

PLANNING FOR DISCONTINUITIES

by

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## PLANNING FOR DISCONTINUITIES

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of the requirements for the degree of Master of Science

ABSTRACT

Organisational plans and planning processes have difficulties that arise from not asking the right questions regarding the occurrence of discontinuities.

The purpose of this thesis is to explore the possibility for improving organisational prediction of discontinuities.

The thesis concludes that the prediction of discontinuities is possible, and that tools exist already that are capable of handling the task to some considerable extent. The tools are an extension of Environmental Scanning to encompass the total Way Of Life; System Dynamics to analyse the cause and effect relationships of the Way Of Life, and Catastrophe Theory to analyse the discontinuity itself.

The thesis outlines further areas suitable for investigation that if successful, would improve the ability of the tools to predict in a more precise manner.

Thesis Supervisor: Professor Edward B. Roberts

Title: David Sarnoff, Professor of  
Management

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Whatever cause that led me to read an article on Catastrophe Theory in April 1976, before any of this was even considered, and to the same cause that led me to consider that System Dynamics and Catastrophe Theory might be able to be wedded.

The people who read this thesis, see what I have been driving at and go away with a slightly different way of seeing things. You will have made it all worthwhile.

Finally, thanks to Stationery Unlimited for typing the final copy of this opus.

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## INTRODUCTION

### The Problem:

Human organisations, especially corporations, tend to prepare formal plans as a device for laying out the strategy to be followed in achieving the organisation's objectives. The plans depend upon the assumption sets regarding the future as it is likely to affect the organisation.

Experience has shown, however, that certain events are likely to occur that are of a fundamentally important nature to the organisation. To date, these events have proven to be intractable to prediction in any reliable sense and upon their occurrence, have required the organisation to react, often in an unstructured, illogical and expensive way.

These events or changes in established/expected patterns of behaviour have been called "discontinuities" and have generally been omitted from the plans, except in the most rudimentary sense of scenario testing and sensitivity analysis. Often the discontinuity that occurs has not even been contemplated, let alone included within the plan.

The problem therefore, is, given the need for planning, how to reduce the likelihood of omitting to plan for possible/probable discontinuities that could affect the particular organisation in a significant manner.

### Purpose of This Thesis:

The purpose of this thesis is to investigate the likeli-

hood of being able to plan for the occurrence of discontinuities in events that are liable to affect significantly, the organisation.

To this end, the thesis will explore our abilities to:

1. determine what events are significant to the organisation.
2. discern social forces sufficiently early to predict that the probability of a discontinuity arising is high and requires planning for.
3. analyse discontinuities in terms of discernible social forces.
4. indicate the approximate degree of seriousness of the foreseen discontinuity, its time and place, by using the models for analysing discontinuities created by "Catastrophe Theory".
5. Use and develop existing analytic tools for the above purposes.

Approach:

The thesis will look at why organisations need to plan, both from a point of view of goal determination and goal achievement.

The planning process will be considered, drawing upon personal involvement in such a process, in a large multinational company. In particular, the use of models, both implicit and explicit, will be considered, especially with



regard to the model's ability to reflect reality and with regard to the determination of the assumption sets utilised by the models.

The determination of the assumption sets themselves, will be considered, and a proposal will be made for discerning, in a systematic way, the social forces that are stirring. This will introduce the "Way Of Life" concept that should enable the cause and effect relationships to be more readily analysed.

Application of a "System Dynamics" approach to the "Way Of Life" concept will be discussed, especially with regard to the changing dominance of closed loops within a system and the parallels that can be drawn between shifts in loop dominance and the abrupt transitions that are discussed in catastrophe theory.

A return will be made to the planning process discussed earlier, but with a view to suggesting changes in the process and to utilising some of the techniques discussed. From this will be raised the ability to move towards predicting the probability of a discontinuity.

Underlying the entire thesis will be an implied emphasis upon planning as a dynamic process about a dynamic process. There will be an endeavour to raise the questions, if not provide the answers, about the philosophy of planning implicit in the existence of an organisation.

Structure:

Chapters 1-5 consider the organisation, its planning process, its use of models and the requirements for assumptions about the future.

Chapter 6 develops the "Way Of Life" concept, Chapter 7 discusses the application of System Dynamics to the concept and Chapter 8 explores the implications of abrupt changes in terms of catastrophe theory.

Chapter 9 discuss discontinuities, whilst Chapter 10 returns to planning and reviews the changes that could be made to the planning process.

Chapter 11 draws the conclusions of the thesis.

ORGANISATIONSIntroduction:

The potential for creating an organisation arises when an individual, with an idea that he wishes to develop, discovers that his own personal resources are inadequate for the task.

The creation of the organisation occurs when the individual succeeds in marshalling other people and their resources, to help him develop his idea. In doing this, the individual has to convince the other people that working to implement his idea will, in the end, help them to achieve their own goals whatever they may be.

The above paragraphs raise or imply two important areas for discussion. The first area relates to "ideas," the crucial first step in leading to the creation of an organisation. The second area relates to "goals and goal congruence." Important work has been done in this latter area from an organisational standpoint -- especially with regard to goal congruence, aspirations, and organisational psychology in general (Schein 1980).

Very little appears to have been written about the impact of ideas upon the creation of an organisation and their role in developing an organisation. In addition, there appears to be a further role for ideas in the context of precipitating discontinuities -- this will be discussed in a later chapter. It is therefore, of some purpose to dis-

cuss the implications of ideas as forces creating and acting upon organisations and as a philosophical underpinning to organisational planning.

Ideas:

The Concise Oxford Dictionary gives one definition of "idea" as a "notion conceived by the mind" but adds further definitions relating to perception of patterns, creativity, and absolute truth.

For this thesis, the word "idea" will be defined to include creativity and perception of patterns (absolute truth is beyond the scope of this thesis).

Ideas are not intangible. They are tangible in a physical sense, in that some physical change has taken place within the brain, some memory space has been allocated and some logic areas have been disturbed in "thinking" about the idea.

In this context an idea is an event -- it can not be nullified, only destroyed by a second, later, separate event. Or else it can be superceded in importance by subsequent events to the extent that the first idea has infinitesimal impact.

An idea thus occupies some space and some time and, because of this occupation, enters into cause and effect relationships. Initially this applies to the thought processes of the individual, and subsequently beyond the individual, to the

extent that the idea alters the actions of the individual from what they would otherwise have been.

The emergence of an idea and its consequent occupation of space and time, creates a boundary condition and sets up dynamics within the boundary, affects the now external dynamics of its environment and creates scope for cross-boundary transactions. An idea thus represents a discontinuity in its own right, i.e. the discontinuity from internal to external.

