occur.

8.2.- Initial Implications for the Design of a System to Identify Changes.

The mechanism as discussed so far, can only account for a very simple simple type of adaption, since the condition of parameters changing at random. A system of this sort can be called ultra-stable by trial and error.

From the point of view of regulation, the ultra-stable system can be regarded as a 'Regulator by Error' -according to the clasification of chapter VI- since the channel carrying information about disturbances goes through the essential variables themselves.

Although organisms and organizations do many times adapt by trial and error, it is also evident that they display more sophisticated modes of adaptive behaviours like foresight and learning.

The mechanism as discussed so far does not permit us to arrive at a design that can deal with information about the future nor with the possibility of storing information on past events in order to use it later for the purposes of adaptation. It does, however provides some fundamental initial hints to arrive to a design that can effectively enhance organizational viability.

Chapter IX is devoted to the discussion of the requirements for foresight and learning, for the moment it is convenient to indicate what is already possible to learn from the study of the basic mechanism.

8.2.1.- Essential Variables, Critical Values and Pre-established Limits.

In the first place consider the relation between critical values and physiological limits, to this purpose see figure 8.1.

The ultra-stable system establishes that for an organization to survive, the set of critical values and the physiological limits must be in a proper relation, otherwise the information coming from the essential variables may have no value.

For instance, in figure 8.1.a the critical area is too wide, in this situation changes are triggered when it is nowhere necessary. In this example the essential variable shows 'normal' periodicity which could be interpreted as presence of disturbance if the critical area is too wide. Such a possibility

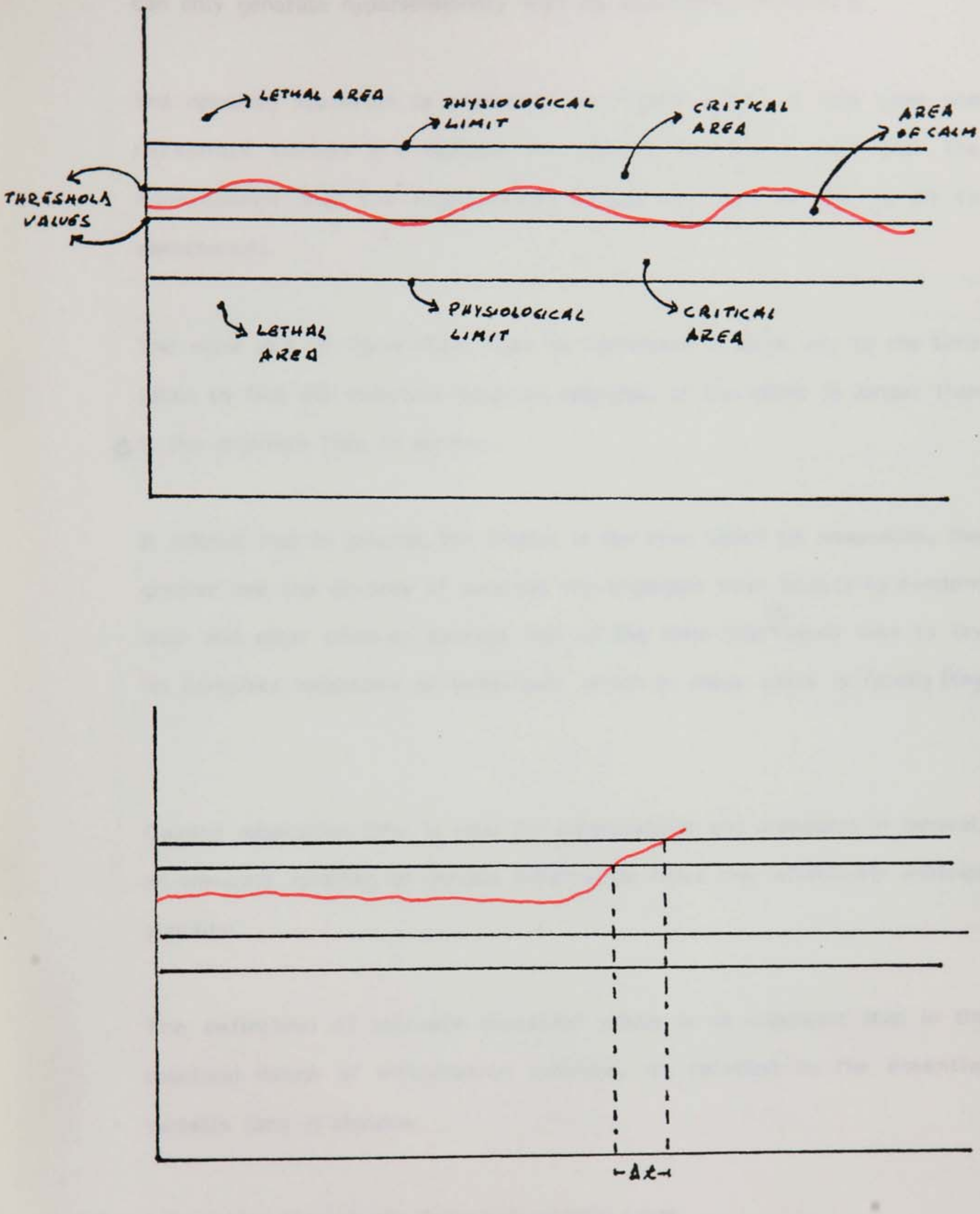


Fig.8.1 Essential Variables and Physiological Limits

can only generate hypersensitivity with its subsequent pathologies.

The opposite situation is presented in figure 8.1.b, in this case the threshold values are defined too closely the lethal area with the consequence that the organization reacts too late or not at all to disturbances.

The value Δt of figure 8.1.b must be correlated in some way to the time taken to find the effective adaptive response. If the latter is longer than Δt, the organism fails to survive

It follows that in general, the shorter is the time taken for adaptation, the greater are the chances of survival. An organism that adapts by random trial and error takes on average half of the time that it would take to try its complete repertoire of behaviours which in many cases is fatally long.

Gaining adaptation time is vital for organizations and organisms in general, an adequate speeding of certain information flows may effectively enhance viability.

The definition of suitable threshold values is an important step in the practical design of information systems, its relation to the essential variable time is obvious.

8.2.2.- Information through the Second Feed-back Loop.

The ultra-stable system of figure 7.7 includes no source of noise affecting the information flows from essential variables to the parameters. The enhancement of adaptive capacity requires as little noise or blocking as

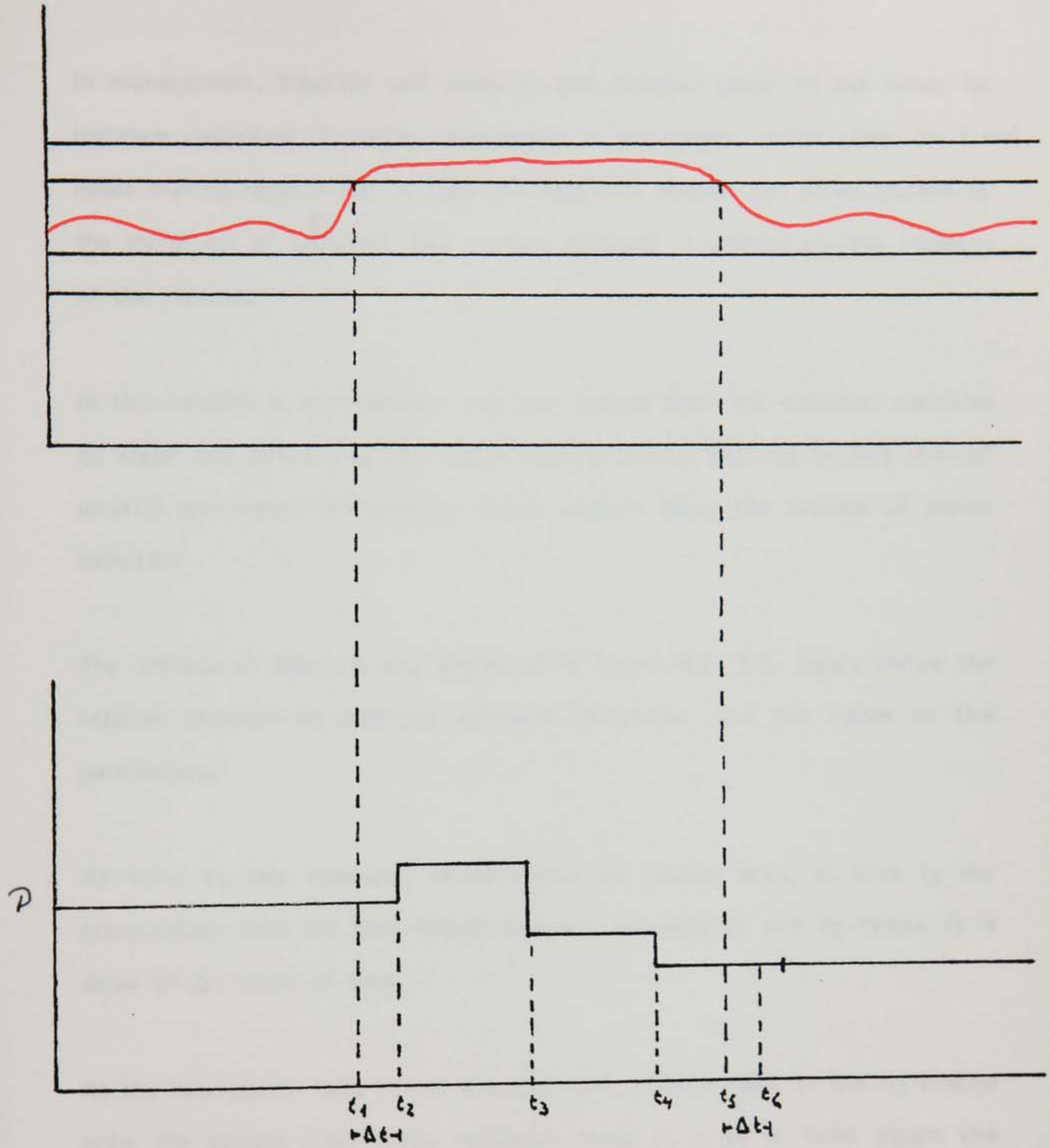


Fig.8.2 Essential Variables and Policy Change

possible in this channel.

In management, blocking and delay in this channel occur all the time; for instance important financial information is produced periodically on fixed dates making reports out of date or irrelevant. Signals are often blurred by the inclusion of additional data making difficult to understand the meaning of the reports.

In this respect it is important that the signals from the essential variables go clean and directly to the policy making points. Failures in this channel usually generate unnecessary trials and/or delay the process of policy selection.

The effects of blocking are described in figure 8.2. The figure shows the relation between an essential variable behaviour and the value of the parameters.

At time t_1 the essential variable gets its critical area, at time t_2 the organization tries its first adaptive move. Between t_1 and t_2 there is a delay of Δt units of time.

As the new policy fails to put the essential variable back to the no change area, the system tries a new move at time t_3 ; as it fails again the parameter changes again at t_4 ; this time it succeeds at t_5, but it realizes of the success at t_6 , since there is a delay time of Δt.

Further analysis would show that, up to some extent the smaller t the greater the chances of adaptation and that this delay Δt is a determining element in the organization's dynamics.

In actual managerial situations, the designer must cater for a direct and clean channel from essential variables to the corresponding decision point, this suggestion complements the meaning of the concept of information in real time as discussed in chapter V.

8.2.3.- <u>Duration of the Trials.</u>

It has been established as a matter of necessity that at each trial the parameters are kept constant for some time to let the behaviour manifest its effects on the essential variables. It is also clear that neither of the two extremes -changing too soon or too late- is convenient to enhance viability. It follows that there is an optimal duration for each trial which in general is defined by by the time taken by the information to complete the cycle through the second feed-back loop of figure 7.7. In the example of figure 8.2, the duration of the trials is of Δt units of time; the same example suggests that the duration should not be shorter than $t_6 - t_4$.

In principle a design should contain an estimation of the optimal duration of each trial or at least provide an indication of the problems that may arise from abandoning too quickly a policy that otherwise would have restored stability; or sticking for too long to a hopeless strategy.

8.2.4.- <u>Types of Changes in the Essential Variables.</u>

The threshold values offer the basic criteria to distinguish between changes that are relevant from those which are not. The initial criteria is then to report whenever the essential variables touch the critical area.

In many occasions however, the essential variables start going to the critical area slowly, but in sustained way; it is then convenient to use some monitoring method capable of providing information on whether changes occurring within the area of normality are likely to take the variable out of limits or not, in a way that some anticipation is possible.

On the other hand it also may happen that an essential variable goes out limits as the result of a transient event and quickly returning to its normal area. In this case it would not help to start changing policies since the system itself can show its stability going back to physiological limits.

The design should include a monitoring system capable of providing information about the probability of such events.

8.3.- Initial Requirements for a Design.

It is now possible to summarize the minimal requirements for the design of a System that identify changes that are meaningful to survival:

i.- Threshold values for the essential variables to trigger action must be properly defined in adequate correspondance with the physiological limits. Alternatively, a set of correlated variables should be found and monitored in such a way that the signal for change of behaviour occurs adequately with respect to physiological limits.

ii.- Provide conditions for immediate effects from essential variables to change of parameters. That is to say, sources of noise and distortion should be avoided.
This is the condition of real time provided that the term is understood as discussed in chapter V.

iii.- Determine adequate time length for each trial. That is to say, a design should include an estimate -as precise as possible- of the time length that information takes to complete a circuit through the second feed-back loop.

iv.- The design must include a filtering method to spot any significant change in the essential variables. By significant is meant any no-transient change that take the variables to the threshold value, and those that even if they do not take them out of limits, indicates a trend towards the critical area.

CHAPTER IX

ENHANCING CONDITIONS FOR LEARNING AND FORESIGHT

The use of the ultra-stable system as an abstract unit of analysis to draw conclusions for Information Sys tems design have already yielded the results summarized in last chapter.

This set of conclusions is sufficient to to shed light on some of the frequently reported problems of current designs, particularly in relation to over-abundance and timeness of information.

It is however clear that the mechanism as described so far does not provides clues to enhance more complex types of adaptive behaviours as for instance anticipation and learning.

These types of behaviours are so typical of higher organisms and organizations that to leave them out would impoverish the design to almost triviality. This chapter discusses the necessary modifications to the mechanism in order to include learning and foresight among its properties.

9.1.- A Mechanism with learning Capacity.

As it has been discussed in chapter VII, the origin of adaptive behaviour does not require learning nor memory capacity, trial and error is sufficient.

Nevertheless, immediate adaptation to familiar situations is so common in nature that the idea of adaptation without learning is hard to accept. The pervasiveness of the phenomena of learning in the organic world is surely due to its enormous survival value.

Learning as the ability to display adaptive behaviour at once, it is obviously advantageous to viability. The quicker an organism displays adaptive behaviour to disturbances the less likely its essential variables are taken to the lethal area, and the readier is the organism to face a second disturbance.

Trial and error as a method for adaptation is not quite efficient, but it is always necessary when an organization faces an entirely new situation. If the organism has some learning capacity, the use of trial and error can be regarded as means to gather information about the proper way of adaptation to a particular type of disturbance.

For an organism to take advantage of learning it is necessary that disturbances and the context in which they take place repeat themselves over the time. Thus, speaking of learning does necessarily require the possibility of repetition of the disturbance and the environment's behaviour.

The condition of repetition demands the introduction of no new fundamental assumption, for as it has already been discussed in chapter V, constraints and invariances are two essential features of nature.

In general the concept of constraint applies to the relation between the maximum variety that a system can display and the variety that actually displays under certain conditions.

The importance of the concept to a theory of survival and viability stems from the fact that as nature is constrained, it fails to display its total variety over the time; events tend to follow specific patterns and to repeat thamselves. Under this hypothesis, organisms and organizations can take advantage from repetitivity of phenomena, they can expect regularities in the way as perturbances take place.

The type of constraint that is particularly relevant at this stage is that of simple repetition, where the repetitive event can be assessed independently from the order that it has in the sequence.

Under those circumstances, an organism 'knows' that given a particular already experienced disturbance, all it has to do is to apply the same policy or parameter that was effective the first time.

An organization adapts itself by learning if once it has shown its adaptation to a particular disturbance it is capable of adapting immediately if the disturbance occurs again, without having to to start looking for the successful policy all over again. Such a mechanism is in principle capable of adaptation to a disturbance before the essential variables are affected by the disturbance.

9.1.1.- A Modified Version of the Ultra-stable System.

To introduce the possibility of learning and foresight requires to modify in some way the representation of figure 7.7.

In the first place consider the environment as a dynamic system describable as a machine with inputs. As such its dynamics is determined according to the prevailing conditions or parameters operating on the variables that define the environment states. In figure 9.1 the environments inputs are indicated by an E.

According to the discussion of section 7.3.1, a change in the value of the parameters of a dynamic system determines a change in its field and consequently a change in its line of behaviour. "A system's stability depends on its field, a change of parameter values will in general change a system's stability in some way" (Ashby 1976b).

Therefore, every change in the environment's parameters may affect the value of the essential variables in some dramatic way. It follows that the set of parameters of the environment may be partioned into two mutually exclusive sub-sets, one conataining those parameters whose changes make no effect on the essential variables' value, and the other containing the parameters whose changes effect the stability of the essential variables. The latter sub-set is by definition a source of disturbances.

Now it is necessary to distinguish two types of disturbances affecting the organization of figure 9.1. The first type is that which was considered in chapters V and VII, this is variety transmitted through the environment without changing the environment's prevailing conditions.

The second type of disturbance is the one that has as a source changes in

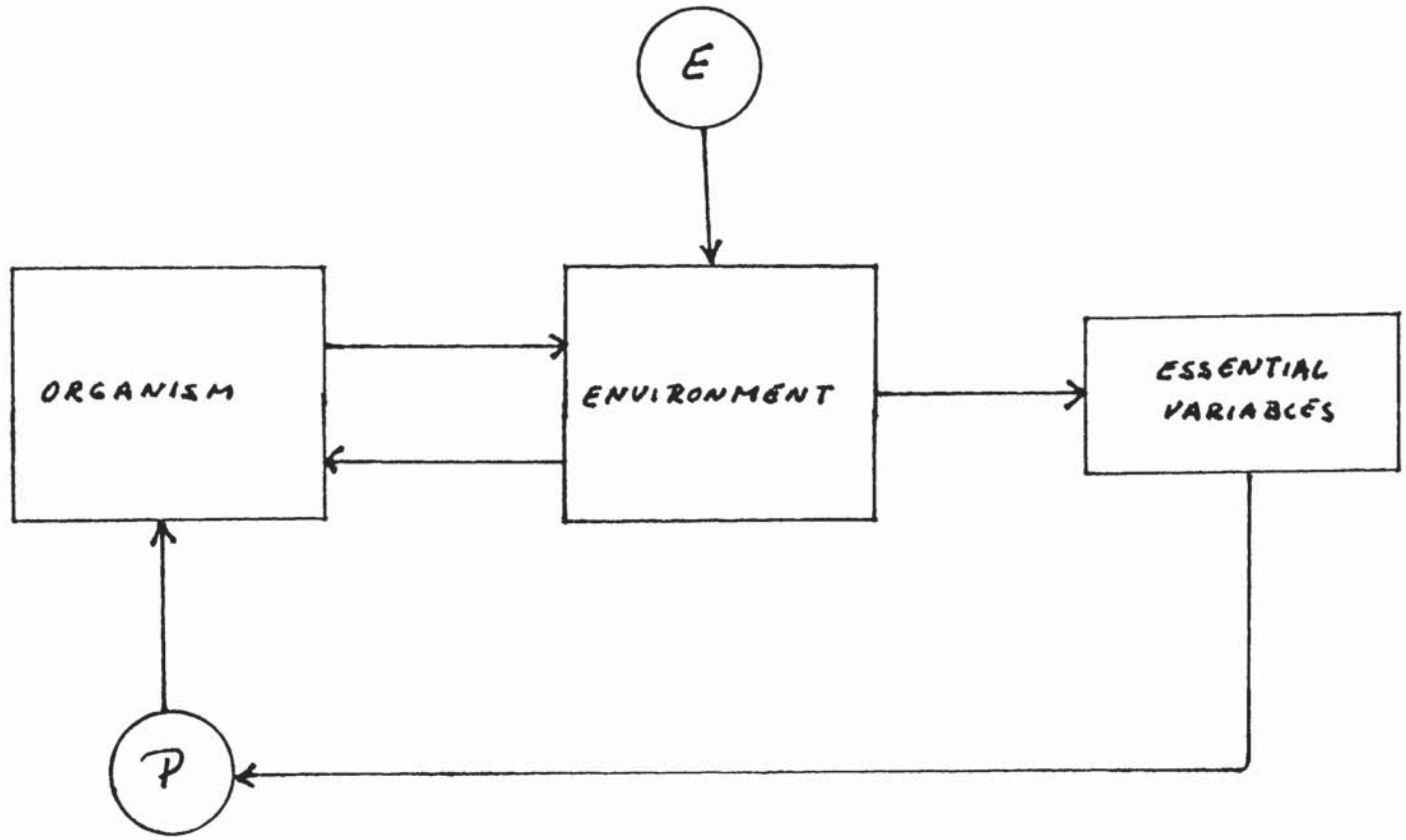


FIG.9.1 THE ENVIRONMENT'S SOURCE OF CHANGE

the environment's parameters and implies a change of the coupling stability.

For the purposes of further analysis, the first type is ignored and the second type is assumed to be dealt with through the second loop.