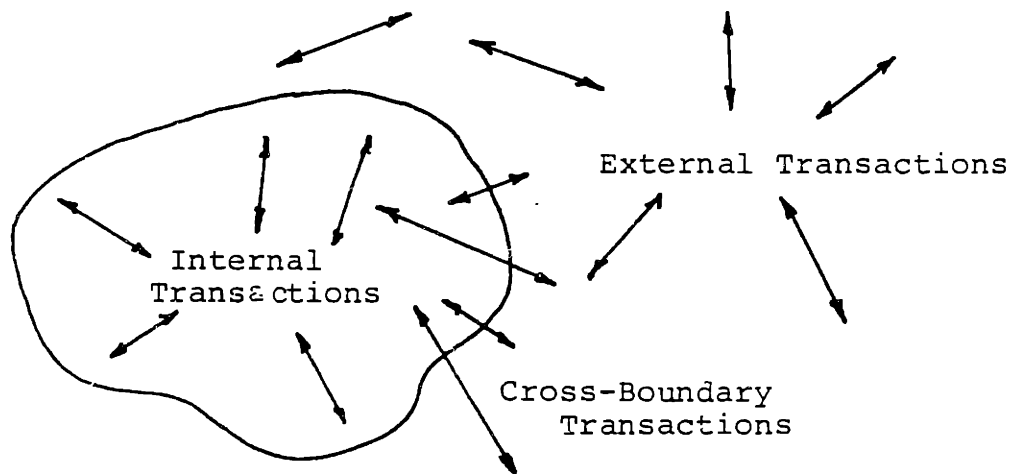


Diagram 1: Internal, External and Cross-Boundary Transactions

The concept of internal dynamics of an idea is relevant because it relates to the "quality" of an idea.

If the initial assumption is one of ideas of equal quality, then the effects of ideas are wholly determined by their time and place (possibly time alone). Shakespeare appeared to grasp this in his words for Brutus:

"...There is a tide in the affairs of men  
which, taken at the flood leads onto  
fortune"

But if the initial assumption is one of unequal quality, then a further question must be asked as to the reason for the difference in the effect of the ideas.

The definition of an idea has a creative aspect to it and it is here that Jacob Bronowski's definition of "creativity" can assist. Bronowski was discussing creations of the order of "Othello" in "A Sense of The Future" but, on a more prosaic level his definition can still apply.

"A man becomes creative... when he finds a new unity in the variety of nature. He does so by finding a likeness between things which were not thought alike before..." (page 12)

If the creative aspect of an idea depends upon finding a unity in variety, then perhaps more ideas and more unifying ideas will arise from people exposed to more variety (e.g. experience and/or education).

In this regard therefore, the more cross-boundary transactions between the internal and external dynamics, the more developed will become the idea -- it relates to more external variety and hence has greater quality.

Thus the effect of ideas could be attributed to their timing (and this will be relevant in the discussion of discontinuity) and their quality, which could be related to the experiential base of the individual.

In summary therefore, ideas have the following charac-

teristics:

1. the inability to nullify an idea.
2. the timing of an idea.
3. the quality of an idea.
4. the apparent importance of a wide experiential base.
5. the inability to explain how the individual "sees" that "unity" (that is the creative aspect of the idea) in the first place.

The discussion about ideas introduces, at the most fundamental level, the model of the external and internal, the concept of the cross-boundary transaction and the fact that one cannot go back. I.e. the present starting place is relevant. (A point not fully appreciated in a concept such as zero base budgeting which implies actions to move the budget away from the starting point of the present spending pattern to the model point of zero).

In the context of an organisation and its creation, the initial idea becomes the goal and it becomes appropriate to discuss what the term "goal" implies, how the goal changes and what occurs when the goal has been attained.

#### Goals:

The goal for the newly created organisation is clear, it is the attainment of the full development of the idea that led to the creation of the organisation.

However, when the organisation is created, a new boundary condition exists -- the organisation versus the now external world. Internal dynamics commence to operate amongst the people within the organisation, placing pressure upon the original goal to adapt to the resultant of the goals of the individuals and their groups. As a result, in any one part of the organisation and at any one time, it can prove difficult to actually determine exactly what is the goal of the organisation.

The external world is also changing and adjusting. Firstly as it would prior to the advent of the organisation, and secondly as a result of the advent of the organisation. These changes also affect the organisation. The ability of the organisation to attain its goal is constantly shifting. If the internal and external dynamics do not interact in a compatible manner, it becomes possible for the organisation to drive for an unattainable goal.

There is therefore, considerable importance to be placed upon the transactions across the boundary, i.e. the dynamics between the internal and external events.

As the organisation grows, its cross-boundary transactions become more important. This can be illustrated by what happens to goals in the planning process.



Goal Transformation:

In the initial days of the organisation, the internal dynamics tend to be relatively simple -- numbers are low, issues are clear and authority is usually clear cut.

These conditions have been referred to by Christensen Andrews and Bowers in "Business Policy, Text and Cases" drawing upon work by Bruce Scott as Stage I in corporate development.

"Stage I is a simple product (or line of products) company with little or no formal structure run by the owner who usually performs most of the managerial functions, uses subjective and un-systematic measures of performance and reward and control systems. The strategy of this firm is what the owner manager wants it to be"(page 133.)

(my emphasis).

In these circumstances, planning is also relatively simple and consists of two major elements:

1. Communication of the goal.
2. Programming for the attainment of the goal.

As the internal dynamics develop, communication acquires an additional dimension, that of achieving goal congruence between parts of the organisation. This additional dimension is considered to remain within the ambit of communication, as it does not alter the nature of planning, only adds to the relevance of planning.

However, there comes a crucial point in time when the nature of planning has to change significantly. This point is reached when it becomes evident that either the attain-

ment of the original goal is imminent or, alternatively; the attainment of the goal is recognised to be unlikely. Planning changes by the need to include a third element -- in addition to those of communication and programming -- that of goal selection.

The addition of this one element alters the whole nature of planning and possibly the whole nature of the organisation. This is because the assessment of the options open as possible successor goals assumes relevance for the first time, and places a far greater emphasis upon understanding the external dynamics and requires a far greater understanding of the organisation itself (in particular its actual and perceived flexibility/adaptability to change).

(It is interesting to note that internal models of the organisation do not seem to be required until there is this shift to a goal seeking mode.)

#### Mutual Dependence:

Implicit within the goal selection mode is the desire to maintain the existence of the organisation. This is an interesting implication because logically, once the original goal has been attained, there would appear to be no further need for that particular organisation.

Several examples exist of organisations voluntarily going out of existence. For example joint venture operations at the conclusion of the venture -- especially in the heavy construction field; special interest groups such as anti-

Concorde; medical groups, such as the teams involved in the eradication of smallpox around the globe.

However the more general case seems to be for the organisation to transform itself for some reason and it is appropriate to explore that reason.

At this point, it becomes necessary to consider the boundary between the organisation and its environment, the growth of cross-boundary transactions and the mutual dependency relationships that are set up. The important area is that of the dependency relationships. Work has been done in this area (Kobrin) with regard to international transactions, but it can and does apply to cross-boundary transactions generally, provided the concept is widened to include mutual dependency.

In other words, the mere existence of the organisation, like ideas, sets up cause and effect relationships. As the internal dynamics and cross-boundary transactions increase, the organisation becomes more firmly embedded within its environment. Conversely however, the organisation becomes an increasingly important part of other organisations' environments.

The mutuality of dependence grows and becomes so pervasive that the demise of an organisation can reverberate throughout an entire environmental system. As with ideas, an organisation can not be nullified. It can only be destroyed by a deliberate action or set of actions.

It is suggested that the magnitude of the event required to destroy an organisation is dependent upon the extent of its cross-boundary transactions. This is well illustrated by the social inability to create the event that would have led to the demise of Chrysler, and of British Leyland. This follows from the fact that the series of cause and effect relationships across the boundary have become too complex to be broken down readily.

The mutuality of dependence therefore, creates conditions that lead to the organisation becoming goal seeking. In fact it could be said that at the point of change referred to earlier, the organisational goal is to find new goals so that the organisation can remain in existence. But it goes further than this, because there is not only an organisational goal to find new goals, there is also an environmental goal to see that the organisation finds new goals. Again, witness Chrysler.

#### Two Implications Of Goal Seeking:

The implications of a goal seeking organisation are interesting. Firstly there is a shift in the time dimension, in that the organisation begins to accept a self-perpetuating mode of existence. The domain of the organisation becomes larger in time and because of this, becomes larger in terms of space and idea. I.e. there is more time to consider and do things that were previously closed out

by the finite time span of the non-goal-seeking organisation.

Planning therefore has to grapple with the problem that more time makes more options available to the organisation.

Secondly, the extent of the mutual dependency relationships can and does offer opportunities for taking risks that without the mutual dependency would be unacceptable, e.g. the cash flow positions of state enterprises are acceptable because the organisation provides jobs that the nation relies upon for social stability. Conversely, of course, the mutual dependency can place demands upon an organisation that it would prefer to do without. With regard to the former, it is remarkable that some business organisations do not seem to appreciate that heavy involvement in a given country might reduce the exposure to political risk.

Planning, therefore, has to closely consider both sides of the mutual dependency relationships in order to understand how the organisation will be acted upon by the environment and how the organisation can act upon its environment.

#### The Need For Planning:

Planning is a process for meeting needs and when we talk about the need for planning we mean the need for the process.

From the earlier discussion, the creation of an organisation depends upon the need to implement an idea. The im-

plementation of the idea itself however, depends upon the organisation being able to marshall the activities of its people (Schein 1980) which in turn depends upon:

1. knowledge of the idea or goal.
2. methods/programmes for marshalling the activities towards that goal.

and when the organisation has reached the goal seeking mode

3. the need to select goals.

Planning is the process of meeting those needs of communicating/goal congruence, activity marshalling/programming and goal selection which in turn depend upon the need for the organisation in the first place.

Summary:

This chapter has endeavoured to illustrate the importance and effects of ideas as the originating force for creating organisations, and as a preliminary step towards providing a common base for linking social and economic events.

Second, the chapter has shown how the original idea, now a goal, becomes transformed and how the organisation, becoming part of a mutual dependency system, tends to become a goal seeking entity with an implicitly unlimited life span.

Third, the chapter has tried to identify the planning process as a means towards meeting and selecting the goals.

## PLANNING

### Introduction:

Chapter two concluded with a statement about the need for the process of planning as a means towards meeting the organisation's goals -- including the goal of seeking for goals.

Anthony and Dearden in "Management Control Systems - Text and Cases" provide a more usual definition of strategic planning as follows:

"Strategic planning is the process of deciding on the goals of the organisation, on changes in these goals, on the resources used to attain these goals and on the policies that are to govern the acquisition of these resources." (page 10)

"... the programming process takes these goals and strategies as given and seeks to identify programs that will implement them effectively and efficiently." (page 396)

This is probably one of the more comprehensive definitions of the planning process, but as this thesis is looking at planning in the light of the internal and external dynamics of an organisation and in particular, in the light of handling discontinuities, it becomes necessary to go behind the definition and look at what it implies, in order to meet the requirements of goal selection, communication and resource allocation.

### The Extent Of The Process:

For the planning process to be effective, it needs to



fully (or better) understand the following:

1. the internal dynamics of the organisation up to the present time.
2. the type and extent of cross-boundary transactions.
3. the external dynamics of the organisation's environment to the present time.

Arising from the above three areas, the planning process needs to be able to understand the degree and extent of;

4. the mutual dependency relationships between the internal and external dynamics.

And because of the extended time frame and future orientation,

5. the need to understand how the internal and external relationships are changing, i.e. what is liable to happen to the organisation and its internal dynamics; what is liable to happen to the external environment and its dynamics; and finally, how the mutual dependency relationships are liable to change as a result of the changes in the internal/external dynamics.

#### Internal Dynamics and System States:

The state of an organisation at any point of time consists of a series of levels of resources, be they people, materials, funds, customer/supplier bases, goals, plans, and ideas.

A concept of system states has several useful features.

It draws attention to the relationships between individual states, i.e. the system as a whole; it implies interacting changes to those states over time; and finally it provides a method for,

1. determining the goal as being a desired set of system states at a specific point in future time and
2. permits the measurement of progress towards the goals by determining how closely the current system state approximates the desired state.

Most organisations have highly sophisticated systems for measuring the levels of various resources. For example, the entire accounting system is largely devoted to that task. Similarly, staff audits in terms of numbers and quality of people, inventory systems, cash systems, and customer/supplier systems all exist and are usually highly efficient as devices for measuring current levels and, sometimes, even the flows into and out of those levels, i.e. their dynamics.

Secondly, the forces that produced the system levels are important because they relate to questions such as, what happens to the system states if the past forces are maintained, discontinued, or altered in intensity? A knowledge of what would happen is useful, but a knowledge of what is liable to happen is even more useful. A systems approach of cause and effect relationships is of assistance here.

But a knowledge of the likelihood of changes in the forces affecting the system states would be most useful of all. It is here that planning for the future should pay some attention to the events of the past in order to assess whether the effects of those past events are still affecting the system states today and on into the future.

For example, is the past event of delaying employment of accountants still affecting the system's ability to develop better and more efficient methods? Does the past decision of the Saudis to use and accept jumbo jets at Jeddah airport still have an effect upon the level of Muslim awareness of Islamic values in the Middle East and possibly the Far East?

Thirdly, the internal dynamics are social. It is not an organisation that makes a decision, it is an individual or group of individuals. It is not enough therefore, to know that a system state depended upon a specific decision or set of decisions. It is necessary to know why that individual made that decision at that point in time, in order to appreciate the full implications of the decision to the current point in time and to make an assessment of the likely implications of that decision into a future point in time.

An interesting illustration of this latter item is the importance placed upon training newcomers about the key events in the history of the organisation, the people involved then, and the key people today, especially with

regard to the internal politics of the organisation.

Fourthly, the systems concept requires the consideration of more than just a knowledge of the various physical processes. It requires consideration of the impact of information upon an individual's motivation.