The channel from Essential Variables to the Meta-controller -see figure 9.2- is therfore reserved to carry information about perturbances that having been originated in a change in E, were not arrested on time either because the Meta-controller could not recognize them as disturbances or because it had no effective policy available.

With theses considerations in mind, it is now possible to proceed with the discussion on the organization's capacity to adapt to repetitive disturbances. By repititon of a disturbance is therefore understood the situation where a change in the value of E results in a configuration of the environment's parameters already experienced by the organization.

Endowing the ultra-stable system with learning capacity requires to introduce new elements into the formulation.

In the first place the organism must be sensitive and capable to recognizing changes taking place in E. This requirement defines an information channel from E to P.

In the second place, the organism, if it is not going to adapt at random requires immediate selection over the set of policies P.

Thirdly, the organism requires the ability to associate with every value of

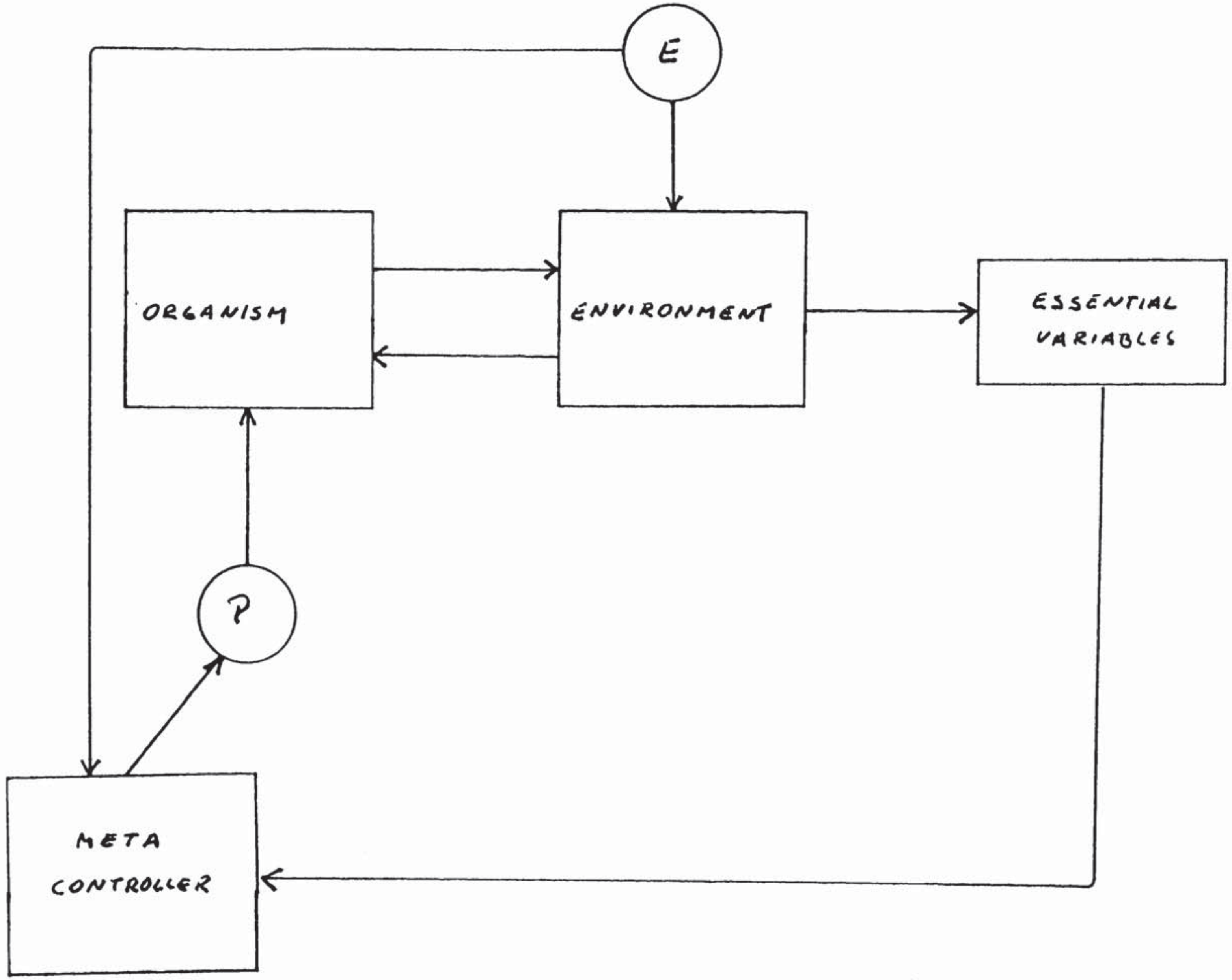


FIG.9.2 THE META-CONTROLLER AND INFORMATION CHANNELS

the set E, a value of the essential variables, and a response value P that is effective towards the perturbations, since in addition to the capacity to 'feel' changes in E it must identify those changes that are harmful to the essential variables stability. That is to say it is required some capacity of abstraction and memory to recognize contexts that jeopardize its survival.

These requirements demand the introduction of a new mechanism that commands P and has the abilities already mentioned; it must function as meta-controller of the coupling organism-environment. A discussion on the way the meta-controller comes about is contained in part IV, for the moment it can be taken for granted.

The Meta-controller of figure 9.2 to be able to display inmediate adaptation to a repetitive environment requires the capacity to recognize the prevailing environmental conditions that defines the environment's behaviour.

A system with these characteristics shows foresight for it literally anticipates the situation of essential variables going out of limits.

In figure 9.2 the Meta-controller receives information from two sources; the channel from E carries information about changes in the surrounding conditions that may affect the essential variables' stability, and a second channel from essential variables reporting whether they are within physiological limits or not. The first one anticipates to changes in the essential variables -it provides conditions for anticipated regulation- whereas the second report changes actually taking place in the target, creating conditions for regulation by error.

It is now possible to summarize the way as the process of learning in a mechanism such as the one of figure 9.2 may take place. Consider first the organism under conditions E as being with its essential variables within limits; then a change from E to E' defines an environment's behaviour that move the essential variables to the critical area. The system starts -by the method of chapter VII- a series of trials in order to put the essential variables back to the calm zone.

Assume that the system succeeds when the combination of parameters P' is present, the system then stores the information that the combination E' and P' gives stability to the essential variables. If after undergoing changes in both E and P, E' occurs again and the system without going to a trial and error process immediately responds with P', the organism can be seen as having anticipated to the disturbance effects, since its essential variables are kept within limits.

A system undergoing this sort of process can be regarded as as one that learns from it own mistakes, it amplifies selective capacity over the set P by 'remembering' past events and shows its foresight by being able to respond to changes of the environment as well as to changes in the essential variables.

The modifications just introduced provide new hints for Information Systems design, but before drawing any conclusion it is convenient to have a look to some other possibilities of learning.

9.1.2.- Immediate Adaptation to Entirely New Situations.

The discussion so far has been focussed on the possibility of learning from own experience and by repetition of contexts. It is often found in reality that individuals and organizations are sometimes able to adapt at once to completely new conditions, without having to resort to trial and error.

The possibility of adaptation to situations never experienced before is probably given by the remarkable amount of constraint and repetition that nature displays. Particles do not wander chaotically in the universe, they combine themselves into stable substances, compounds, organisms, species, populations and societies; the coexistence of homogeneous systemic units provide conditions for amplification of selective capacity.

An organism that is capable of accumulating adaptation -in the way discussed in section 9.1.1- does not need to carry out all the trials itself if it can perceive contexts and homologous adaptive organisms. If it can perceive other organisms engaged in adaptive processes, then, in principle it can learn from others.

A basic requirement for an organism to be able to display this type of learning is to have an information channel carrying information which is not immediately relevant to the state of the essential variables, but which is related to the adaptive process of other individuals.

For an organism that faces the problem of rapid selection of adaptive behaviour, to receive clues to speed up adequate selection can only enhance its viability . The statement suggests that not all variety comes to the organism as menace to its survival, some of it may be effectively used to block that variety that threatens the essential variables.

"The discussion in this chapter has shown that variety (whether information or disturbance) comes to the organism in two forms. There is that which threatens the survival of the gene-pattern - the direct transmission by the Environment from Disturbance to the Out-come. This part must be blocked at all cost. And there is that which, while it may threaten the gen-pattern, can be transformed (or re-coded) through the regulator and used to block the effect of the remainder in the Environment. This information is useful, and should (if the regulator can be provided) be made as large as possible; for by the law of Requisite Variety, the amount of disturbance that reaches the gene-pattern can be diminished only by the amount of information so transmitted". Ashby (1976).

A system that can immediately adapt to a situation never experienced before needs a channel providing variety re-codifiable into useful information, and consequently the capacity to re-codify.

In nature, organisms and organizations show to have this channel in the form of instincts or tendencies to gather information. It takes for instance the form of curiosity and exploratory behaviour in animals, and preference for planning and long term project evaluation in human organizations.

The hypothesis that organizations are capable of displaying foresight and learning rests on the fundamental assumptiom that they also have the ability to associate contexts with the state of their essential variables and with the value of their policies. The assumptions when applied to external adaptive processes provide the condition for re-codification of potentially harmful variety into useful information.

The Meta-controller, therefore should have the ability to establish analogies among situations, formulate hypotheses about the nature of contexts and to make choices of policies according to these processes.

In figure 9.3 two sources of variety are introduced, one acting on the Environment's parameters making its way to the Essential Variables; the other one is shown flowing to the Meta-controller to be re-codified into useful information. The loop Meta-controller, analogy, hypotheses, Meta-controller represents the ability to associate states of the environment with the values of P and the Essential Variables, and consequently to re-codify variety into useful information.

The system as described here, shows its foresight and learning whenever it spots changes at E and responds with a change of parameters that prevent variety from flowing to the essential variables.

9.2.- The Mechanism in Terms of Regulation.

It is now convenient to have a look to figure 9.3 in terms of regulation, the communication channel from the essential variables to the Meta-controller provides the conditions for regulation by error, since corrective action is triggered by signals coming from the target.

It has been shown by Connant (1968) that in this type of regulation the entropy of the target -in this case the essential variables- can not fall to zero, since the regulator gets information about the necessity of correction from the target itself. Corrective action needs variety in the essential variables to be effective.

Figure 9.3 also contains the more interesting case of a regulator that truly anticipates to the occurrence of a change in the essential variables when the information for corrective action is taken directly from the source of disturbances. This type of regulation makes possible that the entropy of the

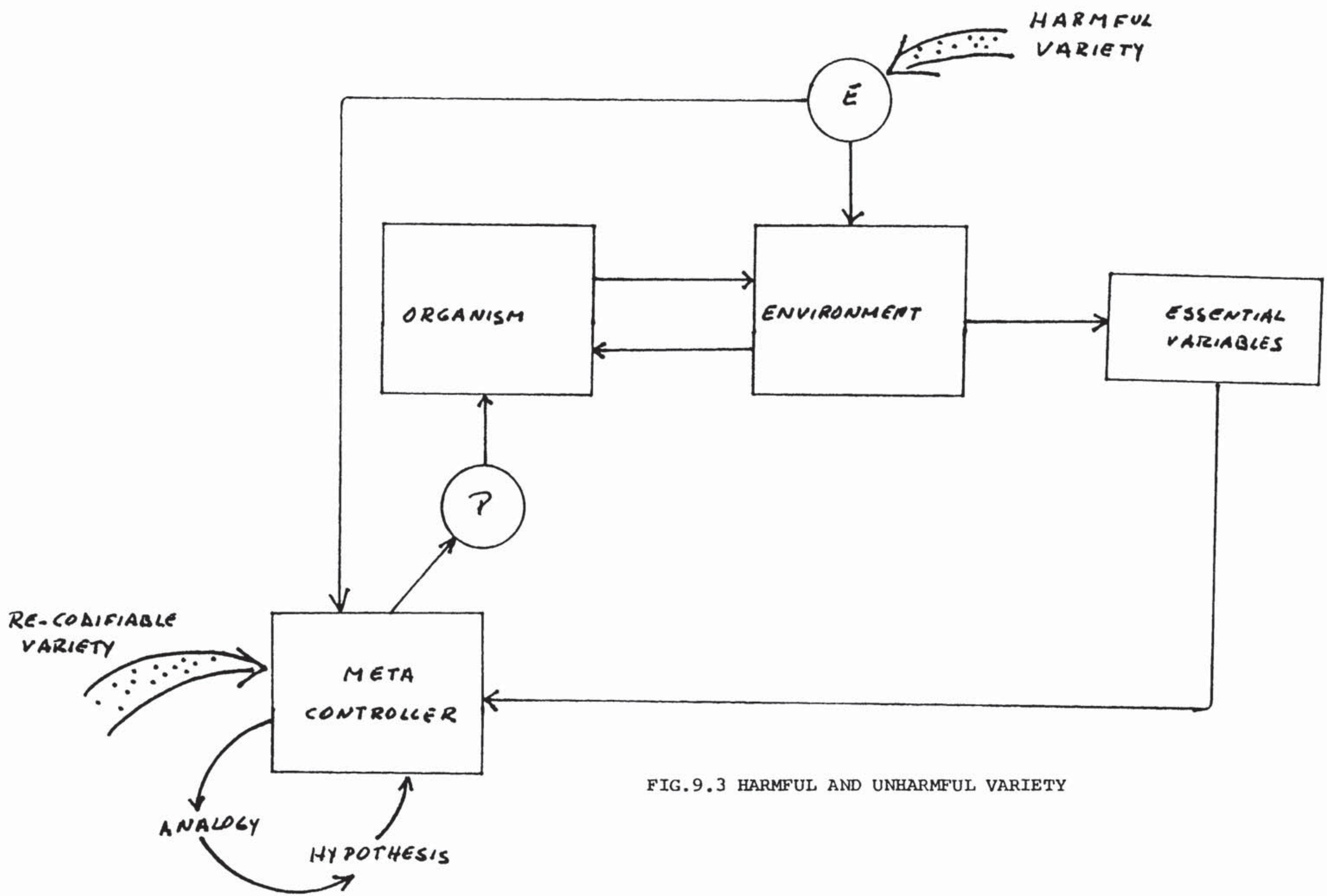


FIG.9.3 HARMFUL AND UNHARMFUL VARIETY

essential variables is kept to zero. "When, however, the regulator R draws its information directly from D (the cause of the disturbance) there need be no residual variation: the regulation may in, principle, be made perfect". (Ashby and Connant 1970).

Ashby and Connant have proved that given a regulator that displays a set of regulatory events R and a set of 'opponent' events in a reguland S, and that the regulator and the reguland jointly determine the value of the outcome, the simplest optimal regulator R of a reguland S produces events in R which are related to the events S by a mapping $h: S \longrightarrow R$. In simpler terms the theorem says that the best regulator of a system is one which is a model of that system in the sense that the regulator's actions are merely the system's actions as seen through a mapping h.

By optimal regulator is meant one whose events are so related to the 'opponent' that their joint action make the entropy of the target minimal.

The theorem is most relevant to the problem of Information Systems design and provides an answer to the problem of the Meta-controller having the ability to establish relations between the states of the environment, the essential variables and the policies. It says that an organization that is both successful and efficient as a regulator requires models of its relations with its environment. It establishes that one of the problems of regulation is the one of searching for models that give adequate account of the relations between the regulator and the reguland.

The type of model which is particularly appropriate for a regulatory process as the one described in figure 9.3, is one that explicitly considers the dynamic nature of the relation between an organization and its environment, in a way that the real time t of the events is mapped into a model time t'; which can be handled experimentally.

With the use of dynamic models it is possible to look at disturbances as uncertainty on the value of the environment's inputs. Simulation permits to work out adaptive responses to hypothetical change of inputs, providing conditions for developing a repertoire of adaptive behaviours to be brought into play as disturbances actually occur.

Although for the purposes of simple adaptation modelling is not necessary, efficiency and simplicity fully justify to consider it a requirement to Information Systems design.

9.3.- Further Requirements for Design.

It is now possible to add further requirements to the list of section 8.3, they are:

i.- An information channel carrying information from the environmental conditions E to the Meta-controller.

ii.- An information channel from the essential variables to the Meta-controller, informing of disturbances undetected at E.

iii.- A means to perceive significant changes in E, analogue to the one used to monitor the essential variables.

iv.- Meta-controller's capacity to associate the states of E with the states of the essential variables.

v.- Meta-controller selective capacity over the repertoire of behaviours P.

vi.- Meta-controller capacity to perceive organization-environment relations at various level of abstraction , in a way that hypotheses formulation is possible.

vii.- The Meta-controller must contain a model that maps the dynamic interaction between organization and environment, in a way that is possible to simulate hypothetical initial conditions to perceive the likely consequences of alternative policies.

Figure 9.4 graphically summarizes the requirements for an Information System that identifies changes and suggests a third type of change.

Since the organization's survival is directly dependent upon the stability of the essential variables, it follows that it is always necessary to monitor their values.

Since in general, changes in the value of the parameters change the system's stability and may have an effect on the essential variables' value; to enhance viability, by shortening the adaptation time it is necessary to determine which environmental conditions significantly affect the essential variables, and monitor their value. .

Since the enhancement of survival capacity is also depentent on the ability to quickly select effective policies, it is necessary to have a conceptualiztion of the way as the sets E and P relate to each other and define as the outcome the value of the essential variables. For all practical purposes, such

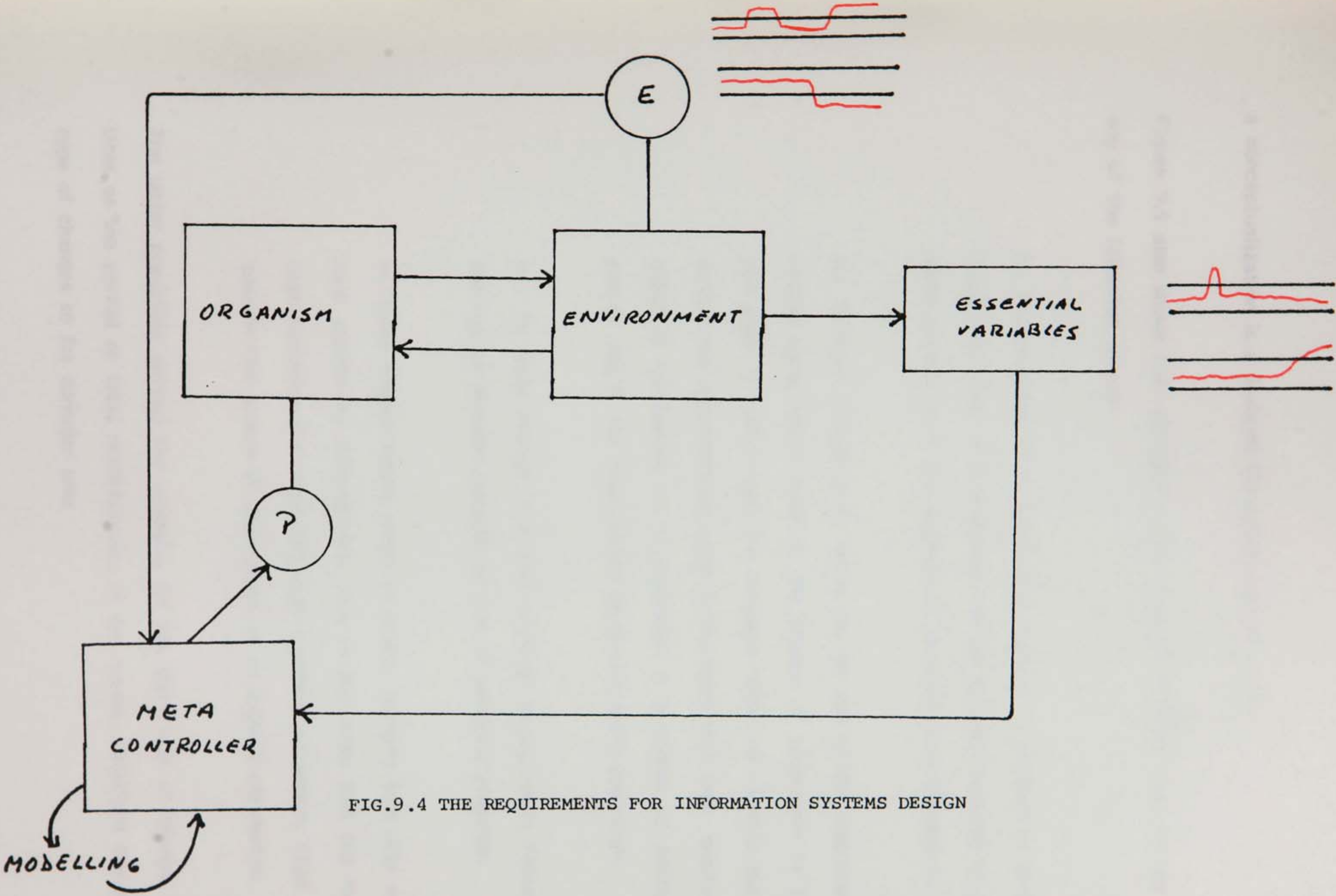


FIG.9.4 THE REQUIREMENTS FOR INFORMATION SYSTEMS DESIGN

a conceptualization is a Systems Dynamics type of model.

Figure 9.4 also shows that changes in the essential variables must be due to any of the following causes:

i.- The presence of a disturbance type 1, as defined in section 9.1.1. This type of disturbance can be directly tackled in the same manner as in the example of situation B in Chapter V.

ii.- To some change in P, which can be due to the organization having made failed trials in the process of adaptation by trial and error, in which case the message "essential variable out of limits" has informational value in the sense that that particular policy is eliminated; or, if originated in a change of policy it can be due to the organization developing some pathology.

iii.- To some change in E that although having been detected can not be arrested because of lack of adequate response.

iv. Some change taking place in reality bringing into play some new source of disturbance. New in the sense that the model that describes the organization-environment dynamics, does not contain this source of disturbance as an explicit parameter.