Planning therefore, implies a large degree of knowledge about the organisation itself; the physical processes, the people processes and the informational processes. It requires this knowledge with regard to the present state of the organisation, the forces that produced that state and finally the internal forces that are presently operating to affect the future states.

Summary:

This chapter has reviewed the need for and definition of planning in the context of the internal and external dynamics and systems created by the coming into existence of the organisation.

It has tried to emphasise the importance of the overall dynamics -- the systems concept -- and to indicate the extent of the data needed to plan adequately.

The chapter has also expressed the goals of the organisation in a different light; that of a coherent set of desired system states at a specific point in time. This approach emphasises the system involved in attaining a goal and provides a basis for measuring progress towards the goal -- i.e. the (hopefully) decreasing difference between the existing and desired levels.

DATAIntroduction:

The amount of data available to the organisation for use in its planning is extensive, so extensive that its collection and use can and does become a major task within the organisation itself.

It is therefore, appropriate to look at the significance of data and its transformation into meaningful information.

Facts:

Facts are "things certainly known to have occurred or to be true," as the Concise Oxford Dictionary puts it. But facts, of themselves are meaningless; they lack a frame of reference. This is well illustrated by taking a random computer print out of digital facts that do not have any headings, it is meaningless.

Frame of Reference:

A frame of reference however, provides information about the context of the facts; it determines what the facts are about, it provides some reason for the collection of facts, it converts the facts into data.

For example, the numbers on the computer printout could have the frame of reference of being currency, and more precisely, currency related to the cost of oil supplies for XY Inc. over the period 1979.

Data:

With the above notes in mind, it is timely to explore the nature of data, their problems and their conversion into information. In so doing, consideration will be given to the significance of frames of reference, in particular how they are determined, and consideration to patterns especially with regard to their recognition, their ability to reduce delays and the role that they play in generating information. This latter item will be considered first as an aid to the generation of frames of reference.

Patterns:

James H. Hayes considered the role of patterns in a monograph entitled "Patterns, Plain and Fancy" which dealt with the ability of the military to recognise the ways that wars were being fought or were liable to be fought by an enemy, in order to determine the best way of counteracting the enemy. Fundamental to this task were the recognition of the overall battle pattern, the need for speed and the largely insurmountable problems of sorting out the significant from the insignificant.

In Hayes' words;

"...Yet on a battle field, the flow of information is about small units and individual actions...In other words, combat intelligence generally follows the chain of command and is about the activities of small units. This flow means that the aggregation of information is generally slow and the development of patterns of activity is slow because the significant must be separated from

the insignificant...This slowness may be called (for want of a better term) 'intelligence lag'..."

This is an important quotation because it draws attention to the low level at which data arises, the slowness of obtaining the data, the need to separate the significant data and the concept that aggregation of data is necessary in order to ascertain the pattern of the activity.

The significance of patterns and their relation to information can be illustrated by a very simple device. Firstly, the following shapes represent a set of facts which become data when we apply a frame of reference such that the shapes represent the elements from which some of the upper case letters of the alphabet are constructed.

|   3   3   \

At this point there is no discernible pattern. However if the data is aggregated or summarised or condensed as follows

|P

then we begin to discern a pattern. Either we have a complete piece of information in the form of the letter "P" or else we have part of the pattern relating to the letters "B" or "R." In other words aggregation or summarising does two things; it enables a pattern to be recognised and frequently, it enables the field of possible patterns to be narrowed down to the extent that action can be initiated at an earlier stage in the cycle of events.



The important point is that data aggregation is necessary to see the relevant pattern that underlies the data.

#### Data and Patterns:

The above example refers to pattern determination, but there is an important distinction between data known to have a pattern and data with an as yet undetermined patterned.

#### Unknown Patterns:

In this case, a pattern has not been determined relative to the data available and steps need to be taken to determine if a pattern exists.

Traditionally, data has been classified and summarised on a basis of sorting "like with like" as is illustrated in any good accounting textbook. The purpose of the classification and summation is to "stand back" from the detail -- to try and see the overall "picture" or pattern.

This is a slow process in the first instance but, once a pattern has been determined speed in data handling and information determination is improved, as outlined below.

#### Known Patterns:

In this case a pattern is known to exist, a series of inter-relationships have been established in the past, and by the use of inference, can be applied to the present and the future.

Data can be correctly inserted into the pattern and the

significance of the data rapidly assessed. Put more strongly;

1. the pattern facilitates rapid assessment of the significance of the data.
2. the pattern provides a means for determining which data needs to be collected, either in the first instance, or else as a support to confirm the existence of the pattern.

The pattern approach is elegantly summed up by the aphorism about "not seeing the wood for the trees."

#### Patterns and Experience/Training

The discernment of patterns is of interest. What is it about a grouping of data that produces a pattern and is that pattern seen by everyone?

When an accountant runs his eye over a pageful of accounting information he sees patterns in the numbers that have meaning to him but surprisingly, not to others. Similarly for a mathematician, or an engineer or a poet or a critic or a programmer. It is exemplified by the boss who immediately puts his finger upon the error or the oddity in the report that a junior presents to him. He sees a pattern that does not ring true.

What is normally called interpretation is probably the recognition of familiar patterns or the extension of patterns to new areas.

Why is this relevant?

It is relevant because pattern recognition seems to be a function of experience, of having seen similar groupings of data before, and then by the application of inference, extending what happened the last time to the current data and pattern.

It is relevant in terms of observing that information generation, rather than data gathering and manipulation, seems to be a function of the "old hand" or else as the result of considerable training in the field to which the data relates. In other words pattern recognition is a function of the individual's experiential base and the individual's ability to use inference upon either incomplete data or else by inference to extend patterns to new types of data.

The term "function" is used in the sense that experience adds to whatever abilities that are innate to the individual such as level of intelligence and ability to think laterally.

### Predictive Patterns

In the context of planning, the ability to see patterns has another aspect and Hayes addresses this in his study.

"...there is another side of the pattern to be considered. If we recognise a pattern, then it becomes predictive, not in an absolute sense, but in the sense of increasing probabilities."

This was illustrated in the little exercise with the elements of the letters of the alphabet, the vertical stroke, when combined with the semicircle increases the probabilities that the letters P or B or R are liable to result from the data.

Patterns therefore form the basis for inter-relating components of the data set. They are generally seen through the aggregation/summarisation of data combined with the application of knowledge of patterns liable to exist for that data and the extension, by inference, that that knowledge can be applied to that data. Determination of patterns can speed up the assessment of data and aid in the selection of data to be collected and provide information.

#### Patterns and Models:

The preceding section has looked at the perception of patterns.

The application of that perception forms the basis for models, i.e. a model specifies the significant inter-relationships that comprise the pattern, in a reproducible form. A model is a more specific form of a pattern, it has moved from the general term that includes the qualitative to the more quantifiable processes.

The abstraction of a model from a pattern has an inherent danger in that it can be too specific i.e. that data is always related to that other kind of data in that manner.

It does not leave adequate room for the more general aspects of a pattern which enables one to say that data is usually related in that manner to that other kind of data."