The latter possibility defines the necessity for the third type of change. This time as the partial or total reformulation of the model. Therefore the three type of changes so far consider are:

- Changes within a behaviour, as those taking place through the first feed-back loop of the ultra-stable system.

-Changes of behaviour, as those defined by the change of parameters and/or policies values, involving transmission through the second and third loop.

-Changes of model, as those defined by the organization's necessity to amplify its conceptual grasp of the its dynamics, involving a change in the Meta-controller.

This classification is concluded in Chapter XII.

CHAPTER X

THE BASIC COMPONENTS OF A SYSTEM THAT IDENTIFIES CHANGES AND AN APPROACH TO DESIGN

10.1.- The Basic Components of a System that Identifies Changes.

Having established the requirements for an Information System that identifies changes that are meaningful to organizations' viability, it is now possible to indicate its basic components, their interrelations and to suggest an approach to practical design. Figure 10.1 shows these elements.

There is in the first place a communication channel carrying information about the states of the organization and its environment. That is to say, informing about the value of the essential variables and about the values of the environment's parameters and organization's policies that effect those variables.

At a higher level there is a second channel that informs on the invariants that define the dynamics of the organization-environment relationship. It expresses itself as a model of the real world and embodies the

Meta-controller's epistemological approximation in terms of implicit beliefs and methods of observation.

The third basic component is provided by the Meta-controller regarded as the mechanism that, as a result of its ability to perceive at both levels of abstraction, defines the mode of behaviours that are suitable for adaptation. This activity is represented in figure 10.1 by the arrow from Meta-controller to reality.

Some of the Meta-controller basic activities is to build models of the way reality works, finding out which environmental conditions and policies are more closely related to the essential variables states, and establishing the manner in which changes should be monitored.

10.1.1.- The Conceptual Channel.

In figure 10.1, the upper arrow from reality to the Meta-controller represents the variety flow that comes from the environment and that can be recodified into useful information. It informs on hypothetical causal relatioships that defines the dynamics of variables and parameters in general.

The closed loop between the representation of the resulting model and Meta-controller indicates the activity of formulating and re-formulating the model as result of the confrontation of hypotheses with the real world. Whatever is the result of the confrontation it is assumed that some model -with some degree of credibility- is always prevailing.

It is in this model where the whole design must rest upon, for it is the model that in the last event defines the variables and parameters to be

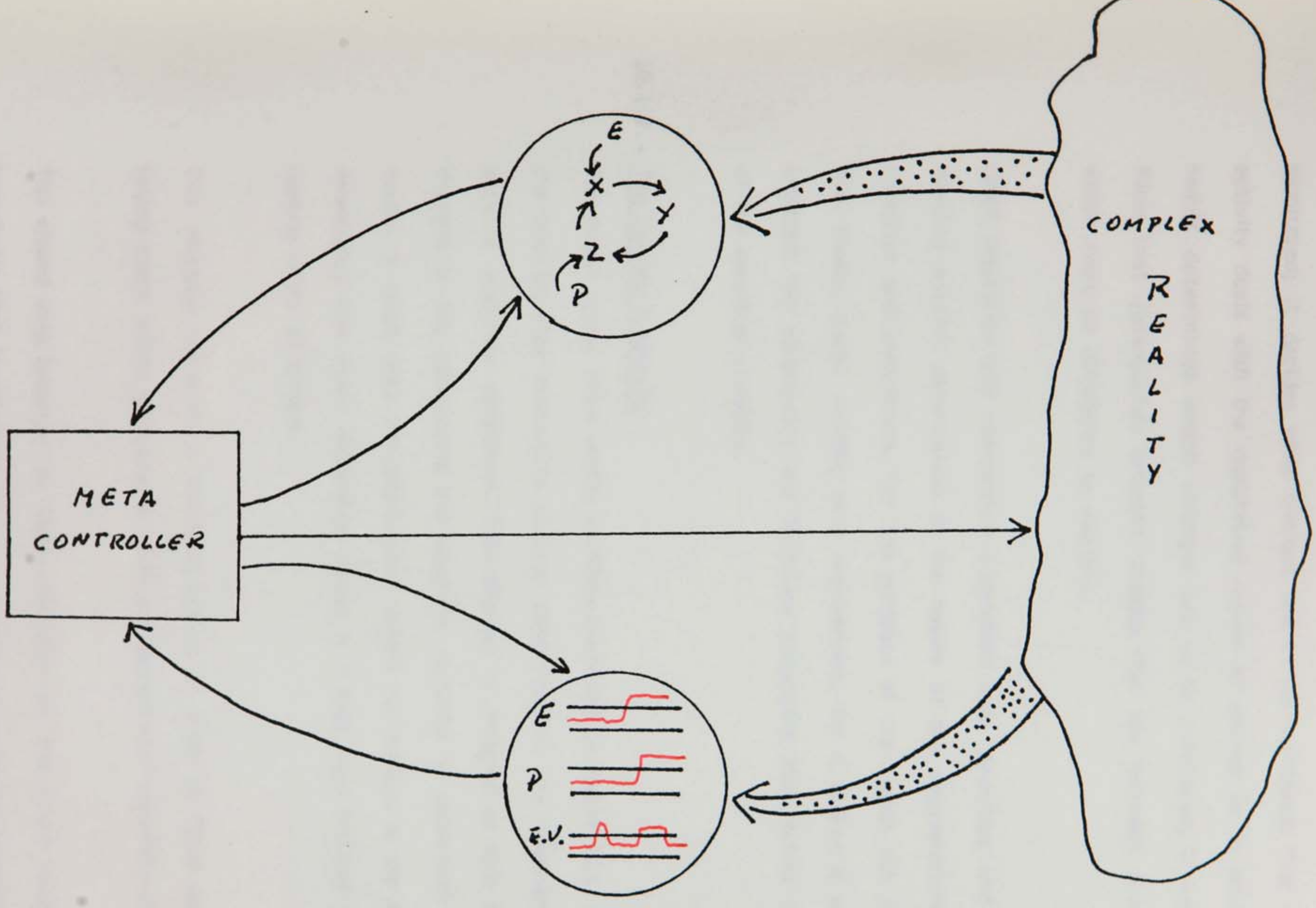


FIG.10.1 THE BASIC COMPONENTS OF A SYSTEM THAT IDENTIFIES CHANGES

monitored; it decides what changes are to be monitored. The modelling activity deals with the qualitative aspect of change in as much as its result determines which changes are to be monitored, it works as a filter that distinguishes between changes that are relevant from those which make no difference to viability.

Good regulation and non-random adaptation need modelling and with it, making explicit assumptions on the nature of the interrelations between variables and parameters. For the purposes of the design put forward in this Thesis, model building is a requirement, for it makes it possible to establish the parameters and feed-back structures that define the values of the essential variables.

10.1.2.- The Sensing Channels.

The lower arrow from reality to Meta-controller in figure 10.1, represents the channel that transmits change detection to the mechanism that selects adaptive responses. This channel is designed to spot significant changes in the parameters and essential variables as determined by the model. It deals with the quantitative aspect of changes in the sense that establishes how much difference makes a change, and informs about the current state of affairs.

The channel includes a filtering device in order to filter out changes taking place within physiological limits together with transient variations.

The closed loop between the Meta-controller and the sensor illustrates the hypothesis that in an organization, the sensor can be deliberately designed and modified according to the nature of the prevailing model.

10.1.3.- The Meta-controller.

This element represents the organization's function of selecting specific adaptive behaviours in response to changes detected as having, or about to have an effect on the essential variables' stability.

The arrow from Meta-controller to the environment closes the loop and represents the organization as acting upon the environment in order to assure that the essential variables are kept within physiological limits.

The Meta-controller in interaction with the environment through these two channels encompasses the whole idea of the managerial function. The closed loops in each of the channels also emphasize the thesis that modelling and information systems design are tasks for management and that these task cannot be delegated to internal or external consultants. From the point of view of efficient adaptation they are the most fundamental tasks of management. Further discussion on ultra-stability in part IV includes a more complete description of the functions of the Meta-controller.

Modelling as it has been argued, cannot be an optional activity; it is a pre-requisite to Information Systems design. The latter to be effective can only be model based.

Information Systems design with no model of the organization-environment interaction, and modelling without an understanding of the information flows and channels capacity are two important reasons why many designs and models fails to support effective decision making.

A separate approach to these activities and ideas like that managers should not bother about models and information systems create no condition for successful implementation.

The identification of these three basic elements as components of a system that identifies changes, and in particular their interrelations in the dynamics of adaptation provides the fundamentals for practical information systems design.

Figure 10.1 shows hypotheses formulation about the organization's dynamics as a necassary function for effective management; it establishes that only once that level of filtering has been achieved the design of the sensing mechanisms to spot changes can follow. An information system design must be a function of the understanding of the organization-environment's dynamics.

10.2.- An Approach to Practical Design.

The purposes of this section are to indicate the necessary tasks to design and implement an Information System design based on the principles and theories discussed so far.

Changes that are meaningful to Corporate Management are those that in one way or another may affect the organization's viability. For this reason the design discussed here can be regarded as an enhancement of survival capacity.

A system is viable if able to display stability in its essential variables; that is to say if able to block harmful variety from getting those variables. Ashby's observation on the relation between the mathematical concept of stability and the biological process of survival fully justifies the use of

Control Theory as a tool for the study and enhancement of organizational, social and ecological survival. Mathematics provides a sound theoretical framework for the formulation of a general theory of viability applicable to organizational, social and ecological phenomena.

The steps to Information System design and re-design are described in figure 10.2. Next section contains a description of the basic tasks to be performed. The initial step is the definition of the essential variables.

10.2.1.- Essential Variables Definition.

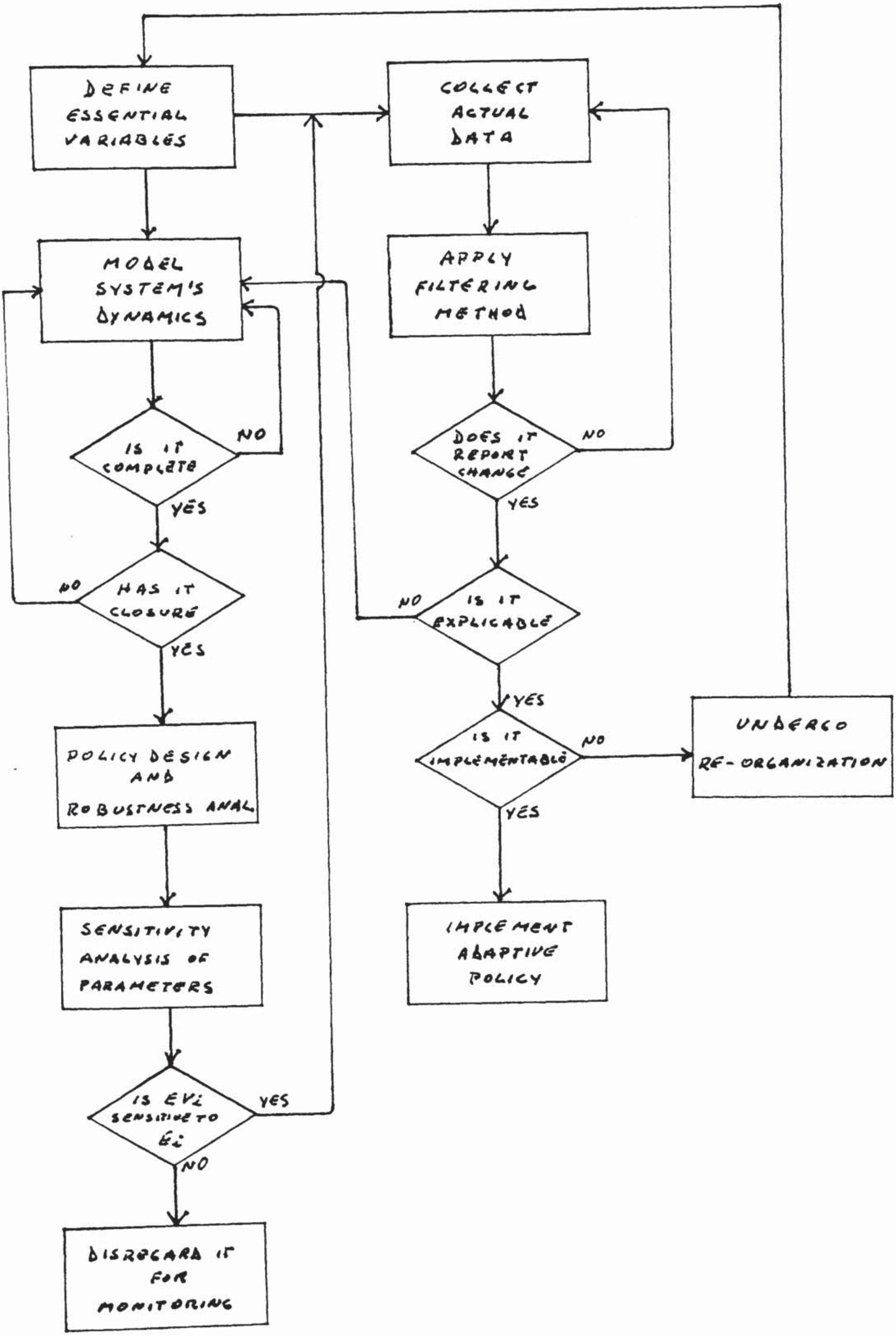
The topic of essential variables has been discussed already twice in this Thesis and in Part IV the discussion is concluded.

Bateson's hypothesis on the necessity of collateral energy source can be empirically verified by observing adaptive processes in mechanisms as diverse as Ashby's Homeostat -with its flow of electricity- to the earth's solar energy based eco-system.

Organisms, organizations, and societies can be looked at as mechanisms engaged in the vital activity of providing adequate sources of energy. Their behaviour is primarily one of gathering energy while keeping their essential variables within physiological limits.

The description defines two types of behaviours, on the one hand that of gathering energy, and on the other hand that which protects the organism from having its essential variables out of limits. This view is illustrated in figure 10.3.

The figure suggests that there is energy available and that the organism



DEFINE ESSENTIAL VARIABLES
COLLECT ACTUAL DATA
MODEL SYSTEM'S DYNAMICS
APPLY FILTERING METHOD
IS IT COMPLETE
NO
YES
DOES IT REPORT CHANGE
NO
YES
HAS IT CLOSURE
NO
YES
IS IT EXPLICABLE
NO
YES
IS IT IMPLEMENTABLE
NO
YES
UNDERGO RE-ORGANIZATION
POLICY DESIGN AND ROBUSTNESS ANAL.
IMPLEMENT ADAPTIVE POLICY
SENSITIVITY ANALYSIS OF PARAMETERS
IS EVi SENSITIVE TO Ei
YES
NO
DISREGARD IT FOR MONITORING

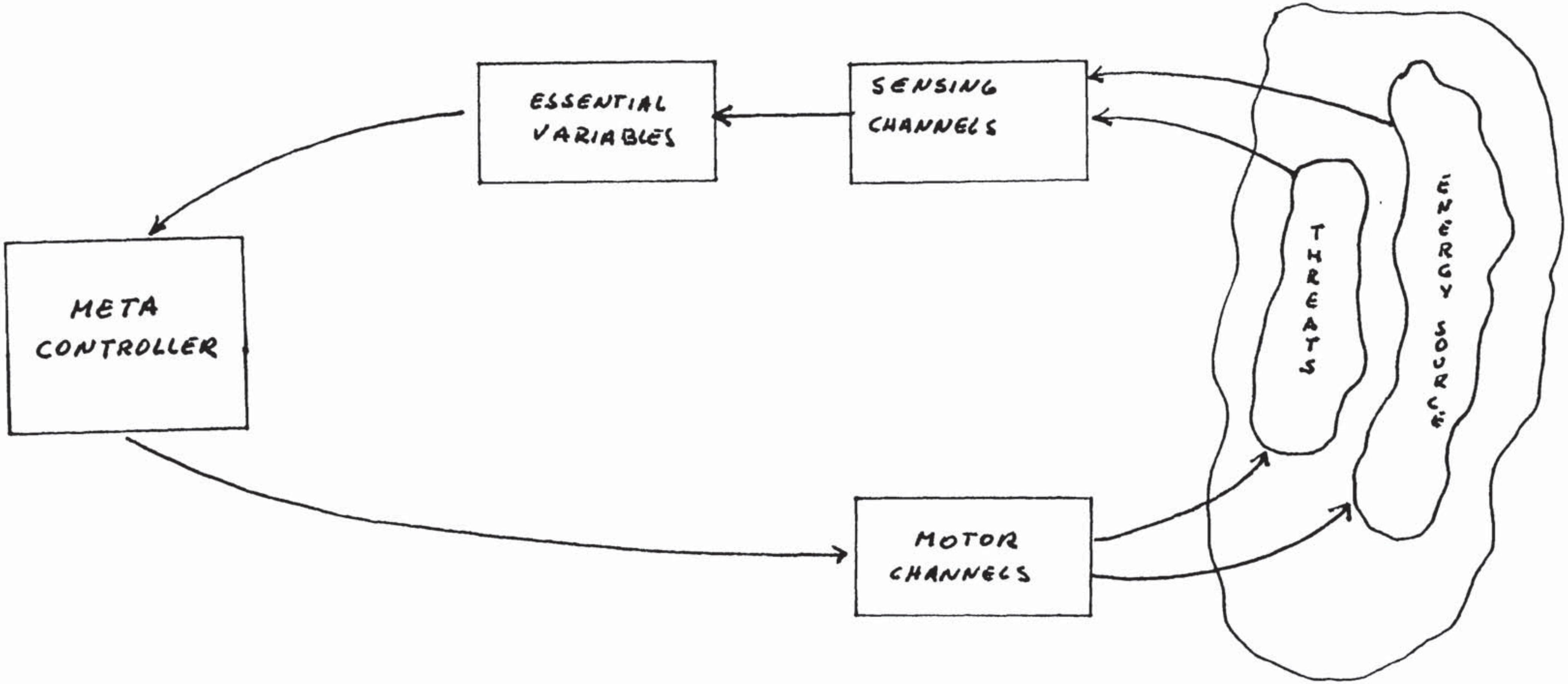


FIG.10.3 AVOIDING AND GATHERING BEHAVIOUR

can get it provided that dangers are adequately avoided.

Since avoiding and gathering behaviours requires a certain amount of energy expenditure, this amount defines the lower limit of this essential variable. It follows that organisms and organizations enhance their survival capacity as individuals if they are able to accumulate energy from an easily accessible source.

In terms of economics, energy gathering can be looked at as the process of creation of use value, and human organizations' basic activity as that of generating an energy surplus by assuring that the total energy expenditure in the transformation of natural resources into use value is less than the amount of energy equivalent to the change value attainable in the market.

It is therefore defensible, possible and convenient to express the problem of organizational viability in terms of cash flows and profits. By doing so this cybernetic study provides the pragmatic manager with a justification for his concern with profits and liquidity.

This discussion however, is not intended to suggest that the energy flow is the only factor that defines viability. In sections 8.2.1 and 8.2.3, it was pointed out that successful adaptation was also dependent on the organism's ability to keep its policies for a period that was not shorter than the necessary to complete a loop and not so long as to cause the essential variables to arrive at the lethal area before a convenient number of policies is tried.

In this way the time taken for adaptation becomes an essential variable in itself, with an upper an lower limit. It is the introduction of this new variable what finally justifies the necessity of a System Dynamics type of model in the design, since its mapping of real time t into a model time t' gives the possiblity to formulate hypotheses about timeness of response and to study the effects of information delays in the dynamic of the organization.

The criteria of energy source provides the starting point for design; it is a well known empirical fact that organizations give a great deal of attention to their financial performance, but this by no means constitutes their only activity. As suggested in Chapter VI, if an organization has at its disposal an adequate level of energy it can get engaged in the fullfilment of some other purposes.

The idea that diferent needs may take the foreground of the organization's attention is shown in figure 10.4. The arrow from the Meta-controller to the essential variables indicates the organization's ability to change and set temporary goals.

The importance of this possibility is that if the set of essential variables is changed from the energy source to some other set, a 'new' information system is required to be run in parallel with the one that reports on profits and liquidity.

The immediate practical consequence of this situation is the possibility of developing several information systems more or less independent which are used in parallel and whose importance alternates according to priorities that the Meta-controlling function has established.