#### Characteristics of Models:

The fundamental requirement for a model is that a variation in a model input will result in a variation in a model output in the same way that a variation in a real life input affects the real life output. This characteristic requires the determination of adequate (not total) inter-relationships between inputs and outputs i.e. the pattern of the process.

Following from this, is the obvious conclusion, that data inputs that do not affect the output are insignificant and can be ignored. This apparently trivial conclusion forms the basis for separating data into significant and insignificant categories and provides the screen for minimizing data collection by limiting it to the significant data alone.

A well constructed model about a process (frame of reference) should collect and use, only that data that affects the outcome of the process in a significant manner.

Models therefore, by their abstraction of the essentials of a pattern, their ability to segregate the significant from the insignificant, and their ability to use only part of the data about a process, provide an

indispensable means for deriving meaningful information about the process in a speedy and cost effective manner. They are the only practical means for reducing vast amounts of facts, about the processes around which planning revolves, to manageable information.

Summary:

This chapter has endeavoured to look at what is implied by data and how it can be managed. It commenced with some needs;

1. the need to apply a frame of reference to the facts in order to produce data - i.e. facts about some thing or some process.
2. the need to aggregate and summarise the data in order to see the underlying pattern.
3. the need to use patterns to provide meaningful information.
4. the need to interpret the significance of the information by assessing the relevance of the pattern to the frame of reference.

The chapter continued by indicating that patterns are a "general" case for models, that models permit the determination of data needs and data significance, and that models, by their ability to use partial data, can speed up the production of meaningful information.

The chapter picked up the threads from the section on the effects of ideas by drawing attention to the fact that recognition of patterns, (that important and vital aspect of providing information) appears to depend upon the experiential base of the individual assessing the data. This has significance in the decision as to whom to assign to a planning post.

Finally, the chapter closed upon a recognition that only models, albeit with some limitation, can provide a practical means for handling the vast quantity of facts available to the planning process.



MODELSIntroduction:

The preceding chapter ended on a requirement for models as a means of simplifying data into comprehensive sets of useful information and as a means for predicting subsequent states of the system being modelled.

Use Of Models:

Models can be used in at least two ways -- either by taking an existing or known state and, by applying known dynamics, transforming it into a prediction of a future state; or by taking the existing or known state and then using the model to determine what the dynamics need to be in order to arrive at a desired and subsequent state.

Before exploring this further, it is appropriate to consider some of the statements about models made by René Thom (1975)

"In those ambiguous or catastrophic situations where the evolution of phenomena seems ill determined the observer will try to remove the indeterminacy and thus predict the future, by the use of local models."

"All models divide...into two a priori distinct parts: one kinematic, whose aim is to parameterize the forms or states of the process under consideration, and the other dynamic, describing the evolution in time of these forms."

Thom provides a rigorous mathematical support for these statements and elaborates extensively, and in a topological sense, upon the terms "local," "kinematic," and "dynamic."

In the context of planning and without distorting Thom's use of local too much, a parallel can be drawn between the "surface" of all data around a process and the "local" region of that data that is specifically relevant to the process, i.e. the "local" model.

Similarly, the "kinematic" is the present or initial level of all the states in a system, i.e. resources, manpower, funds etc. whilst the "dynamic" is the set of rules governing how the levels evolve over time -- in a stable manner.

In Thom's words "there is the following general model to parameterize the local states of a system" --

"... the space of observables  $M$  contains a closed subset  $K$ , called the catastrophe set, and as long as the representative point  $m$  of the system does not meet  $K$ , the local nature of the system does not change. The essential idea introduced here is that the local structure of  $K$ , ... is in fact determined by an underlying dynamic defined on a manifold  $M$  which is in general, impossible to exhibit. The evolution of the system will be defined by a vector field  $X$  on  $M$ , which will define the macroscopic dynamic... Although the goal is to construct the quantitative global model  $(M,K,X)$  this may be difficult or even impossible."

The above quotation begins to set the scene for discussion about catastrophe theory and discontinuities, but it is relevant here because it emphasises the quantitative global model  $(M,K,X)$  as being difficult to attain.

Thom goes on to develop standard forms of  $K$ , the catastrophe set, which can be ignored for the moment, leaving the global model dependent upon the initial state of

M and the evolution of the system by the vector field on M.  
Thom states that rather than define the global model --

"...in most cases we proceed in the opposite direction: from a microscopic examination of the morphogenesis of a process and a local and global study of its singularities, we can try to re-construct the dynamic that generates it."

This is, in other words, the process of having a defined goal (or set of future states of a system or the evolved M), the knowledge of the initial position (or set of initial levels or the shape of the initial M) and then using the model to work back to the rules for going from the present to the goal (i.e. the rates affecting the levels, or the definition of the vector field X on M).

Why is all this relevant?

Firstly, there are the two aspects of the model, the kinematic and the dynamic, each of which needs consideration in a specific manner in the planning process.

Secondly, there are the two ways of using a model, one to know the vector field X and to then determine the evolved M, and two, to know (or state) the desired future M and to determine the vector field necessary to move from the present state to the required future state.

Organisations apply both uses to their implicit and explicit models.

#### Internal Models:

For example, in modelling the internal dynamics of an

organisation, the organisation tends to use the method which requires the determination of the vector field. This arises logically from the fact that an organisation is goal centred and goal seeking. It is the means of achieving the goal that is the unknown, not the goal itself.

This is emphasised time and again by the importance of programming, to use Anthony and Dearden's term. It is the action to be taken to achieve the goal that constitutes the main element of organisational plans. In some instances, especially with the goals of sub-units within the organisation, it is possible to build very deterministic models where the dynamics are in fact known, e.g. refinery linear programs.

#### External Models:

In contrast to the internal models, there are the models of the organisation's environment -- the external world. Model is an appropriate term, because every assessment of the future implies some use of a model, be it a rule of thumb or a full scale scenario. Here the use of the model depends, not on knowledge of the goals of the external world, i.e. the evolved future state of the world, but upon knowledge of the vector field, the dynamic, the reason for the particular evolution. This why the forecasting, the prediction, of the external world is so difficult -- not only does the predictor have to make assumptions about the dynamic that is likely to

apply, he also has to make assumptions about the likely goals of the external world.

In assessing what is liable to occur in the external world, it is sometimes useful to assume knowledge of the external goals and, having done that, to assess what would have to occur in order to attain those goals. I.e. by applying the method of using the internal model to the external model, more light might be cast upon what is happening in the external world.

At least one major international organisation has endeavoured to consider the external world in this way, but to date it has represented too large a step in the evolution of the planning process for ready acceptance. (Possibly because it could imply that the organisation could adjust its environment in a significant sense.)

To this point therefore, models consist of a means for removing indeterminacy within a system, i.e. they are predictive, dependent upon a kinematic and a dynamic and can be used to predict either the future kinematic, or given the future kinematic, used to predict the required dynamics.

These characteristics largely determine the construction of a model, the data and the degree of its aggregation, the information that it produces and the life span of the model.

#### Mixed Models:

The models identified so far are fairly simple either/or

cases, but there is the case of the mixed model to be considered. In this case, the goal of an organisation might relate to a specific level of a specific part of a system.

In this case, the model is used to predict the dynamic for attaining that specific goal whilst simultaneously using assumptions about the dynamics about other parts of the system to predict the levels of the remaining parts of the system. The difficulty here is that the predicted dynamic to achieve the specific goal might be at variance with the assumed dynamics used for calculating the future states of the rest of the system.

Organisation

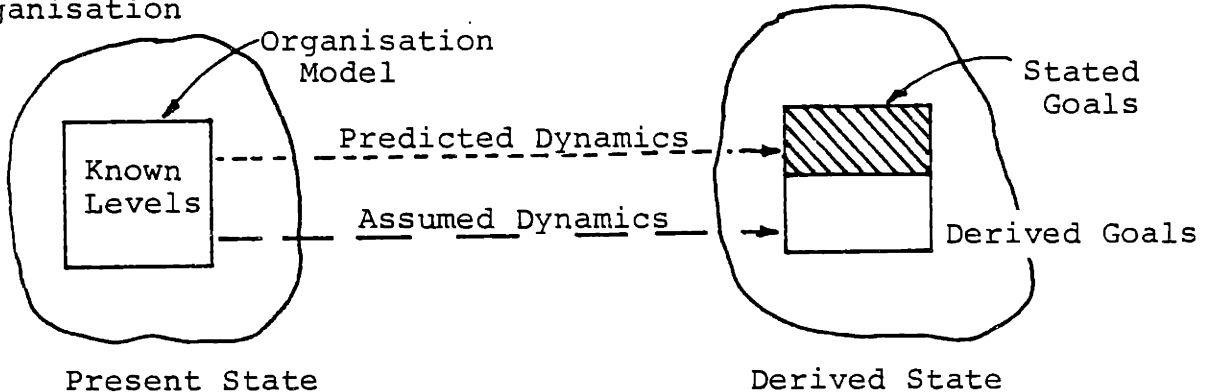


Diagram 2: Mixed Models

The "virtue" of such a mixed model, and they are common, lies in the benefits achieved by not modelling the entire system as it relates to the goal. The major benefits are reduced time and reduced cost in attaining a roughly workable model. The detriments are characterised by the occasional nasty discovery that parts of the system are not in phase and wrong decisions have resulted from using the model.

It is interesting to note that mixed or partial models of the system seem to be a function of the size and extent of the cross-boundary transactions. At earlier stages when the number and extent of cross-boundary transactions are relatively limited, there appears to be a preponderance of mixed models. At some point in time the increase in the cross-boundary transactions seems to so increase the extent of mutual dependence between the organisation and its environment, that specific organisational models using the goal approach, and specific environmental models using the dynamic approach seem to be required.

#### Life Span Of Models:

The life span of a model is dependent upon the maintenance of its predictive ability. If this ability deteriorates the model will produce output that whilst correct in terms of the model, is not adequately related to the events that the model has been built to predict. This can arise from two causes or a combination of both:

1. the model has become obsolete, or was inadequately constructed, and does not correctly represent the now relevant kinematic and dynamic, or
2. the data fed into the model were wrong.

With regard to the first item, the model is constructed to be local, in that it should only use those data that are directly relevant to the process being modelled, at the

time it is being modelled. But what is relevant can, of itself, be subject to dynamics (and as we will see later, discontinuities) that cause elements in the model to wax and wane in relevance, or in the extreme, to eliminate or introduce elements in the model. This un-modelled shift in relevance is a cost of the simplification and "localising" process involved in modelling and will tend to place a finite term upon the model's ability to predict events.

For this reason alone, models need to be subjected to continuous review -- not only as to their internal consistency, but also in terms of their ability to include all the presently and foreseen events of relevance to the issue. Or in other words, the model of the process can be right initially but wrong subsequently. There is some doubt about the ability to construct a model that applies for all time, or even for more than one or two years before it becomes unacceptably obsolete.

#### Hierarchy Of Models:

The discussion of models has not covered the practical hierarchy of use of the two types of models. To date it appears safe to state that no one organisation has total influence over its environment. Or to reverse the statement, organisations are subject to their environment.

If this is true, and in practice it appears so, then the hierarchy of models becomes quite clear. The results



from the environmental model which uses assumed dynamics to predict future environmental states, provides inputs to the organisational model, which predicts how to move from the present state to a specified future state.

#### Goal Determination:

If the predicted organisational dynamic conflicts with the predicted environmental states, then a condition arises that requires a change in the organisational dynamic (if alternative dynamics are available) or else a change in the organisational goal unless the organisation can so utilise its mutual dependency links to change the relevant portion of the environment. (This latter item is nicely illustrated by the organisation that employs a lobbyist to try and effect environmental change for the organisation.)

#### Data Sets:

It is time to consider the different data sets of the two different types of models. In particular, reference will be made to:

1. an intention set which is specific to the model predicting the dynamic and
2. an assumption set which is specific to the prediction of the future kinematic.

### Intention Set:

Within an organisation, the single most important part of the planning process is the determination of what the organisation's executives "intend" to do. These "intentions" form the basic input to the organisation's internal model, which, in conjunction with the assumptions about the external environment determine whether the organisation can successfully integrate all the diverse intentions.

The intentions set is characterised by three factors:

1. it is personal to specific managers and hence becomes a means for target setting.
2. it is amenable to control by the organisation in a way that the external environment is not -- i.e. it is the area whereby the organisation adjusts to its environment.
3. it is the mechanism for achieving goal congruence with the organisation.

Personal involvement in the acquisition of intentions, their compilation and assessment, emphasised their importance and how their importance was appreciated by the top management. More time was spent by the executive management upon this area, than upon any other part of the planning process.

Integration of the intention set requires some form of a model that looks at the organisation as a whole. It is only by putting the entire organisation together that inconsistencies within the intention set can be perceived.

Assumption Set:

The assumption set enables the "intention set" to be seen within the context of the expected evolution of the external environment. It is characterised by the following factors:

1. it is far more complex than the internal organisation.
2. it is represented by a vast amount of available data which is not easily seen to be significant or insignificant.
3. it is not easily controlled or influenced by the organisation.
4. it is subject to the most alarming degree of unpredictability and discontinuity.

The subsequent chapters will concentrate upon ways of determining how to cope with these characteristics.

Summary:

This chapter has introduced two concepts about models, based on work by Thom. They are "relevant data" and the analysis of the model into an initial position or "kinematic" and its evolutionary vector or "dynamic."

The chapter has considered the two main purposes of models as being the ability to predict the future state (or kinematic) using data known or assumed about the dynamic, or else to predict the dynamic using data about the desired future state. The latter use tends to relate to models of the organisation, whilst the former to models about the organisation's environment.

The chapter has looked at the output of models, i.e. the prediction, and its relation to subsequent events. If there is an inadequate relationship, it arises from either shifting degrees of relevance of events between the world as modelled and the world in reality, or else the lack of predictive ability relates to incorrect data.