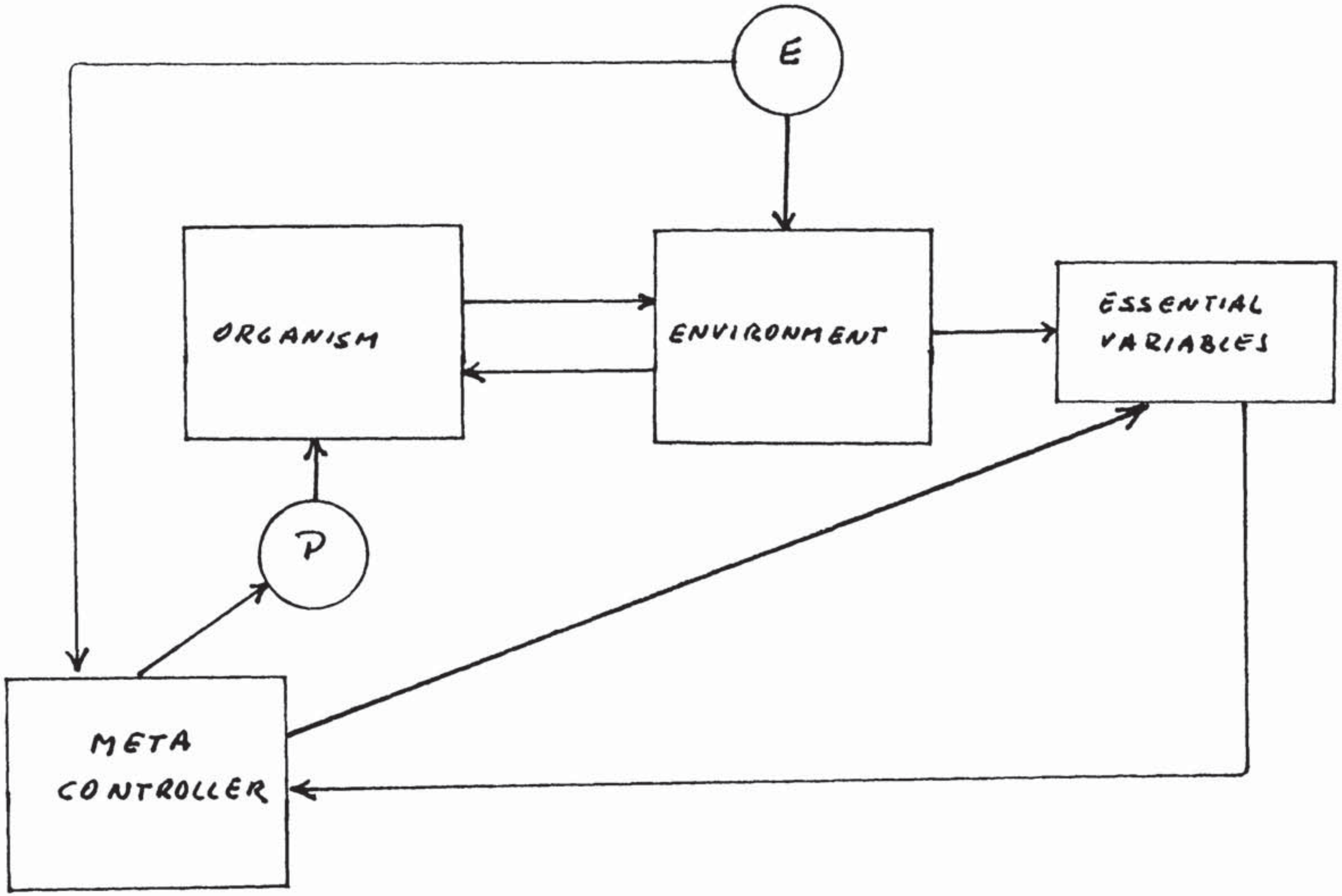


FIG.10.4 THE EFFECT OF THE META-CONTROLLER ON THE ESSENTIAL VARIABLES

10.2.2.- Modelling the Dynamics of Organization-Environment Coupling.

The Ultra-stable system as described in figure 10.4 shows that the organization's viability is affected by disturbances coming from the Environment; in particular by those that originate in changes in the value of the parameters. In general, uncertainty in the value that the parameters of the system can take can be regarded as a source of perturbations.

For the purposes of practical design it is necessary to identify the specific variables and parameters that have an effect on the value of the essential variables.The identification of parameters that affect the essential variables and effective policies requires a detailed study of the dynamics of the organization-environment relations. This study is best achieved by the process of building a dynamic model.

10.2.2.1.- The System's Variables and Parameters

Every dynamic modelling process starts with the definition of an initial set of variables that provides a provisional description of the system. In this case the initial set is given by the essential variables.

The immediate problem to be tackled is to identify what other variables are to be part of the system in order to achieve an understanding of its dynamics. Coyle (1978) has suggested a method for extending the model according to the criteria of completeness and simplicity.

Coyle says that the model to be complete in some respect must have the property of closure; meaning that the model must contain at least one feed-back loop and that all the variables lie on a loop, have been defined as exogenous to a loop, or provide supplementary output from a loop.

To answer the question of how many variables should be included in the model, it is necessary to bear in mind that in general there is no limit to the number that can be included . There is however the fact that individuals' capacity to process information places practical limits; for this reason there must be some methods to stop the modelling process before its complexity makes it unmanageable.

Coyle has suggested that the purposes of the model building exercise and the results obtained by closure testing of increasingly complex versions of the model are to indicate when to stop including new variables. The idea is that no model can be consider complete in the sense of including every single aspect of reality, and that the requisite of completness is given by the model's closure in relation to its feed-back loops.

For the purposes of the design of a system to identify changes the problem of model size can be solved by defining what variables are wanted to be regarded as parameters. The important methodological issue is to keep the integrity of the closed loops in the regions of dense linkage.

Once the model provides a reasonable explanation of the real world and unveils some counter-intuitive factors it can be used for the purposes of design. The necessity to enlarge it is provided by the dynamic of running the System in relation to new unexplained perturbances.

10.2.2.2.- Policy Design as Development of a Repertoire of Behaviours.

Once a working model is available it is possible to work out the combination of environment's parameters and organization's policies that make the essential variables resistant to disturbances. This process is equivalent to finding the combination of policies that makes the model robust against a wide set of disturbances.

10.2.2.3.- Sensitivity Analysis of the Parameters.

The dynamic of the essential variables of an organization is not equally sensitive to every parameter of the environment. Changes in some of them may dramatically affect their values and consequently the organization's viability.

It is therefore crucial to identify those parameters to which the essential variables are particularly sensitive. The purpose of sensitivity analysis is then to establish which changes in the environment are important to the organization's survival and to establish the critical values of variables and parameters and the limits of adaptation time.

Sensitivity analysis in general involves the idea of making experimental changes in the value of the parameters and/or in the structure of the model in order to observe the effects on the value of the essential variables. When the model involves a large number of variables and parameters, trial and error or purely intuitive trials may be unfeasible since the number of combinations of paramaters value and model structure grows exponentially leading to the necessity of a huge number of simulations. In that case it may be convenient to resort to some other method of analysis as those derived from control theory (Coyle 1978).

10.3.- Monitoring Actual System Performance.

Once the essential variables and the critical parameters have been identified, the set of indicators of the systems viability is complete to proceed with the process of real time monitoring.

For each essential variable and critical parameter actual data is collected and analysed to see whether there is any evidence of change. To this purpose any short term forecasting technique can be used, provided that if indicates with some level of confidence whether the series is experiencing a significant change in its mean value.

Beer (1981) has suggested that bayesian forecasting as developed by Harrison and Stevens (1971) can be particularly useful to spot any significant change and to associate a probabilty with the occurrence of a change of direction in a trend.

Bayesian forecasting in opposition to other techniques like Cumsum or Trigg's method can be best used as a filtering device because it focusses on the direction of the change rather than in its size. Thus the occurrence of a large transient change has not an important effect on the interpretation of a datum, except in the sense that frequent transient changes have the effect of being reported with increasing certainty about their transientness.

The method is also useful because even when the essential variables are within physiological limits it may report a trend towards the critical area, as a message of a slope change or step change.

If the monitoring system indicates no significant change taking place, no signal is triggered to the Meta-controller and the next item of data is processed, the process goes on until some significant change -according to the criterion of physiological limits or trend towards the lethal area- is spotted, only then information flows to the Meta-controller.

10.3.1.- Corrective Action.

According to last section, corrective action should be taken only when significant changes are detected either in the essential variables or in the critical parameters. Changes may have a variety of origins and this should be clearly established before proceeding to implement new policies.

Changes in the essential variables can in principle only be due to minor disturbances originating in some temporary variation in the normal interaction of the organization with its environment. In practice however they can be due to a failure of the anticipate regulation either because lack of an effective policy or because the monitoring system failed to recognise the change on time. In both cases the Meta-controller should respond with some adaptive move from its repertoire of behaviours.

Some changes however may have origins in factors outside of the explanatory capacity of the current model, for instance due to some implicit parameter becoming active. This type of change can not be detected at the source of disturbances and can only be detected at the essential variables' place; thereby the importance of error controlled regulation.

The latter type of change is particularly crucial to viability because they show the organization's vulnerabilty, their positive effect is that they point out the obsolescence and limitations of the current model to explain the dynamics of the organization.

This type of change triggers a change in the model and this way it offers a means to up-date and correct the prevailing assumptions on the organization's behaviour. It can be interpreted as indicating a failure trial in the long term trial and error adaptation process of explaining environment's change.

In this way the design put forward here provides a means to validate the model as historical process of confrontation with the real world analogous to the process of knowledge dynamics discussed in Chapter I. The model and the whole Information System that supports can be seen as a Popperian theory ready to be tested empirically and to be maintained as successful for as long as empirical evidence permits it.

As a result of this process the model size and structure is subject to the dynamic of the organization-environment itself.

PART FOUR

INTRODUCTION

In this part, the Ultra-stable system's ability to adapt to a rapidly changing environment is discussed further. It starts from the fundamental fact that for the purposes of survival, time for adaptation comes to an organism as an essential variable in itself, whose stability must be regulated.

Considering this necessity, Chapter XI discusses further modifications to the initial formulation and shows that there are some organizational requirements to speed up adaptation time, namely that the components parts of the organization develop some form of autonomy and independence.

Chapter XII looks again at the organism as a regulator and in the light of the Requisite Variety Law considers further conditions for viability; it establishes the the degree of interaction among the parts defines a third type of essential variable whose regulation makes further organizational demands. It proceeds to develop a model of the functional organization of viable organisms.

Finally, it concludes with the taxonomy for changes started in part three and shows its relations to Bateson's categories of learning.

CHAPTER XI

RAPID ADAPTATION IN THE ULTRA-STABLE SYSTEM

The design discussed in part III can be regarded as complete in the sense that is supported in a theory that contains the necessary and sufficient conditions for adapation. The Ultra-stable system as discussed in chapter VII fails however, to explain some other important features of adaptive organizations.

The main objective of this part is to discuss further the possibilty of enhancing the survival capacity of human organizations. For this purpose it is convenient to have second look at the ultra-stable system in order to see its limitations and to discuss the modifications that are necessary to enhance adaptability further.

The discussion will unveil the important relation that exists between self-regulation and self-organization, giving in this way content to the idea that cybernetics is the science of effective organization. The analysis and modifications to the Ultra-stable system of part III will help to a better understanding of the way as the Meta-controller comes about and works.

The starting point for this discussion is the fact, already mentioned that time for adaptation itself can be regarded as an essential variable of the organism; and the empirical observation that living organisms and organizations are complex entities in the sense that their behaviour is determined by the interaction of many components.

The Ultra-stable mechanism as discussed in Chapter VII in turn, is quite a simple representation where the environment and the reacting part appear as indivisible wholes through which information flows.

In this part the assumption of indivisibility is lifted, the organism and the environment are considered to be the coupling of many interacting parts and the consequences of this step are discussed in the context of regulation theory.

For this purpose is useful to have a look at Ashby's own views on the problem of adaptation in complex systems, since several of his hypothetical solutions provide bases for the conditions of viability as discussed by Beer (1979).

The first observation in this respect is that when the number of parts of an adaptive mechanism -like the one presented in ChapterVII- increases beyond a moderate number, the adaptation time increases at an exponential rate reaching very quickly astronomical dimensions; a phenomenon nowhere found in natural adaptive organisms.

11.1.- Adapatation Time in the Ultra-stable System.

The hypothesis of considering adaptation time as an essential variable is justifiable on empirical and logical grounds. Organisms that are unable to re-establish stability to their essential variables within a short period are obviously more vulnerable to the effects of new disturbances.

While working with the Homeostat as embodiment of the Ultra-stable system, Ashby found that as the number of parts increased, adaptation took longer and longer. This loophole in the theory was of the utmost importance for its latter development, it showed that the basic formulation had to be modified in some fundamental way if adaptation of complex organisms was to be explained. It also provided conditions for Beer's developments in organization theory.

To proceed with the discussion it is convenient to have a look first to the dimiension of the problem and then to the ways as the theory is modified and amplified.

Consider first the existence of a system made up of one hundred parts -each one with one essential variable- and with changes of policies acting at random where each change of policy gives 50% of chance to each essential variable of going within physiological limits, and assume that the probabilities are independent.

For this system the problem of survival can be translated into the question of how many trials are necessary, on the average to achieve adaptation?.

As each variable has a probability of 50% to be kept within limits, at any trial the probablilty of total adaptation is only of $(0.5)^{100}$; thus the average number of trials before adaptation is achieved is 2^{100}. Assuming a duration of one second per trial the system would take 10^{22} years; which for every practical purpose is equivalent to never.

The example illutrates the magnitude of the problem, though it does not consider the dynamic relations between the organization and its environment, since the calculation is only based on the relations between policy change and essential variables.

Ashby investigated several more general cases to conclude that the number of trials -hence adaptation time- grew proportionally to some base risen to the power of the number of the system's components.

He found that the most fundamental difference between an actual adaptive organism and those hypothetical mechanisms was that the latter takes an incomparably longer time to adapt.

Further investigation and experimentation with the Hoemeostat showed that what makes the adaptation deceptively slow was the fact partial success counted for nothing. At each trial the mechanism attempts adaptation to all its variables, being unable to retain stability in those essential variables already within physiological limits.

It has been shown that when partial success is allowed, conserved and accumulated by the mechanism, an equally exponential reduction of time for adaptation is posssible. In Ashby's terms, "A compound event that is impossible if the components have to occur simultaneously may be readily achievable if they can occur in sequences or independently" (1976).

Taking advantage of this possibility, Ashby introduced some modifications to the basic formulation of the Ultra-stable system in a way that rapid adaptation is possible.

The starting point is the observation that a system composed of many parts that achieves adaptation in a reasonably short period of time is one that can benefit from partial success. That is to say a system that while adapting to a disturbance that takes some essential variables out of limits does not upset the stability of the rest of the essential variables.

The modifications to the initial formulation are based on the fundamental hypothesis that in a system composed of many parts or variables, partial success and accumulation of adaptations is possible if there is little or no interaction among the components.

The use of this hypothesis implies the fundamental presupposition that adaptive organisms are highly reducible entities. This presuposition has already been made explicit in Chapter V, next section is devoted to show how reducibility may contribute to speed up adaptation.

11.1.1.- Adaptation Time in the Richly Joined System.

Consider first what happens with adaptation when a system is made up of several parts that have inmediate effect on each other. Figure 11.1 illustrates the situation of a system whose parts interact while adaptation is taking place.

In this figure some changes of notation are introduced; the essential variables and their states are indicated by 'meters', there are three subsystems with their respective reacting parts, environments and sets of policies.

For simplicity this diagram shows richness of connection between the

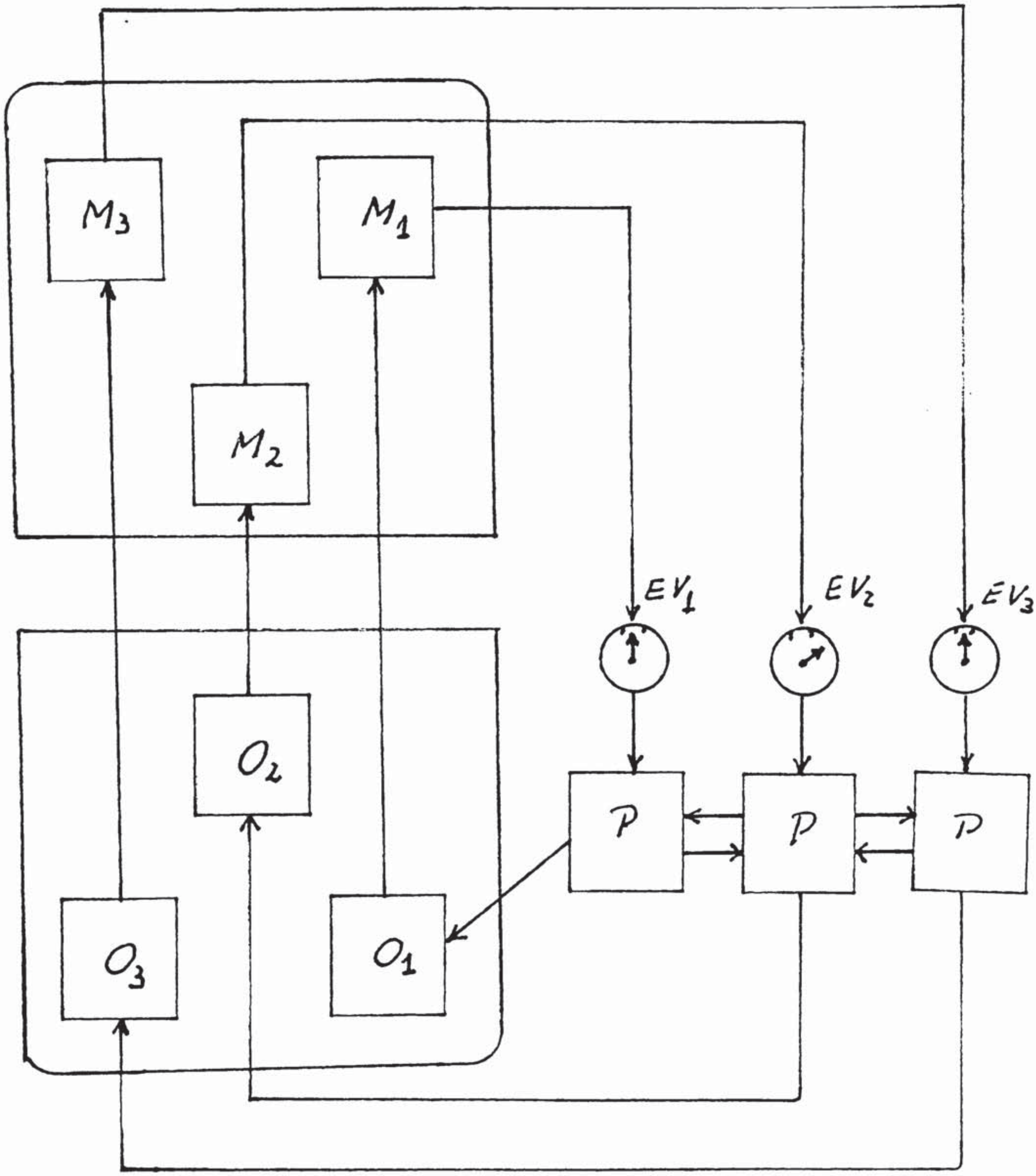


Fig.11.1 The Richly Joined System - A

policies only; it is assumed that each organization's O_i part interacts with the 'independent' environment M_i, which in turn have an immediate effect on the 'independent' essential variable EV_i . P_1 ,P_2 , and P_3 define the sets of parameters that has immediate effect on the respective parts of the organization.

M_1 represents that part of the environment that plays a part in determining how a disturbance eventually affects the essential variable EV_1 , and the same with M_2 , and M_3. Similarly, O_1 represents that part in the organism that is affected by changes in the parameters P_1 and that in the end has an effect on the EV_1 through the environment M_1.

Figure 11.1 represents an organism that at a particular moment has essential variables EV_1 and EV_3 within physiological limits, while EV_2 is out of limits. It follows that the system is not in equilibrium since the veto theorem states that at the next step there must be a change at P_2.

Since P_2 has an immediate effect on the rest of the policies, at the third step P_1 and P_3 must also change. As changes are transmitted through the loops the chances of keeping EV_1 and EV_3 within limits decrease. Only no change in P_1 and P_3 can guarantee that adaptation is retained in the rest of the system. As variety proliferates through the system the possibilities of rapid adaptation diminish; only simultaneous adaptation of the three essential variables blocks the flow of variety through the loops.

In this example, increasing the probability of adaptation, that is to say diminishing the number of necessary trials and consequently the time of adaptation, it is necessary that no information flows from P_2 to the rest of the step mechanisms.

The same type of analysis can be made observing figure 11.2, this time immediate effects occur among the components of the reacting part. Again for simplicity some arrows have been omitted.

This time it is the richness of connection between the organization's parts that makes rapid adaptation difficult, since their change also tends to upset EV_1 and EV_3 through the environment.

The same conclusion can be extended to the case of a compound organism facing a richly connected environment. If the assumption of richness of connection is extended to the whole linkage, adaptation for the organism adaptation turns out to be an altogether impossible event.

11.1.2.- Accumulation of Adaptations.

It follows from the discussion of last section that organisms that successfully adapt to terresttrial environments are likely to be composed of highly autonomous parts confronting disturbances coming through environments that naturally split into 'independent' parts. The theory establishes that a mechanism -whatever its embodiment- must be highly reducible to be able to adapt within a short period of time.