The chapter has determined a hierarchy of models in terms of usage. The model of the organisation uses results from the model of the environment as input and the data needs differ for the two types of usage.

The chapter has also considered the characteristics of the data sets -- intention and assumption sets -- needed to operate the internal model.

## WAY OF LIFE

### Introduction:

As indicated in earlier chapters, the assumptions about the organisation's environment that are used in determining the goals selected and the means towards those goals, are of fundamental importance to the well-being of the organisation.

The determination of those assumptions is the topic of this chapter and it will be undertaken in the context of the global environment. However the process described here has a general relevance and is not limited to global models alone.

### Frame of Reference:

The chapter will stress a "Way of Life" concept that goes beyond the more traditional approaches to environmental scanning, the assessment of political risk and the noting of specific aberrations in specific countries. The frame of reference will be the "Way of Life" at the national state level, and will endeavour to stress the importance of providing answers to the following three questions;

1. what factors distinguish that nation state from all others?
2. what are the dynamics behind those factors?
3. how are those dynamics changing in themselves?

### General Discussion:

The purpose behind the questions is to determine the

"pattern" of the nation so as to be able to assess how it will evolve and, within the internal model, how that evolution will affect the organisation and how the organisation will affect the nation itself. In effect, the Way of Life concept will enable a causal loop structure, of the nation, to be built, and, by taking the residual of the nation state with its inter-actions with other states, the concept will enable a global causal structure to be perceived. The concept, of itself, is not new. It has been applied many times to specific economic or political studies on such topics as energy or coal or the spread of communism.

What is different is the attempt to portray that other, non-economic factors matter, factors that can and frequently do have alarming economic consequences.

The Way of Life concept is a means towards endeavouring to reduce the surprise element of those alarming economic impacts by, at the least, considering the possibility of their occurrence.

This is, of course, an immense task, but it can be reduced to more manageable proportions by having a very clear knowledge of the organisation's cross-boundary transactions with its environment. In general, Ways of Life that do not directly enter into the cross-boundary transaction set can be ignored.

There is a caveat however, and it is fundamental. The various Ways of Life of the different nation states are

inter-connected and form a causal loop structure of their own. Accordingly, changes, or at least the recognition of the fact that changes can occur, in Ways of Life outside the direct cross-boundary transaction set, need to be considered in determining the assumption set about the environment.

The picture so far, can be portrayed as follows:

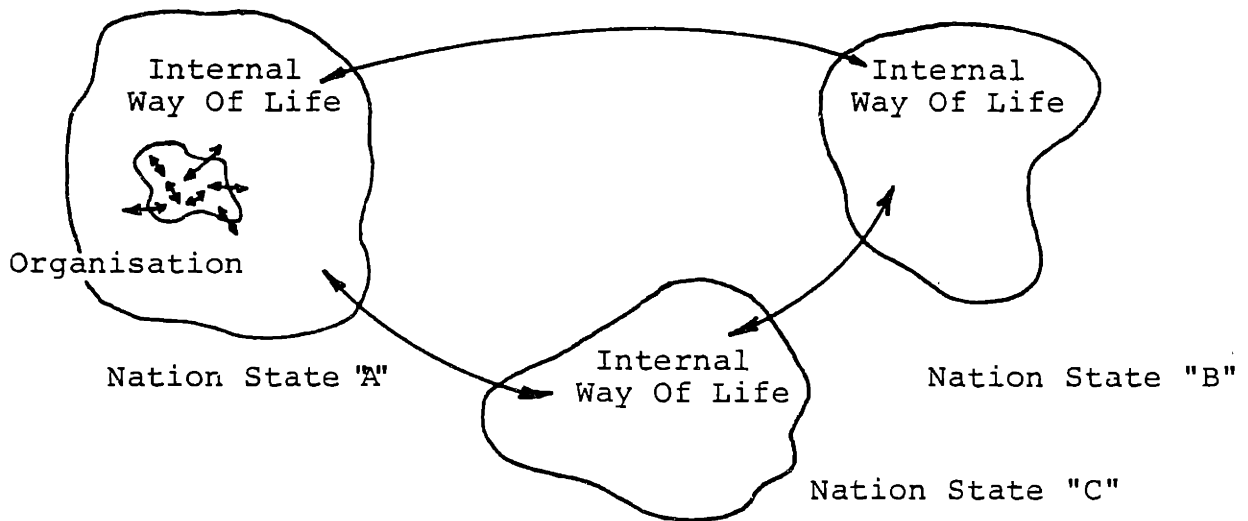


Diagram 3: Interrelated Ways Of Life

Nation state "A" interacts with the organisation and with nation states B and C. But C also interrelates with B and it is this link that is too easily overlooked.

The Distinction Between Nation States:

The first question posed earlier was, what factors distinguish the nation from all other nations? This is equivalent to determining the barriers to cross-boundary transactions between the nations.

It is a fascinating thought - that nations differences are the result (cause?) of restrictions upon cross-boundary transactions. For example, one of the factors distinguishing the British from the French is a British restriction upon having a civil code as a basis for a legal system. Similarly, and in a physical sense, the presence of the Channel provides a restriction upon the merging of the two Ways of Life by hindering easy migration (especially in the past).

The following areas for investigation are posed as a means for determining the specific Way of Life. The areas are not exhaustive and they imply a pattern specific to the individual and to the problem at hand.

I.e. the Way of Life is shaped by:

1. a value system comprising political, economic and religious beliefs.
2. a physical position and its characteristics and resources.
3. a specific history.

Items (2) and (3) tend to influence item (1) and item (1) will influence the "future" of item (3).

W.M. Jones in a paper entitled "Predicting Insurgent and Governmental Decisions: The Power Bloc Model" provides one of many excellent examples for assessing specific aspects of a Way of Life -- in this case political power and influence. Similar examples are provided by Fred Emery in



"Futures We Are In"; by Daniel Chirot in "Social Change in the Twentieth Century" and by Guy J. Parker in "Sources of Instability in Developing Countries." S. J. Kobrin takes a more quantitative approach in his paper "Foreign Direct Investment, Industrialisation, and Social Change."— The whole field of environmental scanning abounds with specific examples that can be applied towards determining the Way of Life structure.

An indication of the inter-relationships can be gained by taking one of the items listed above, for example, resources.

For example there is the impact of the discovery and use of resources in terms of shaping the future -- and in some instances -- a long way into the future. In England, tin was discovered several thousand of years B.C. and that discovery led to considerable culture change, population migration and the shaping of a culture that still remains distinct today -- that of the Cornish folk.

Coming closer to the present, the discovery of oil in the North Sea made quite specific changes in the U.K. balance of payments, but more importantly, it made previously desired changes in the "Way of Life" possible. This came about by the oil revenues providing stop-gap financing which enabled social change to take place without social upheaval.

The government of the day did not have to (and did not) exercise rigid controls upon inflation to the extent that

the social changes taking place did so in a relatively peaceful manner. (It was quite apparent what would have happened if those controls had been exercised -- there was a very real possibility of social discord upon a large scale.)