Empirical evidence to support this hypothesis can be easily found; an observation of the immediate surrounding shows that it is nowhere evident that a particular change leads, at the next step to a change in everything else. Clearly changes tend to generate specific chains of reactions which

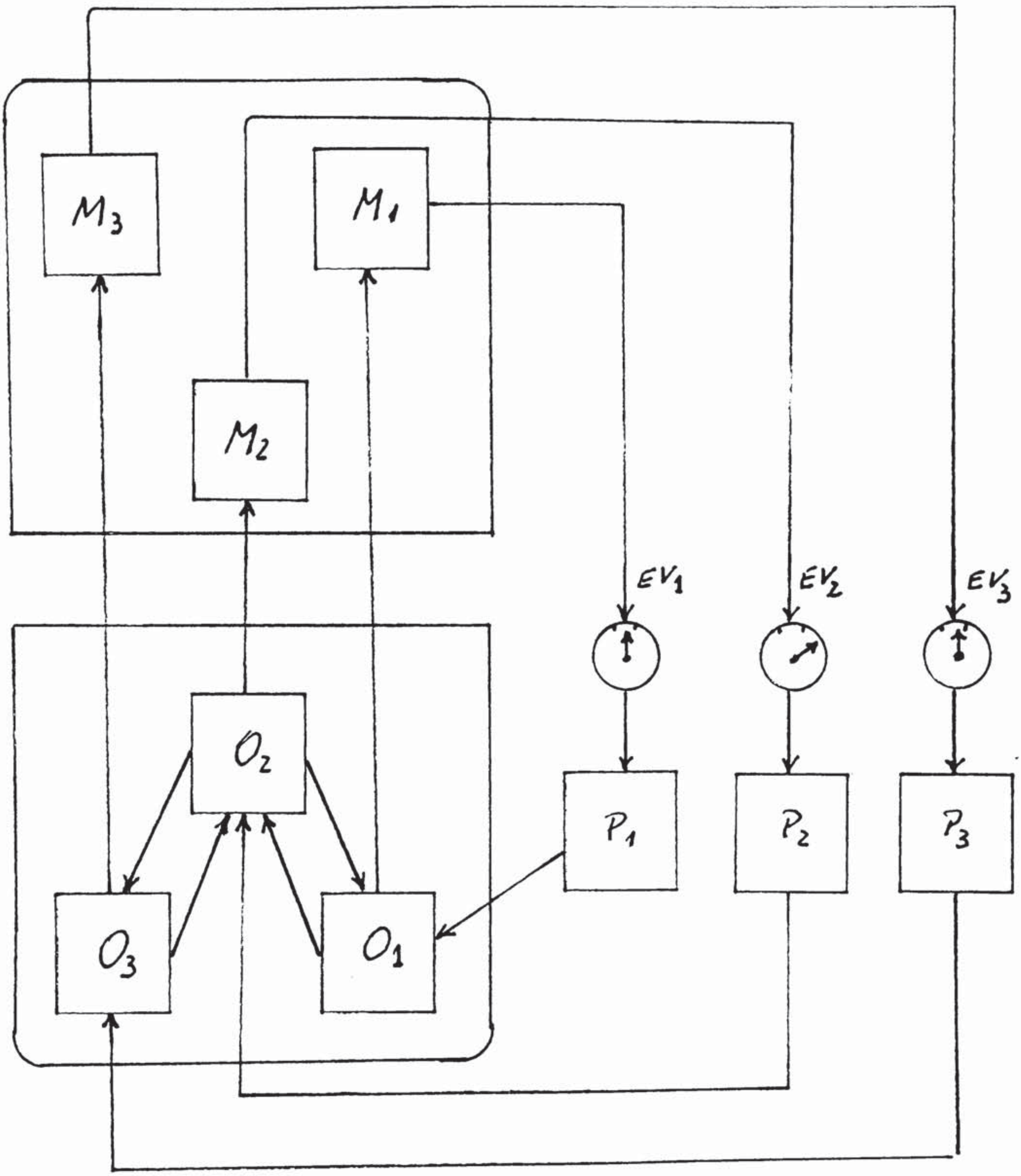


Fig.11.2 The Richly Joined System - B

are localizable within particular sets of variables.

Ashby's conclusion is that the often implicit assumption that organisms are richly joined ensemblages of parts must be lifted. To illustrate the point further, figure 11.3 represents a 'system' composed of several totally independent parts.

The figure represents a collection of elementary Ultra-stable systems as the one discussed in part III.

This whole can display adaptation of EV_2 without upsetting EV_1 and EV_3, consequently speeding adaptation up. By the same token, if the system has to deal with more than one disturbance affecting different essential variables; the system can tackle them one by one in parallel.

Obviously, this system only tenuously resembles an actual organization, however its similarity is almost complete to an organism displaying a reflex reaction.

That natural adaptive entities are somehow reducible is not all that can be said about them, it is however an important characteristic. None of the figures considered so far in this chapter provide an adequate topology of an adaptive organization but they are useful to illustrate the extent to which successful adaptation depends on the degree of interconnection.

When discussing independence between the parts of a given embodiment, it is important to bear in mind that the concept applies to a particular description rather than to the thing as a whole. The condition of independence only refers to those aspects that define the embodiment in

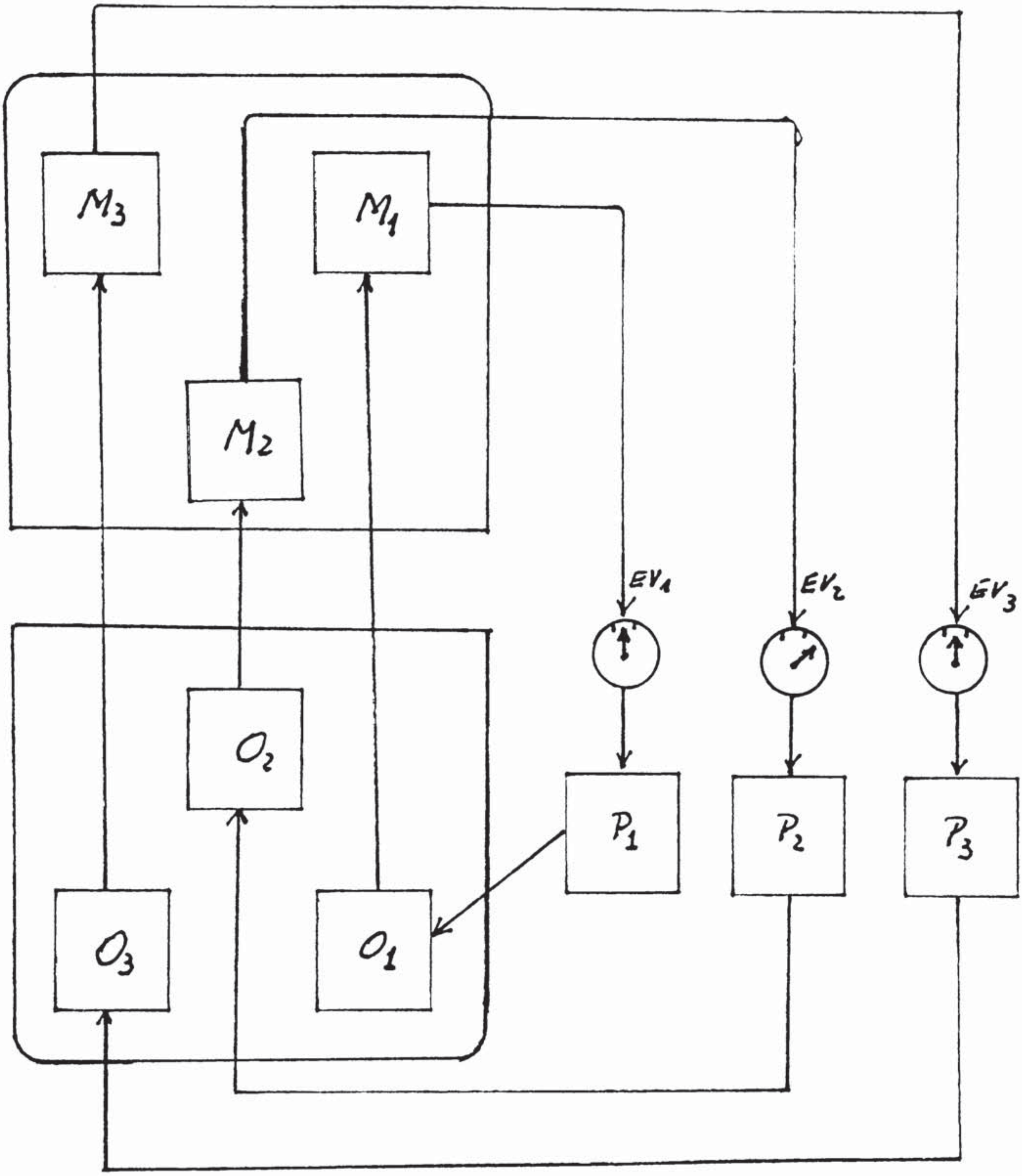


Fig.11.3 The Totally Reducible System

relation to an observer in terms of a specific set of variables and within a well determined period of time.

The concept therefore, makes sense within a specific period of time and it does not refer to any abso lute property of the embodiment. Dependence and independence refer to purely functional relationships and in no way to the presence or absence of anatomical or physical connections; the diagrams therefore imply no physical characteristic of organisms nor environments.

None of the figures discussed so far provide a sufficiently complete description of an adaptive organism.

The rest of this Thesis is devoted to working out a better description, the starting point is the idea that the degree of interaction that exists among parts must be somewhere in between the richly joined and the totally reducible system. For this purpose it is convenient to have a look at the propeties that a moderately joined system shows.

11.2.- The Poly-stable System.

What is wanted is a description that can provide rich dynamic behaviour and at the same time the property of being partially reducible. Ashby's Poly-stable system (1976)can provide those and some other interesting properties which are common to adaptive organisms.

The Poly-stable system basicaly consists of the coupling of a number of Machines with Inputs. Such a system is obviously state determined as the individual machines themselves thus, provided it is properly isolated, if left to its own dynamics it must follow a unique trajectory towards some equilibrial state or cycle.

A system constructed in that simple way may provide almost any degree of complex behaviour; as the number of machines increases the behaviour of the whole -although determined- gets more and more complex to the extreme of causing any degree of uncertainty to an observer with limited information processing capacity.

Again, the time taken by the Poly-stable system to settle to an eqilibrial position or cycle depends on the amount of interaction among the machines.

A useful way to observe the hypothetical behaviours of such a system is to define a variable i as the number of variables at equilibrium at a given moment. Three typical types of behaviours can be noticed according to the amount of interaction among the parts.

Consider for instance a system composed of n variables and whose parts are very rich in equilibrial states. Given a disturbance that takes the system out of equilibrium, the system follows a typical trajectory like the one in figure 11.4.

At time t_1 the disturbance affects the system's variables getting some of them out of equilibrium, a unit of time later all the system variables return to their equilibrial position making $i = n$.

A second type of behaviour is given by a Poly-stable system whose parts are richly joined, as figure 11.5 shows it the system once perturbed and taken out of its equilibrial state does not inmediately come back to equilibrium; its number of equilibrial variables fluctuates describing a sort

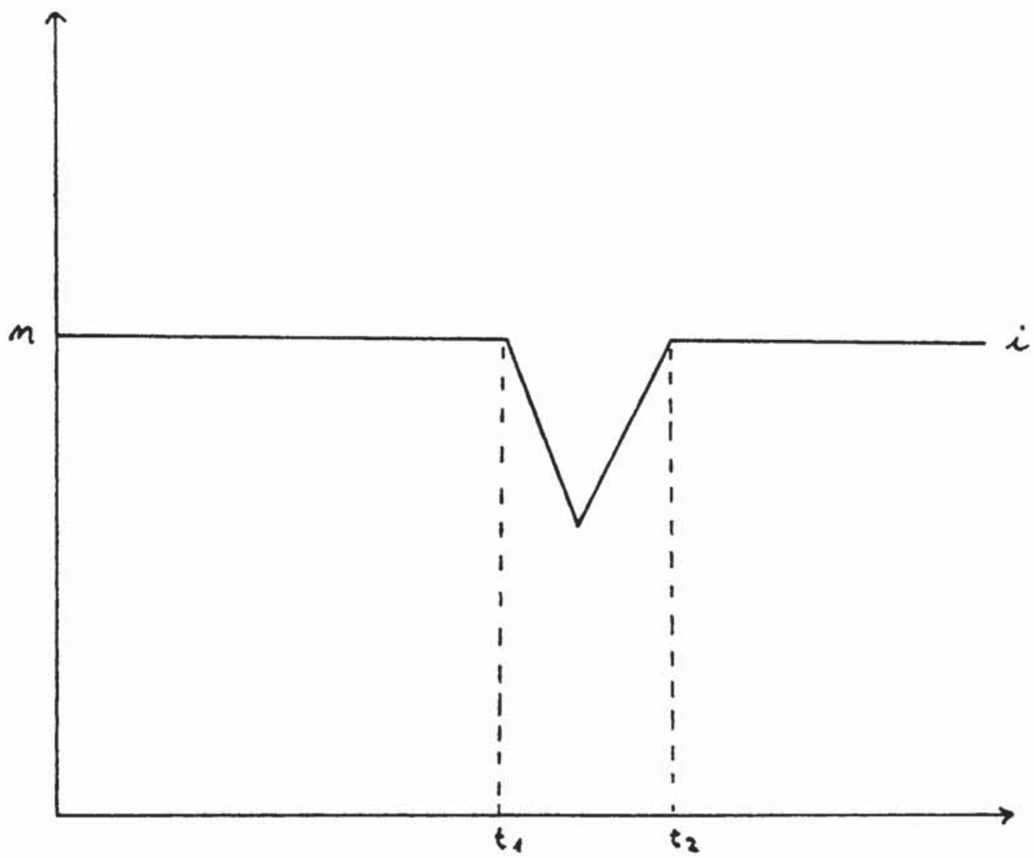


Fig.11.4 Trajectory of a Poorly Joined Poly-stable System

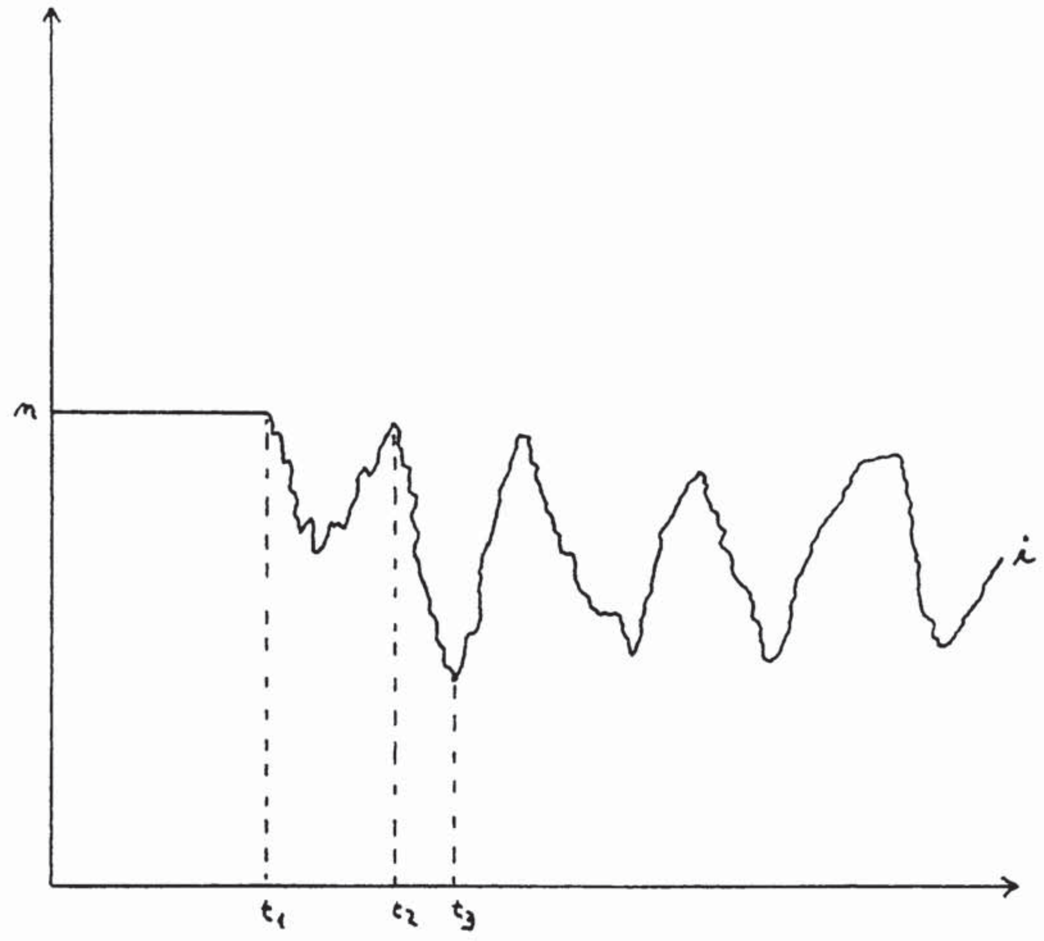


Fig.11.5 Trajectory of a Richly Joined Poly-stable System

of random walk around an average value.

The system's equilibrium is interrupted at time t_1, at time t_2 nearly all its variables are in equilibrium but its richness of connection puts half of them out of equlibrium at time t_3. As time elapses, the number of equilibrial variables fluctuates around some average.

These two types of Poly-stable systems somehow describe the possible trajectories of systems like those figure 11.2 and 11.3 respectively.

A third and more interesting type of Poly-stable system is one whose parts are rich in equilibrial states, but not as much as to make the behaviours trivial and uninteresting like those of figure 11.4. Such a system is likely to display behaviours such as the ones in figure 11.6.

When the totality of this type of system's variables is observed, the simplicity of i's trajectory is nowhere apparent. Instead the set of variables will show a kaleidoscopic appearance where some variables will show their temporary independence by going in and out of equilibrium until eventually the whole set will reach equilibrium.

Figure 11.6 shows the system returning to equilibrium after disturbances at t_1, t_4, and t_7.

A Poly-stable system that is rich in equilibrial states has several other properties which are relevant to the study of complex adaptive processes. Next section indicates some of them.

11.2.1.- Localization and Dispersion in the Poly-stable System.

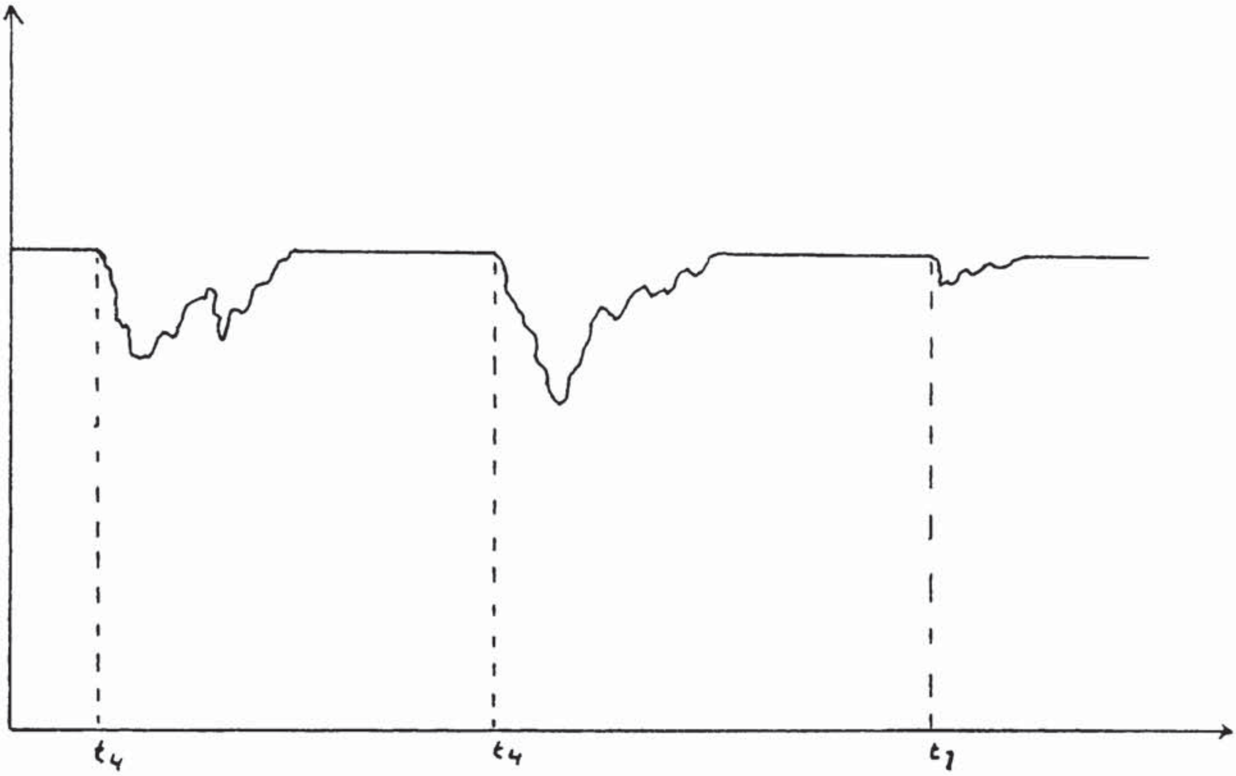


Fig.11.6 Trajectories of a Moderately Joined System

The Poly-stable system as every other state determined machine reacts always in the same manner to the same disturbance. That is to say, whenever a particular stimulus displaces it from its equilibrial state, the variables that are activated are always the same and experience changes following the same sequential order.

In this respect the reactions to stimuli are functionally localized resembling an organism that has parts specially 'designed' to deal with particular stimulus.

In the Poly-stable system , the localization of functions although unique and well defined, may be difficult to identify with certainty. The difficulty being dependent on the observer's ability to perceive which and when the variables are activated. Thus the question of localization in a fairly complex Poly-stable system is ambiguous since from the point of view of its determinacy, localization is an indisputable fact, whereas from the point of view of an observer with limited capacity of perception, the localization is uncertain and problematic.

The problem of localization in organizations can be illustrated by the way as a company reacts to the stimulus 'Customer Order'. A company's behaviour will follow a well specified trajectory, possibly as the one described in figure 11.7.

A second important characteristic is that of dispersion, a Poly-stable system describing a trajectory towards its equilibrial states shows dispersion in the sense that the set of variables active at one moment is usually different from the set active at another moment.

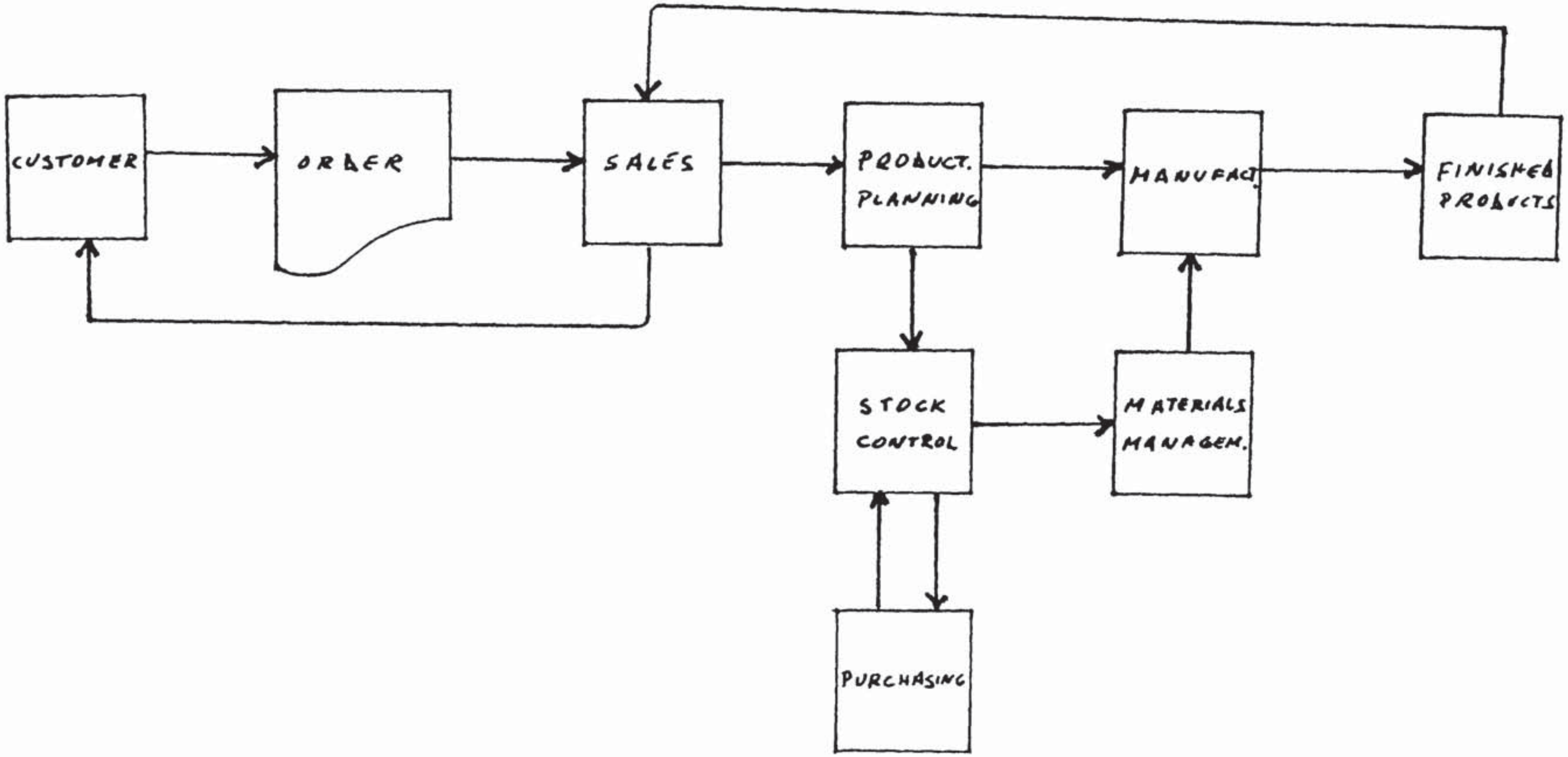


FIG.11.7 CUSTOMER ORDERING AND ITS LOCALIZED EFFECTS

The pattern of activity in the system tends to be fluctuating, while some variables show vivid activity at one moment, others are constant, the latter can be looked as part of the temporary unchanging background of the adaptive process. In the longer term dispersion can be interpreted as the organism adapting to changing environments.

It is now convenient to summarize the characteristics that are common to the Poly-stable system and to to natural adaptive processes.

i.- The poly-stable system can quickly go, through complex behaviour, to equilibrium resembling adaptive organisms.

ii.- It shows some reducibility in the sense that richness of equilibrium in its component parts provides the 'walls' of constancy that are necessary to have subsystems behaving independently.

iii.- It shows localization, like an organism that has parts specially 'designed' to cope with specific types of disturbances.

iv.- It shows dispersion resembling organism's ability to adapt to 'changing' environments little by little.

11.3.- Adaption to Complex Environments.

In section 11.1 the condition of reducibility was established and figure 11.3 was used to show how complete independence improves adaptation speed. The figure however gives a too crude representation of an organism that adapts since complete reducibility is rare in the organic world.

The third type of Poly-stable system as described in last section provides a more natural description of an adaptive oragnism. From now on this system is used as surrogate of the actual coupling between an organization and its environment.

The discussion that follows contains two important cases of adaptation, the first one is to do with the situation of an organism that adapts to an environment which is serially connected in the sense that complexity unfolds over time step by step. The case is representative of a wide class of adaptive process where an organism learns to adapt to a complex environment little by little.

The second case is to do with the situation where an organization adapts to an environment that is altogether complex in the sense that disturbances affect several essential variables at the same time.

11.3.1.- Adaptation to a Complex Environment over the Time.

The property of dispersion accounts for the familiar phenomenon of organisms adapting to changing environments.

Figure 11.8 shows the situation of an organism that has to stabilize three essential variables to a fairly complex environment. According to the initial discussion in this chapter, if the organism tries to stabilize all of them at once it may take a fatally long time. The figure shows that if adaptation proceeds by stages adaptation can be quicker.

The first part to achieve adaptation is obviously A since it is isolated in the sense that nothing affects it, once A is adapted B becomes isolated

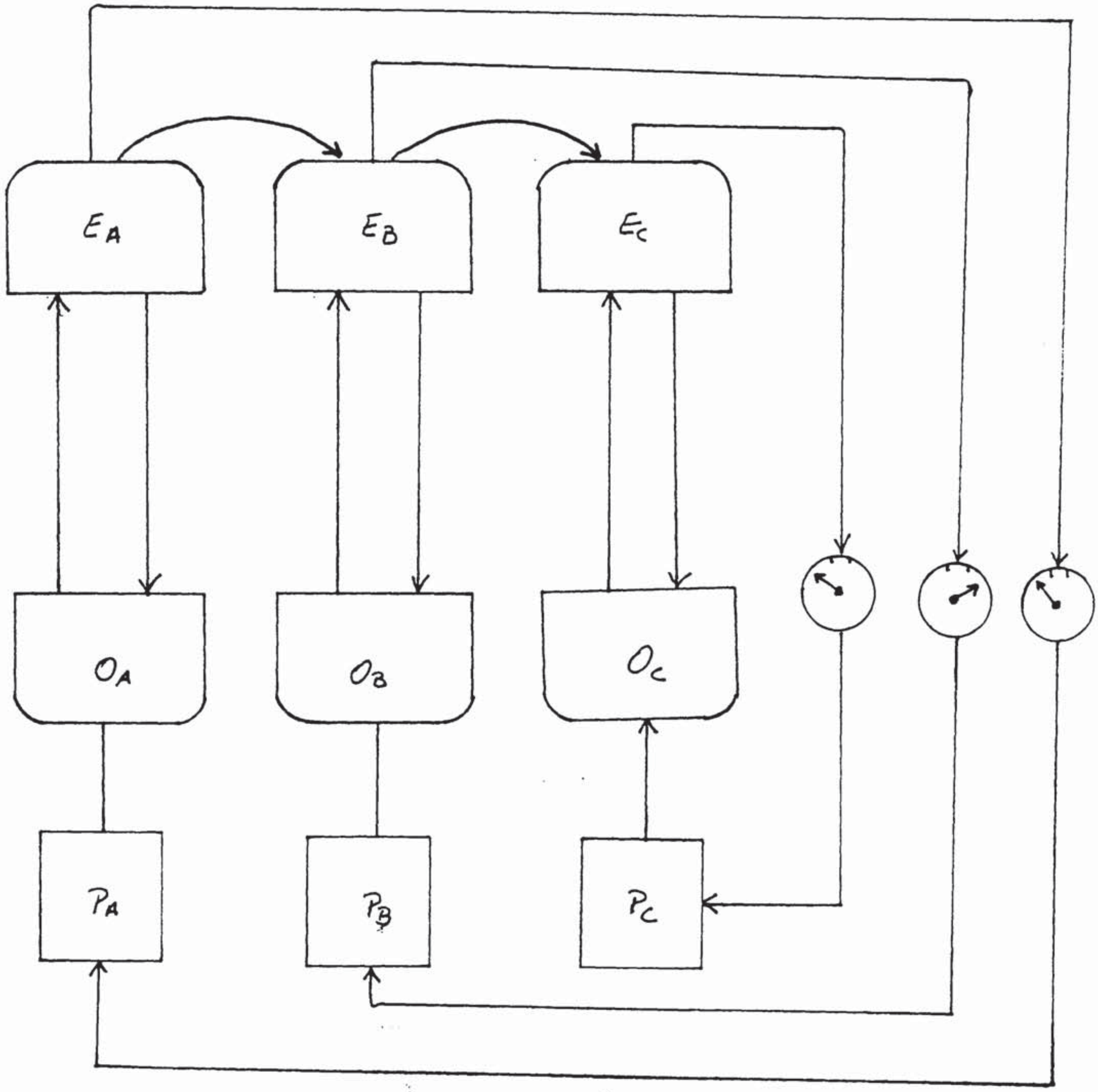


Fig.11.8 Adaptation to a Serially Connected Environment

and can stabilize its essential variables and then C.

The example is in no way trivial or irrelevant since it epitomizes an extremely common adaptive process, namely the process of adaptation to complex environments when the complexity naturally unfolds over the time.

The situation can be illustrated by an animal that masters the techniques of hunting. Before becoming proficient and able to adapt to the rapidly changing environment of hunting, the animal has learnt to walk and run without colading with objects, next it has learnt to stalk, chase and kill. As it proceeds with its learning process, it retains adaptations and only when in full command of the sub-environments it can effectively show its adaptation to a rapid succession of them.

In a managerial situation it happens for instance when a company starts producing rubber hoses for domestic gardening, then makes hoses for the local car factory, then rubber parts for the same industry and finally any rubber part for any use.

In both examples the organism and the organization have learnt to adapt to a complex environment by progressive development of several skills. That is possible if the complexity of the environment serially unfolds over the time, had the organism and the environment tried to adapt to the complex environment at once they would have almost certainly failed.

11.3.2.- Adaptation to Complex Environment at Once.

Of a higher degree of complexity is the problem of adapation when the environment's parts interact in a way that several essential variables are affected simultaneously.

According to section 11.1.1.- If the environments are richly connected adaptation may be altogether impossible. This applies to the Poly-stable system and to actual organisms as well.

The case of interest here is that when the degree of interaction is low so the organization still has the chance to survive a compound disturbance.

Figure 11.9 gives an example of an organism adapting to an environment with interacting parts. To follow the adaptation process consider part B as being adapted and temporarily independent from A and C, thus B comes as part of the background which is ignored for the purposes of considering the reactions after disturbances at A and C.

Organism and environment A on the one hand; and organism and environment C on the other can in their turn be regarded as the coupling between two dynamic parts where one can be indicated as the environment of the other.

As the properties of ultra-stability are applied to this new level of coupling (between A and C), the coupling must follow a trajectory towards states that keep A and C's essential variables within physiological limits. It follows that in a complex whole made up by the coupling of several ultra-stable systems, parts adapt to parts as in Chapter VII an organism adapt to its environment.

It is important to notice that the original sets of parameters values that were effective in providing stability to A and C as independent parts, are reduced by the coupling to some sub-set which affects both A and C when interacting. In other words, as time elapses the coupling A and C will selectively retain those parameter values which are effective in maintaining within physiological limits A and C's essential variables.

The conclusion can be easily extended to the case of the coupling of several parts. For instance if the the three parts A, B and C of figure 11.9 are perturbed and allowed to interact, they would undergo changes until a combination of behaviours that re-establishes stability to all parts is found.

An observer of such process would find that that the parts show coordination, since they 'prefer' those behaviours that are convenient to their survival as well as to the survival of the rest, and consequently to the survival of the whole.

The discussion makes clear the meaning of the term coordination. It is the inevitable property of any coupling of ultra-stable systems of retaining those conditions that are effective not only to the survival of the individual parts, but to the stability of the whole set of essential variables.

The example of figure 11.9 is based on the hypothetical situation of an organism coordinating its behaviour through the environment, without necessity of internal connections.

The diagrams still shows a simplicity uncommon in the world of phenomena, and they can be misleading if considered to describe the permanent physical structure that organisms show in nature. They are

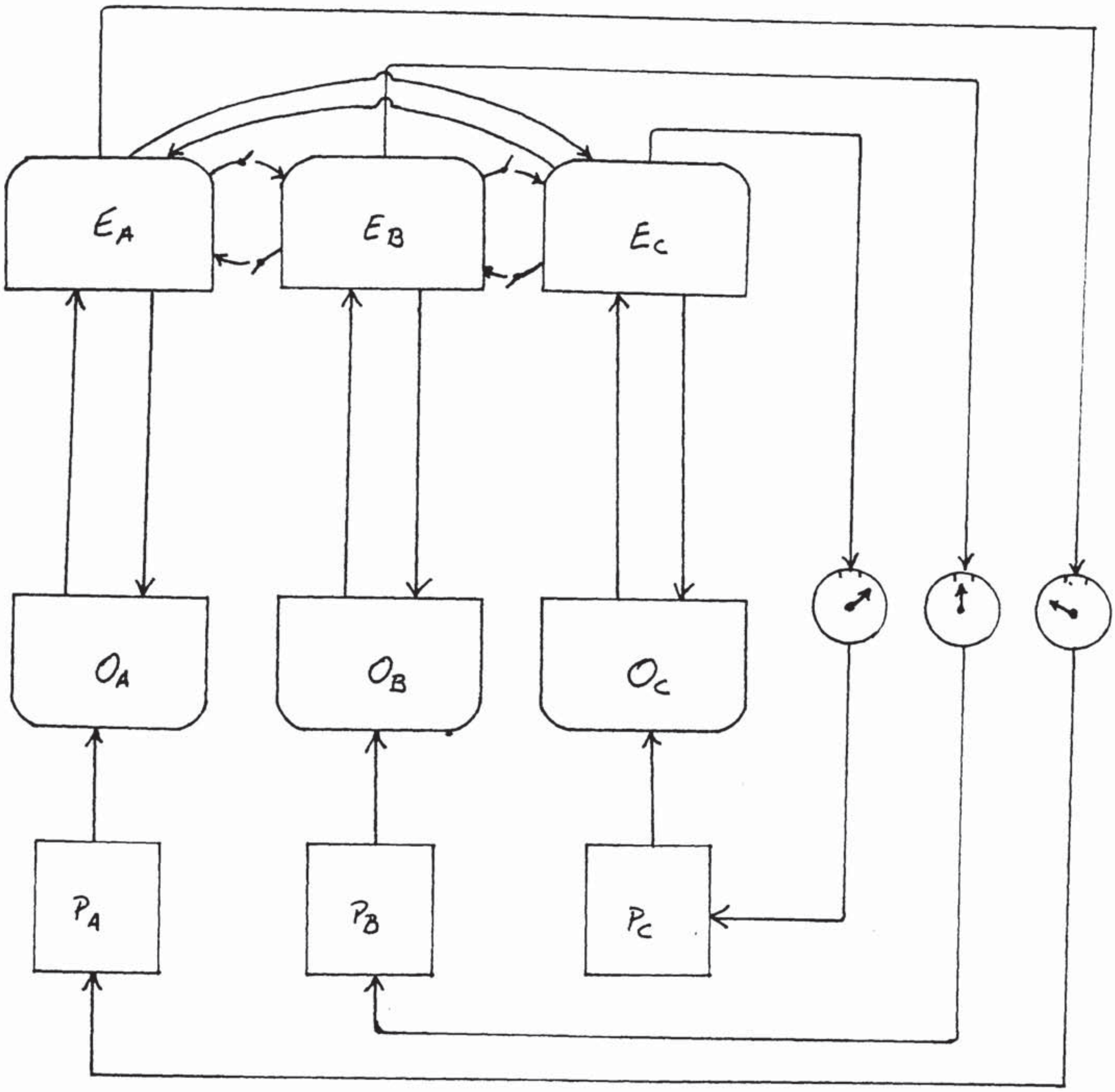


Fig.11.9 Immediate Adaptation to a Complex Environment

however indisputably useful to study the functional aspects of adaptive processes, if functionality is kept in mind they should not mislead.

The discussion of this Chapter has shown that as the number of parts of a systemic whole increases, the time for adaptation augments exponentially in relation to the number of parts, unless the parts show a high degree of independence.

The properties of the Poly-stable system are therefore used to continue the discussion on ultra-stability in complex organizations. The example of figure 11.9 shows the adaptive process in an organism of totally independent parts adapting to a complex environment, it showed the possibility of coordination through the environment. Real organisms' parts however do show interaction, next Chapter contains further modifications to the Ultra-stable system in order to give a fuller account on organisms' functional adaptive organization.

CHAPTER XII

FUNCTIONAL ORGANIZATION FOR ADAPTATION

The last Chapter discussion showed that adaptability in organisms that face complex environments depends on the amount of connectivity present among the variables and parameters of the system.

The theory states that the chances of survival augment if variables are not allowed to communicate or if the amount of communication is not allowed to increase beyond a certain level.

The condition of independence can be empirically verified in human organizations. In management for instance the point has been made by Ackoff (1967) in relation to the common sense assumption on the desirability of greater exchange of information among different units. He argues that increasing information exchange among different units is not only unnecessary, but that experience shows to be harmful.

The point is also illustrated by the common fact that in most organizations certain type of information is declared to be confidential. Confidentiallity in companies is established not only to prevent competitors from getting information about the company, but much of it aims to keep internal stability.

Figure 11.9 shows no connections among the organization's parts; Ashby has demonstrated that that in principle there is no need to introduce internal connections into the discussion for they are not necessary to explain ultra-stability in complex organisms. "Coordination between parts can take place through the environment; communication within the nervous system is not always necessary". Ashby (1976b).

Ashby's observation is important in many respects, it helps for instance to understand the nature of the phenomenon of coordination and its pervasiveness in the organic world and shows that in principle no 'internal' mechanism is necessary for coordinated behaviour to be displayed. It also illustrates how autonomy may provide conditions for rapid adaptation.

Empirical evidence however, shows that higher organisms and organizations do develop internal connections and unless there is some objective advantage, evolution would have never favoured such development. It is therefore necessary to introduce some further modifications to the figure 11.9 so it provides a more complete topology of the functional arrangement of adaptive organisms.

In the context of human organizations, coordination through the environment frequently occurs, for example when two or more divisions react independently and in a similar manner to some change in the market.

This form of coordination however may be excesively slow in some situations for instance when different units set their targets. From the point of view of speed of adaptation it may be an advantage if the internal parts of an organism can communicate to show a coordinated response at once without having to go to through a trial and error process through the environment.

There is however a second and probably more important reason for organisms and organizations to develop internal connections; this discussion is the topic of next section.

12.1.- The Organism as a Regulator.

To consider the problem of necessity of internal connections it is useful to look at the system of figure 11.9 from the point of view of regulation. For this purpose a functional diagram of regulation as discussed in Chapter VI has been superposed in figure 12.1.

In this figure, disturbances through the environment threaten to transmit information to the essential variables, whereas the organism's role is to arrest that transmission in a way that the essential variables' values are kept constant.

With this picture in mind there is no difficulty to consider the problem of survival in terms of Requisite Variety. The application of the Law establishes that the amount of regulation achievable by the organization has a limits which is given by its own variety.

The problem of the organization's survival in terms of regulation can be regarded as the one of minimizing entropy in the essential variables; by the Requisite Variety law it is known that the varieties of the Essential Variables, the Organization and that Environment are related by the expression:

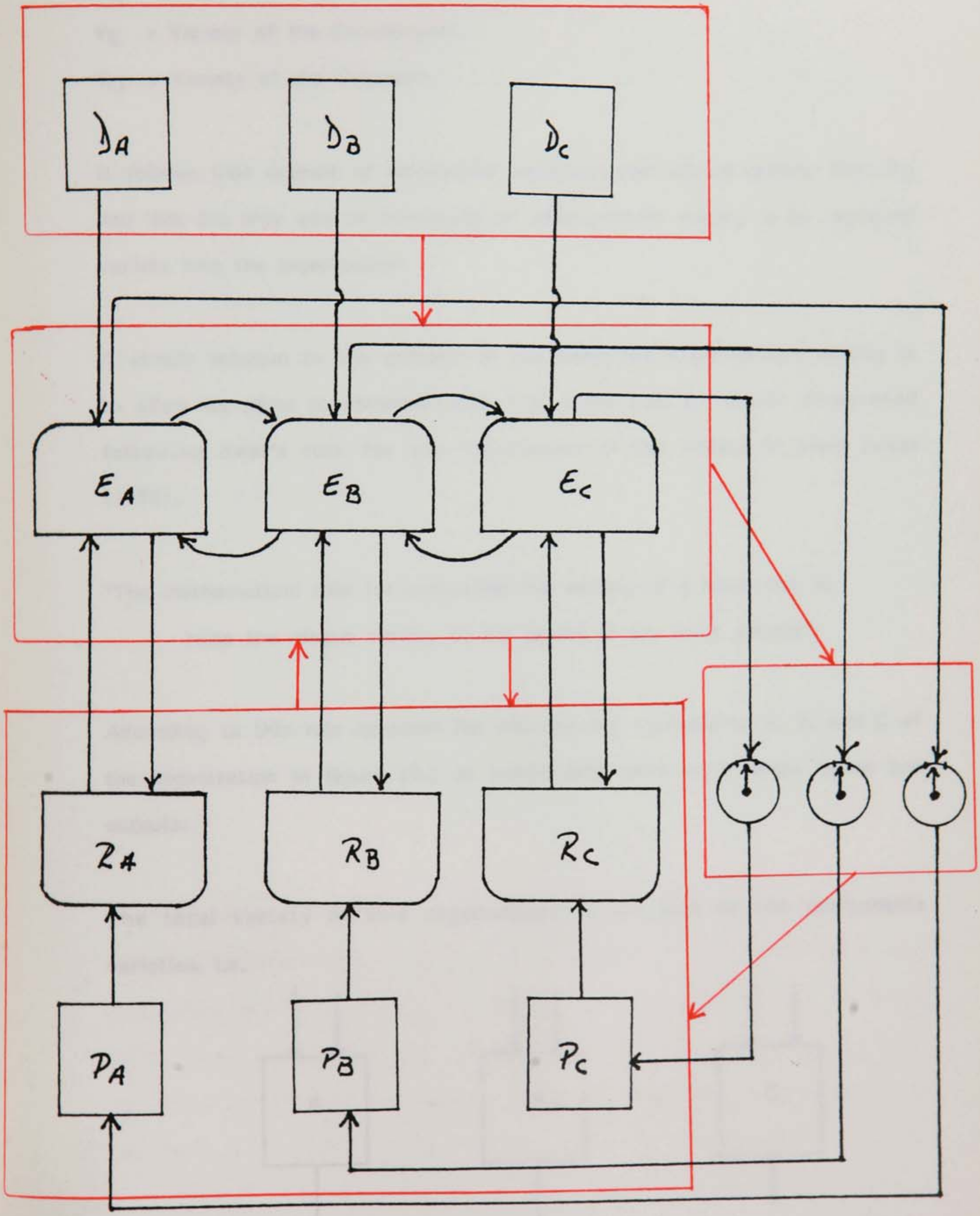


Fig.12.1 The Organism as a Regulator

$$V_{EV} \geq V_E - V_O$$

V_{EV} = Variety of the Essential Variables

V_E = Variety of the Environment

V_O = Variety of the Organism

It follows that amount of achievable regulation can not be greater than V_O and that the only way of increasing an organization's variety is by 'pumping' variety into the organization.

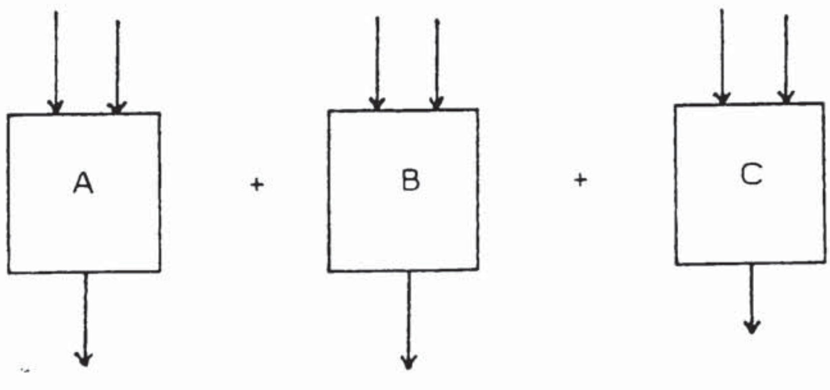
A simple solution to the problem of increasing the organization's variety is to allow its parts to communicate. The point can be easily illustrated following Beer's rule for the calculation of the variety of black boxes (1979).

"The mathematical rule for computing the variety of a black box is:

raise the otuput variety to the power of the input variety".

According to this rule consider for instance the components A, B, and C of the organization in figure 12.1 as independent units with binary inputs and outputs.

The total variety of this organization is the sum of the components varieties. i.e.

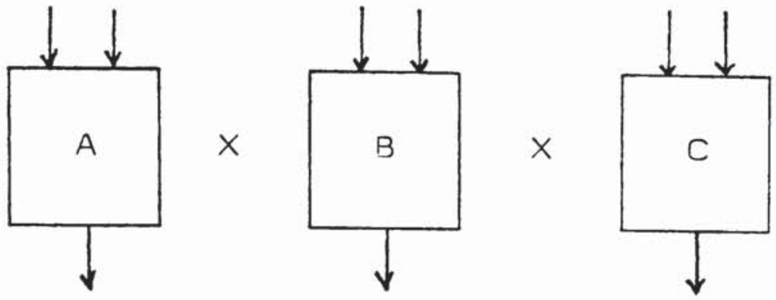


$V_A = 2^4$ $V_B = 2^4$ $V_C = 2^4$

Total Variety $2^4 + 2^4 + 2^4 = 2^5 + 2^4 = 48$

Figure 12.2 Variety with Non-interacting Components.

Whereas a system with the same input/output configuration, whose parts interact, the resulting variety of the whole is:



Total Variety $= 2^4 \times 2^4 \times 2^4 = 2^{12}$

Figure 12.3 Variety with Interacting Components.

The example shows how is that developing internal connections has a survival value. This advantage can also be understood following this line of reasoning:

Consider that organization's parts as machines with inputs, every coupling needs extra parameters to establish the modes of joining; and these new parameters otherwise inactive may become active, increasing the number of fields for at least as many as the number of new parameters; consequently increasing the organism's repertoire of behaviours due to the posssibility of new fields.

The survival value of internal connections demands the introduction of new elements in the study of adaptation in organisms composed of many parts. Next section considers this element and its consequences.

12.2.- Internal Connections and Coordination.

In figure 12.4 connections among the components of the organization are introduced. A careful comparison with figure 11.2 and 11.3 shows that this diagram is basically the sameas the other two put together.

In Chapter XI however, the point was made that connections prevented rapid adaptation, thus having negative effects towards survival. Now the argument states that richness of connection enhances the chances of survival in as much as the repertoire of behaviours is enlarged

The arguments are indeed conflicting and show that both extremes are bad. From this point of view, the problem of management and in the last event of organizational viability can be looked at as one of keeping the organization's interconnections in balance, in a way that the variety is generated by an amount that is not too much as to 'swamp' the organization's ability to adapt quickly nor too little as to make the repertoire of behaviours insufficient to confront the environment's variety.

It follows that the amount of interconnection defines a third type of essential variable. The problem of survival in organisms that are composed of many parts has been probably solved by developing a functional organization capable of providing this balance.

The subject has been discussed at length by Beer (1979) who has developed a model that establishes the necessary and sufficient organizational

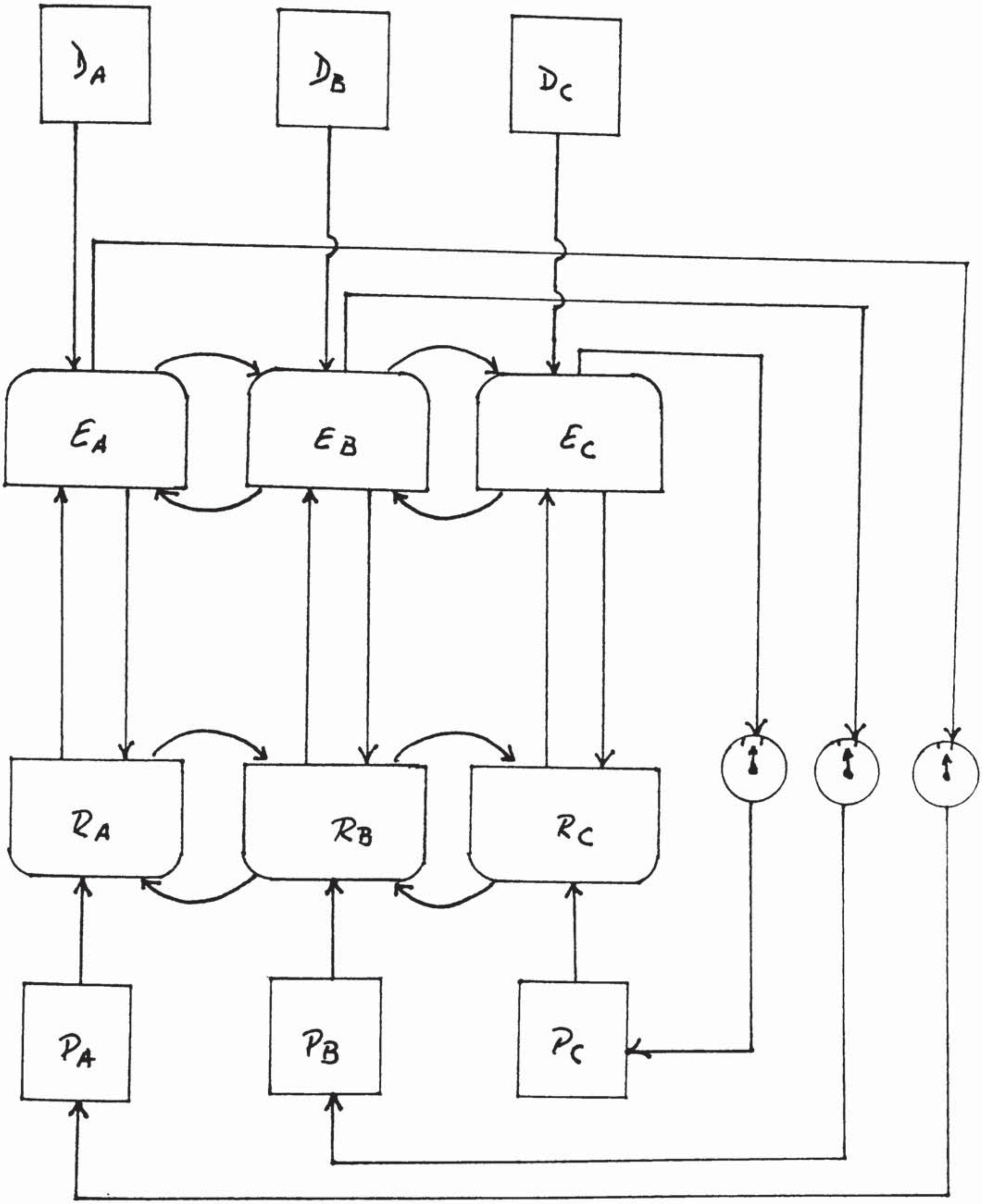


Fig.12.4 An Organism Developing Interaction

conditions for viability.

An organism with internal connections is capable of keeping its capacity for rapid adaptation if displays coordinated behviour in the sense that as parts experience changes they do not upset the stability of the other parts.

In a more general sense, coordination occurs if, as parts experience changes while undergoing adaptive processes the changes do not upset the adaptive processes of the other parts.

In the system of figure 12.4, consider the set Q as containing all possible states of the whole, and the set T as containing all the equilibrial states of the whole; as in figure 12.5.

According to the veto theorem, it follows that the parts may follow any trajectory within the space T, without upsetting the equilibrium of the whole nor of its parts.

Coordination therefore is a property of the behaviour of the parts in relation to the whole, that is to say the statement is about the whole coupling and therefore stands as a meta-systemic feature of the parts.

Coordinated interaction does take place in the management of organizations; the activity of production planning for instance , can be regarded as a process of selecting states for the parts -production units- which are compatible with the stability of the whole organization rather than with the stability of the units in particular. Similar roles are sometimes performed by budgeting units and other instances of resource allocation, these units' role can be regarded as to make sure the the organization's states do not

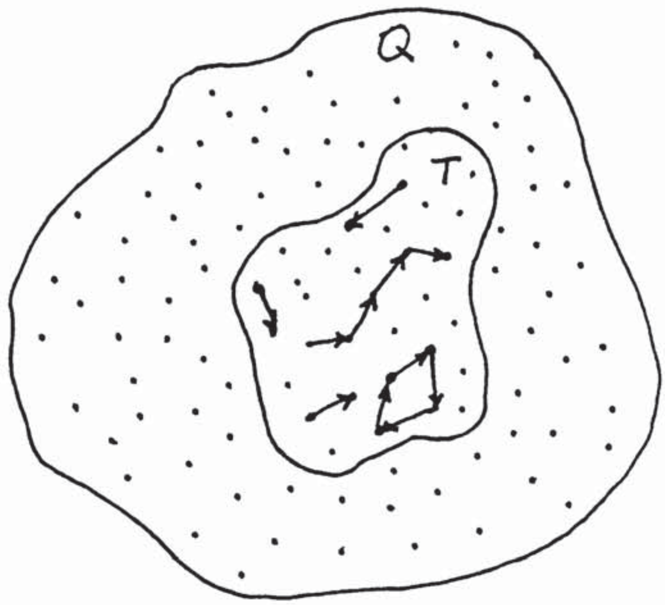


Fig.12.5 A System's Phase-space Showing its Region of Stability

go out of the space T.

12.3.- Coordinated Commands on the Behaviour of Parts.

It is now possible to look at the Meta-controller function in greater detail than as discussed in part III.

The Meta-controller is endowed with the ability to select from all possible policies those which were effective towards specific disturbances. It follows from the discussion of last section that as the organization is composed of many parts the selection of policies must be constrainted to the subset that is compatible with the condition of coordination and isolation of the parts.

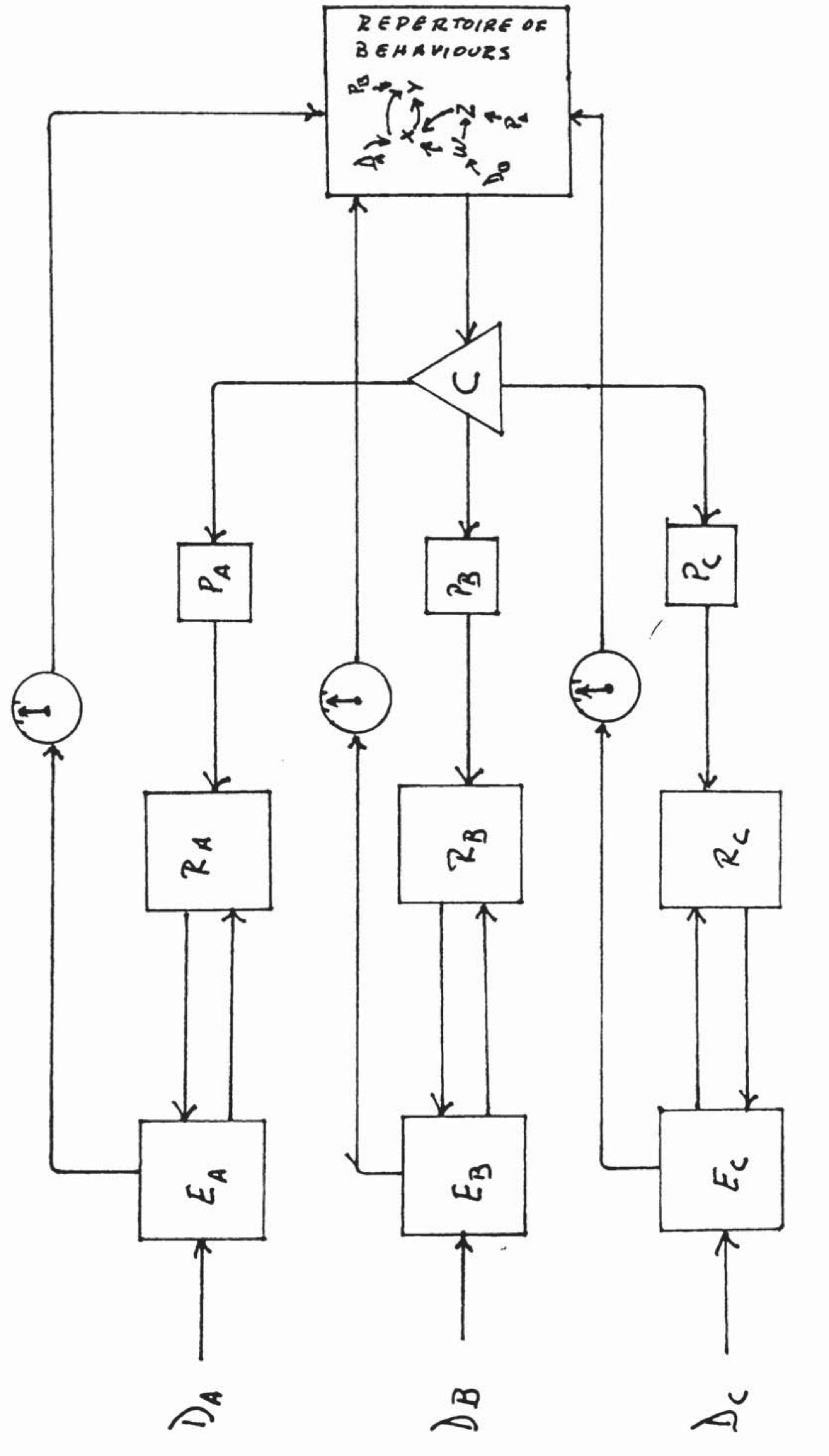
Figure 12.6 introduces the Meta-controller function of command towards the component parts. It appears receiving information on the value of the essential variables Type One and selecting from a repertoire of behaviours, as defined by the prevailing model.

In this figure, the triangule C represents the coordinatory restriction on the set of effective policies given by the necessity of independence for rapid adaptation. It says that choice of policies must keep the organization's set of trajectories within the space T of figure 12.5.

The box R represents the operator that defines the value of the parameters P_A, P_B and P_C according to the prevailing explanatory model. In Beer's languages C and R correspond to Systems Two and Three respectively.

In figure 12.6 only the first type of essential variables is included, for practical purposes they would be the ones that in an organization are usually defined by level of liquidity and rate of profit. The introduction of

Fig.12.6 Coordinated Response to Perturbances



the other two types of essential variables comes next and with them the completion of the discussion of ultra-stability in organizations.

12.4.- The Effect of Adaptation Time as an Essential Variable.

Figure 12.6 accounts for the possibility of ultra-stability in relation to the first type of essential variables. As they are taken out of limits the Meta-controller proceeds to try changes of policies according to its repertoire of behaviours; choices are made from the specific set available according to its model of reality.

As an organism fails to re-establish stability in its essential variables and the set of policies is exhausted time elapses and the latter as an essential variable itself approaches its critical area.

As it gets to its threshold value, by the method of ultra-stability the organism must trigger changes.

These changes to be possibly effective must belong to a different class, since exhaustion of policies makes ineffective to try them again and again. It must induce changes of what has been unchanged while the process of adaptation was going on. What is required is to throw away, if only temporarily the prevailing repertoire of behaviours and select from a new one.

Therefore the type of change required is one of the current model of reality; the essential variables type one must be reconsidered in relation to a new outlook of the organization-environment relation.

The process of changing the repertoire of behaviour may take the form of increasing the current model's size in order to introduce new parameters and policies which would provide more alternatives to be tried or can take the form of complete rejection of the old paradigm and the development of an entirely new model; the specific form that this change will take can only be defined in the concrete situation. Whatever it is the form, in practice it must involve a change of the current model. Figure 12.7 introduces time as an essential variable and indicates a higher order of ultra-stability generating changes in the model.

The newly introduced element is labelled Model Generator whose changes are triggered by the exhaustion of alternatives in the repertoire. It feeds information from the environment to generate alternatives that may have adaptive value in the context of completly new situations. It defines what Beer calls system four.

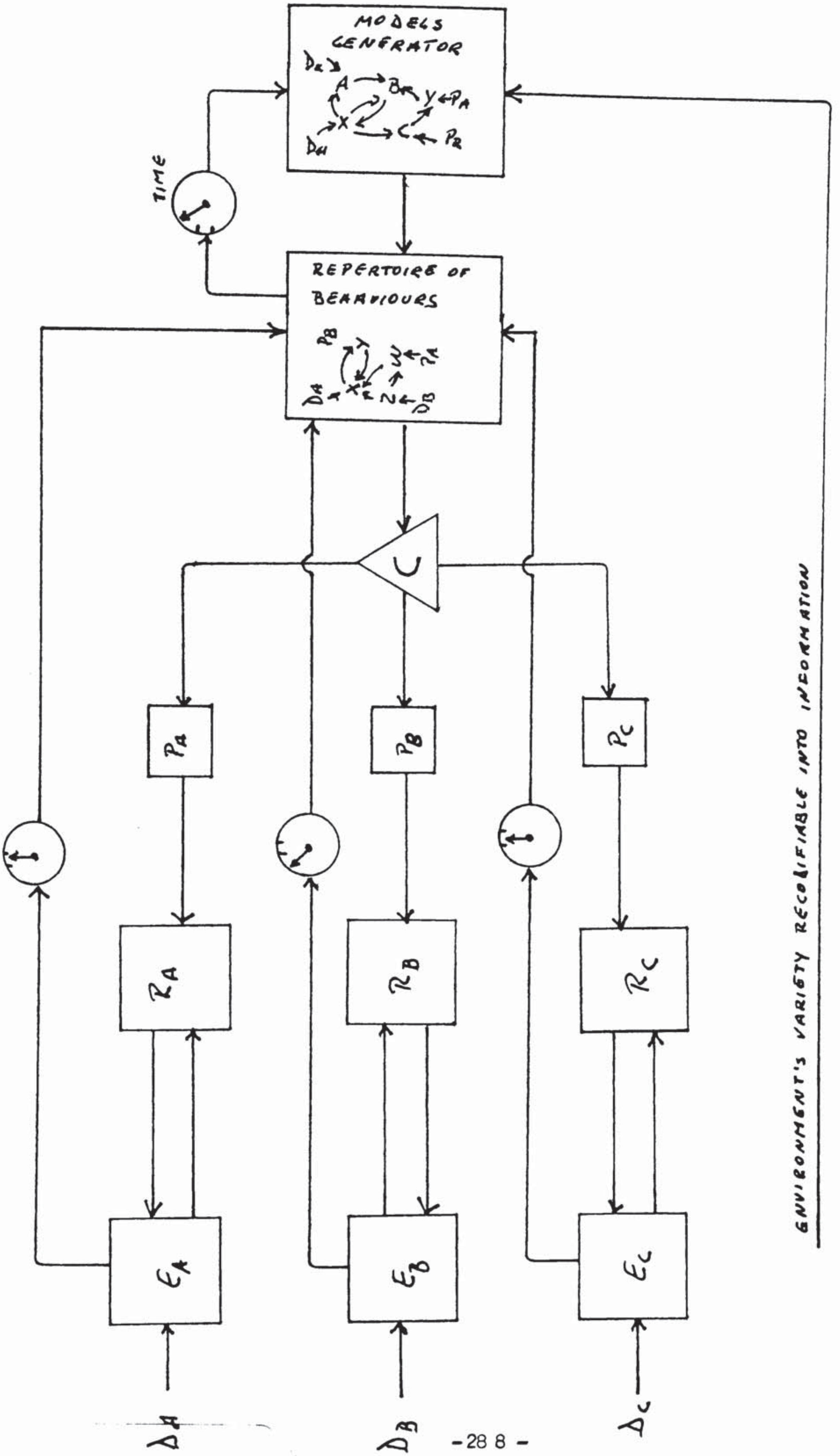
12.5.- <u>New Behaviour and Actual Implementation.</u>

There is still the problem of whether it is possible to implement the new adaptive moves provided by the Model Geneartor according to the current linkages among the parts.

As it is known a poly-stable system with a finite number of components and a well defined set of linkages can only provide a finite number of behaviours. Any increase of the number of possible behaviours requires either an increase of the number of linkages or acquire new parts that eventually could display the required behaviours. The restriction equally applies to every conceivable embodiment; as much to the nervous tissue as to an aggregate of individuals.

Both alternatives may affect the organization's ability to achieve adaptation

Fig.12.7 The Emergence of a Model Generator



in a short period, and as such they can be regarded as sources of disturbances towards the essential variable 'degree of interconnection'. Therefore, the organization's survival demands a function in charge of regulating against those perturbations; the new function is introduced in figure 12.8.

This function's role is that of regulating the actual organization of the system, it monitors the way the parts relate to each other in a way that effective policies can be implemented and that the whole system does not get swamped by uncontrolled proliferation of variety. In Beer's terms corresponds to system five whose function is that of providing continuous self-organization.

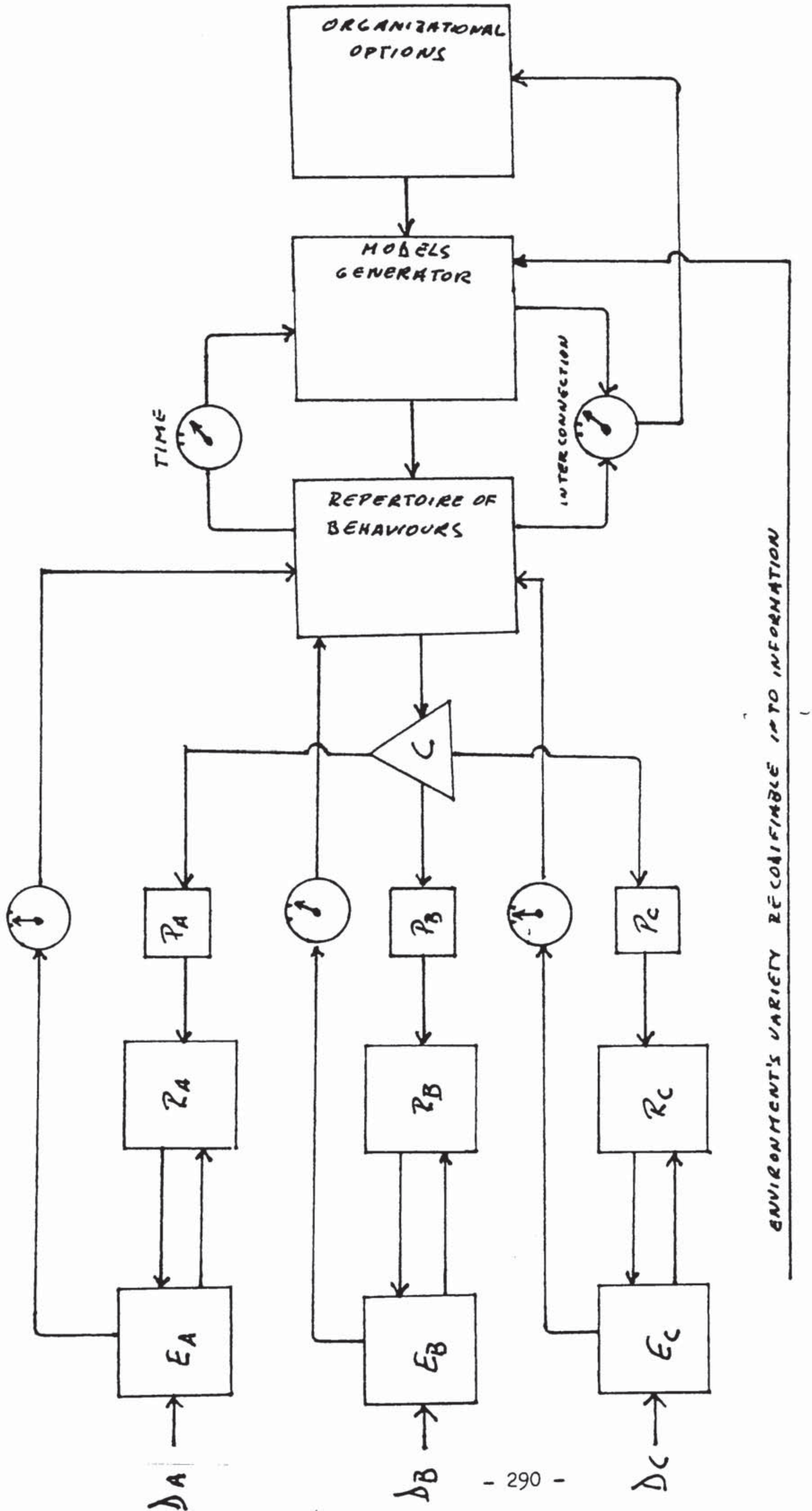
Re-organization of the system on new basis can provide 'room' for the possibility of developing new behaviours when the organization have no variety left.

Despite self-organizing properties, an organization may fail to respond on time to disturbances. There is in this case a last resort left, which is the possibility of a temporary change in the essential variables' priorities in a way that the organism can postpone adaptation further.

The situation may occur for instance in an organization that having such a bad cash position decides, for some time to make a loss in order to retain its solvency. At the very moment that the change of priority defines a target that includes profit rate out of the calm zone, the organization's survival is temporarily facilitated by the event making a loss.

The dynamics of goal setting therefore, defines another function of the

Fig.12.8 The Emergence of Organizational Options



Meta-controller. In chapter VI this role was mentioned in relation to an organization whose viability is unthreatened; the argument equally applies to the endangered organism.

The system providing the organizational options and goal setting dynamics completes the requirements for the regulation of the different type of essential variables. The diagram of figure 12.8 is in this sense complete, since unless a fourth type of essential varriable is indicated, it accounts for all the regulatory processes that take place in an organization..

The essential variable 'degree of interconnection' going out of limits defines the necessity of fourth type of change, namely that of change of organization. This completes the taxonomy started in Chapter VII.

The simplicity of the diagrams may still be misleading since actual organizations are usually made up of much more than three parts and interactions appear in many directions.

Simplicity was however wanted, first to understand the essence of adaptation and learning processes, and second to find out the minimal requirements for the design of System for Change Identification.

The simplicity of diagram 12.8 may give account of the complexities of an organism that adapts to a very complex environment, although the actual complexity of the latter surpasses the diagram by many orders of magnitude . Ashby suggested that in actual organisms, specially in higher organisms, the reacting part of figure 7.7 may contain many subsystems of the same form; each with its own sub-set of essential variables, carrying out sub-adaptive processes integrated in complex sequences of timing and conditionality functionally suitable to the adaptation of the organism as a whole.

Beer has introduced the idea of recursivity to adaptive processes and with it he added a very important dimension to the cybernetic theory of organizations. It is not matter of this Thesis to discuss the consequences of this new dimension, but it is necessary to point out two important implications in relation to this work.

In the first place, it gives coherence to the idea that Information Systems as the one derived in Part III are Corporate only in a logical sense.

From the beginning of the study of the Ultra-stable system to the discussion on the system's requirementes no reference to the notion of organizational hierarchy has been necessary. Several times however, it has been mentioned that the design aims to support Corporate Mangement decision making.

In this Thesis the idea of Corporate Management does not refer to any seniority of hierarchical position within an organization, but to the higher logical level at which changes of behaviour, of model and of organization are dealt with.

Conversely, non-Corporate changes are those that take place within a particular behaviour, as defined in chapter VII, tha is to say through the inner loop of figure 7.7.

In Beer's terms figure 12.8 correspond to one level of recursion, where information flows through two loops forming a logical hierarchy of two components. One part consists of variety flows generated as the policies are implemented, and the second component of the variety flows generated as the organization displays its adaptation to disturbances.

The Information System arrived at in part III is for Corporate Management in this logical sense, it equally applies to any level of recursion.

Finally the idea of recursion opens up the possibility of information flows between the level of recursion themselves. The problem has been somehow considered by Beer with the introduction of the concept of algedonic signals, but some further research in this respect may still be necessary.

In principle the introduction of algedonic signals presents no theoretical problem provided the conditions of viability are respected in a process of design, in practical implementation the process may present some difficulties that would be worth to study.

The idea of algedonic signals as information flows through different levels of recursion rests on the hypothesis that in an actual organism, each level has its 'own' set of essential variables monitored and adapted at that level. Each level has no concern on the stability of the essential variables downwards except as a result of sustained failure of a level to keep its essential variables within physiological limits.

As an organization fails to display adaptive behaviour, the essential variable time keeps out of limits; algedonic regulation uses the time variable as the trigger of a signal to the next upper level of recursion in order to obtain attention from above.

This section completes the taxonomy of changes started in Chapter VII, introducing change of organization as the fourth type of change. This classification relates to Bateson's taxonomy of learning in the interesting way which is discussed in next section.

12.6.- Type of Change and Learning.

Changes within a behaviour correspond to Batson's category of Zero Learning, where the changes are not subject to correction by trial and error. They are fully dependent on the particular context in which a behaviour is displayed. In managerial terms they can be epitomized by highly structured day to day operations resulting from the implementation of current policies.

For instance Zero Learning type of change in a Company are those defined by the placement of a Purchasing Order by a customer. The whole sequence of changes that follows the placement is not subject to trial and error and it is fully dependent on the 'company's current practices and on the specific conditions under which the order is placed.

Changes of behaviour are those defined by a change of policy that usually respond to some change in the environment that affect or may affect the essential variables stability. For instance as when a company react with a new credit policy to a fall in the global demand in the economy.

In Bateson's taxonomy these changes correspond to the correction of errors within a set of altenatives; in the above example the set of alternatives is provided by the repertoire of behaviours defined by several alternative credit policies plus some other alternative means to increase liquidity. This corresponds to Bateson's Learning Type I; it involves changes in the specificity of response in opposition to the specificity or response of changes within a behaviour.

Changes of Model occur when the adaptive choice is made not from a repertoire of behaviours, but from a set of repertoires. These changes are triggered by the presence of disturbances to which the prevailing modeldoes not contain any adaptive response.

In Bateson's classification these changes correspond to Learning Type II, where corrective changes occur in the sets of alternatives from which the choices are made.

Changes of organization may occur whenever the adoption of an effective new repertoire of behaviours can not be implemented within the current organizational setting. In these circumstances only some re-arrangement of the way as the parts of the organization relate to each other can account for adaptation.

In Bateson's hierarchy it corresponds to Learning III, it works as a change in the system of sets of alternatives (repertoires) from which choice of repertoires are made.

Changes of organization occur as a re-arrangement of the relationships among components and/or by acquiring aditional variety from the environment forming a new more complex unit. The fourth type of adaptive change corresponds to a new level of integration among the components which is in general characterized by an increment of regulatory capacity in order to deal with newer types of perturbations.

CONCLUSIONS

1.- On the Necessity of this Work.

Complaints about Information Systems contribution to effective management is a topic that regularly reccurs in current literature. In fact, this has been the case for several years since the already classic paper by Ackoff (1967).

The use of Corporate Models to support strategic decision making shows a similar record, a number of factors are generally acknowledged as the causes of the problems, which has resulted in the development of many approaches and re-approaches to design and implementation.

The framework for analysis of knowledge dynamics discussed in Chapter I provides a perspective to look at the problems of Information Systems design from a scope wider than focussing on specific practical difficulties. It shows the importance of epistemology in relation to research and practical work.

On the other hand, Argyris has suggested that solutions derived from conventional explanations are likely to contain inner contradictions that may well end up in negative results.

This sole fact, perhaps fully justifies the attempt to approach the problem of design from epistemological basis that differs in some fundamental way from the currently in use.

The use of cybernetic principles to work out an approach to Information Systems design permits us to dispense with the theoretical basis that supports most of current designs which, in general are encapsulated in Simon-Anthony's approach to decision making and in the methodologies derived from systems engineering.

2.- On the Use of Cybernetics as Theoretical Basis.

The view of organizations as viable systems provides a new perspective to the problems of design and shifts attention towards the requirements for regulation and stability.

The premise that the basic concern of viable organisms is to secure a safe source of energy gives simplicity to this approach and provides the designer with a concrete starting point, namely the essential variables defined as a rate of profit and a level of liquidity.

The develpments of parts three and four however, show that viability is not subject to the pure availability of an energy source, but that time for adaptation, the degree of internal connections, and their organizational consequences play a decisive role in the processes of survival.

The use of the Ultra-stable system as theoretical unit of analysis provides simplicity and generality to the explanation and rigour to the recomendations.

This outlook shows that cybernetics contains the theoretical elements to deal -without ambiguity- with the concepts of change, information, regulation, stability, survival and organization. It makes explicit the relationships between these concepts and the problem of Information Systems design, establishing the precise way in which survival and viability are dependent upon information systems.

The reader familiar with cybernetics will have no problem to see that the same theories and principles has been applied all over Part I to analyse and evaluate current developments in Management Science and Information Systems in particular.

3.- On the Design for Change Identification.

The design discussed in Part Three shows the way the activity of Information Systems design is inseparable from that of modelling. It makes explicit the relations between Information Systems and decision making, in the sense that the quality of the latter is crucially dependent on the quality of information; this being defined by the fidelity with which the model that originates it explains the actual processes.

The conditions for ultra-stability, learning and foresight demand that there must be three basic components in the design.

In the first place a model of the closed loop type of relationship that exists between an organization and its environment. The model is defined as an explicit description of the causal relationships that exist between the organization's essential variables and environmental change.

For practical purposes this is a system dynamics type of model that maps the real time t into a model time t' in a way that simulation is made possible.

The model constitutes the organization's views of its relations with the real world; and as such it is the corner stone on which the behaviour of the organization depends. It provides the set of parameters or elements in the environment on which management's attention must concentrate upon.

Sensitivity and robustness analyses of the model provide a filtering method to select the set of elements on which monitoring should fall and the means for policy design respectively.

The second basic component must be a method to observe and evaluate the organization's actual performance. The modelling process defines the set of elements of control, namely Essential Variables and parameters which are to be monitored.

The idea of monitoring those elements is to spot any significant change in their current actual values and that may affect the essential variables' stability, in order to generate adaptive responses.

For practical purposes the method of monitoring is the application of some forecasting technique to the time series defined by essential variables and parameters.

In the third place there must be a controlling mechanism capable of modelling, interpreting information in terms of the model, and of selecting and implementing policies to arrest the effects of perturbations on the essential variables.

The Meta-controller must be also capable of identifying the need to change the model . The system put forward in Part Three caters for this possibility, it establishes that the model must be revised and changed every time that the essential variables experience changes that have no explanation within the context of the prevailing model.

The Thesis offers a framework for an adequate practical use of Systems Dynamics models. It emphasizes their potentialities to indicate what is really important for an organization's survival, instead of using them as mere simulators of the future; it shifts attention from simulation of the future to the explanation of the determining elements of the organization's behaviour. Their predictive character comes as an optional and less important property.

By changing emphasis this way, the usually untractable problem of model validation against historical data evaporates. The model validates itself by continuous confrontation with current actual performance; the failure of the model to explain a new disturbance comes as positive information indicating the necessity of a fresh approach to the organization's dynamics.

The Thesis also offers a framework where to place appropriately short term forecasting. It shifts attention from the quality of the forecasted figure to the rather more important issue of indicating if actual changes that are taking place in the behaviour of variables are sufficiently significant as to justify policy changes. It properly integrates dynamic simulation with short term forecasting.

The integretation of these three elements shows the way management should be linked to the functions of modelling and monitoring of performance. These components in their systemic relationships define a mechanism for learning and consequently for successful adaptation and survival.

It provides a framework for a reasonable approach to Corporate Planning, defining the context for this activity by the means of long term decision making, dynamic modelling and short term forecasting.

4.- <u>On the Organizational Consequences of the Use of Cybernetics.</u>

The structural conditions for rapid adaptation as discussed in Part Four provide a link between the problems of Information Systems design and in general of regulation and control with those of organization. The discussion shows that conditions for adaptation define some organizational invariance in the world of phenomena, thus Cybernetics provides basis for a general theory of organization.

The discussion links Beer's model of viable systems to Ashby's theory of ultra-stability and adaptation; it shows the significance of defining cybernetics as the science of effective organization.

Finally the relation established between the taxonomy of changes discussed in Parts Three and Four and Bateson's categories of learning is relevant to Information System design and deserves a final digression in relation to Argyris views on the subject.

The classification developed in this Thesis can be particularly useful to classify types of information within an organization and provides a framework for the designer.

It helps for instance to avoid the logical error of designing systems with no reference to the dynamic of the organization-environment relationship; this is probably the case of the majority of Data Processing systems.

Data Processing systems deal with changes that fall into the category of change within a behaviour or Zero learning type, in the sense that they are not subject to correction by trial and error and are fully dependent on the particular context on which a behaviour is displayed. They are those that take place through the inner loop of figure 7.7.

Most of current approaches to Information Systems design are attempts to produce 'meaningful' information for management by gathering and classifying data from daily data processing operations, putting them into periodical reports that are handed to managers for their information.

"The massive technology of management information systems, quality control systems, and audits of the quality control systems is designed for single loop learning" Argyris (1977).

Argyris final contention is that for the purposes of effective design it is necessary to draw a distinction between Local and Distant Information Systems, concluding that what managers really need is the latter type the deals with double loop learning, whose characteristics are to contain abstract descriptions of key performance indicators, informing about the outputs of complex processes and not about the processes themselves; in contraposition to Local systems that deals with single loop learning that inform about concrete descriptions of unique situations, accounting for evaluation of performance of specific processes.

The system derived in this Thesis, no doubt corresponds what to Argyris calls Distant, in as much as it contains abstract descriptions of key performance indicators, representing the outputs of complex processes and deals with learning beyond the first loop.

5.- Scope for Further Research.

This Thesis responds to the necessity of conducting research on how to develop effective Management Information Systems. The use of cybernetics as the theoretical framework to this purpose and in particular Ashby's theories of regulation, adaptation and learning has made possible a fresh look to the problem.

The topics of Information Systems and Organizational Learning surely deserve more attention, cybernetics in general and the results of this investigation in particular can provide a useful starting point. In addition to this, it is felt that further research is also necessary in the closely related topic of the implications of the recursivity theorem to the whole problem of design.

This Thesis started from the premise that the enhancement of knowledge requires working at two logical levels. The first was to do with the formulation and testing of hypotheses within a particular epistemology, most of current developments have been based on the prevailing views on Management and Organizations.

The second level was concerned with the necessity of questioning and changing the assumptions of conventional wisdom.

Part One was mostly devoted to an examination of the currently believed theories on Management and Organizations, and to demonstrate the necessity of working on different theoretical basis. Part Two gave a brief introduction to the funadamentals of the cybernetic explanation and its relation to the problems of Management and Information Systems, as an alternative epistemological approximation. Parts Three and Four contain the results of facing the problem of design with the theoretical tools of cybernetics.

The conclusions and recommendations for design are bound to the validity of the cybernetic explanation, their validation or rejection are matter of historical confrontation with practice; actual design and implementation of the approach developed in this thesis is the most immediate scope for further work in this direction.

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