Under the heading of what makes a nation distinct are the following questions:

1. what are the critical factors to the Way of Life?
2. what are the critical factors to the Way of Life as seen by the nation itself? (i.e. what are the factors and values that will be protected at some or all cost?)
3. what are the critical factors' strengths and weaknesses? (e.g. will religious values and morals be downgraded by economic success?)
4. what does the nation have that other nations want, and the converse, what do other nations have that this nation wants?

The answers to the questions posed above, and to other questions like them, provide the data for constructing a model of the Way of Life. What is missing, however, is the set of inter-relationships, the pattern, between the factors, or as they really are, the key determinants of the Way of Life.

The inter-relationships are conceptually easy to determine. One merely (!) asks what happens to all the other determinants, if "A" is changed?

Practically it is a very different story, as any economist or planner will contend.

But the contention is made, and will be made again several times, that precision is not necessary, in fact it is dangerous in that it results in too much detail, detail that obscures the overall pattern, to the extent that it can not be perceived.

Lack of precision does involve a risk, in that the incorporation of more data might result in a significant change to the pattern being perceived.

Subsequent chapters, especially those relating to catastrophe theory, will depend upon the contention that, given an adequate knowledge of the present level of a system state, it is sufficient to know that some general relationship exists between that state and other states within the system, and that it is either a direct or inverse relationship.

This information is qualitative; it is however fairly readily determined and, whilst qualitative, permits the construction of a basic causal loop structure of the significant aspects of the Way of Life of a nation state including non-quantitative aspects.

Such a construction, of itself, is of immense value to an organisation because it can provide answers to questions about the flow through effects of given or proposed actions. It can not, however, provide information as to the evolution

of the system, through time, because the dynamics, the rates of change are missing.

The Dynamics of the Key Determinants:

Ideally, each determinant should be precisely related to the others and each determinant's "dynamics" should be able to be precisely quantified. In practice this is not generally possible, either because some of the determinants are not measurable (e.g. political will) or else the relationships between the determinants represent the resultant of many much smaller determinants which only have significance in combination.

But for this area too, precision is unnecessary because of the obscuring aspect of too much detail. It is sufficient to know (in the first instance) that a dynamic is either increasing or decreasing -- is either intensifying or slackening.

R. Wesson and F. Hayes Roth, in a paper entitled "Dynamic Planning For Air Traffic Control" have as one of their "core ideas" the concept of varying granularity of step size, both in terms of time (which is equivalent to varying the "delta time" in System Dynamics) and in terms of events (which is equivalent to the degree of detail used in causal loop diagramming). The point of importance is that the step size of both these dynamics should be varied to suit the particular part of the system being considered.

In other words the "first cut" at the Way of Life can be quite coarse and just indicate, for example, that a particular state is intensifying. If that state has a fundamental influence upon the organisation's cross-boundary transactions, then a closer cut is liable to be necessary and justifiable.

Jay Forrester in "Industrial Dynamics" has the following to say:

"Once a functional form is found that exhibits a qualitative shape that matches our existing knowledge of the facts, we shall usually find neither the necessity nor adequate data to refine the problem further...it is probably best to proceed with other parts of the model until such time as model tests themselves reveal critical sensitivity to some of the uncertain assumptions" (page 97)

Forrester interrelates with Thom by using the topologically loaded terms of "functional form" and "qualitative shape." He further relates to Wesson and Hayes Roth's concepts of "varying granularity" when he implies the need for further data when the model tests themselves reveal critical sensitivity. But the key importance of this quotation is the acceptance of adequate data, not perfect or complete data.

Just as there were supplementary questions relating to what the Way of Life is, so too there are additional questions relating to the dynamics affecting the evolution of the Way of Life, e.g.

1. what are acceptable changes to the Way of Life and

why?

2. what are unacceptable changes and why?
3. what are the necessary conditions to instigate either of the above types of change?
4. what is the likelihood of those conditions arising?
5. who exerts control over the likelihood of those conditions arising and why?

Regroup:

The end result of all the above, i.e. the posing of the questions and the provision of answers, should be a simplified (but still highly complex) pattern of the key determinants of a nation's Way of Life. There should be a broad indication of the inter-relationships and a broad understanding as to the expected evolution of those relationships. It should be possible to construct a causal loop diagram of the system and it should be possible to derive both use and understanding from it.

The Way of Life concept as portrayed, permits a total approach to the system and, by considering the direction of change, the acceptability of change and the inclusion of all the relevant opposites (e.g. opposition parties, guerrilla movements etc.) a fair representation of what is likely to occur is possible. (See Jones paper referred to earlier. He points to the necessity to consider all the likely

opposing forces.)

From this an organisation can make informed rather than intuitive judgments as to its likely environment.

More fundamentally however, the total approach to the environment enhances the possibility of actually asking the relevant questions about future impacts and changes.

Summary:

Organisations' internal models depend upon assumptions about the external environment. Traditionally, these assumptions have been at best limited and at worst sadly incorrect.

The chapter has introduced a "Way of Life" concept as a means to determining what are the key determinants of the environment, what are the dynamics of those determinants and what are the likely effects of changes to those determinants.

The concept has some power, in that it covers the total Way of Life and provides a means for integrating the economic systems, as well as the political and ethical systems, into one total system.

The concept accepts and almost requires, general relationships and broad directional relationships, in order to be able to perceive the fundamental pattern, and as a spinoff, as a means of reducing data collection to the basic minimum.

The approach is one of System Dynamics, but with the addition of varying granularity, i.e. for some parts of the system the time step can be long whilst in other more rapidly evolving parts of the system, the time interval needs to be short.

Similarly, the event step can be wide, (detail is not necessary) or narrow (where detail is important).

Numerous models exist for assessing parts of the environment, but each seems not to cover all the factors affecting the determinants. The causal looping approach overcomes this



in two ways:

1. it emphasises structure
2. it enables non-quantitative factors to be considered in a structured manner -- e.g. information links and the existence of value systems can be considered.

Finally, such a system or process or approach to studying the environment of the organisation, provides a framework for assessing the likelihood of abrupt change arising, the discontinuity, the unforeseen event, that disrupts the best of plans.

SUMMARY OF PART ONE

Part one of this thesis has endeavoured to lay the foundations for a discussion about discontinuities arising from the activities of men, i.e. social activities. The foundations have considered what brings an organisation into existence; how it is goal centred and becomes goal seeking; and how the existence of the organisation sets up a series of cross-boundary transactions between the organisation and its environment.

The need for planning has been discussed, as a means towards meeting the organisational needs of goal determination and goal implementation.

In meeting those needs, attention has been drawn to the nature of and problems of data; determination of patterns and hence information and from this, the use of models as a necessary device to provide information and to provide a screen for data selection.

Models were discussed in some detail, in order to emphasise their kinematic and dynamic aspects and to draw attention to the two major ways of using models as a predictive tool i.e. to know the desired future kinematic and predict the dynamics to achieve it, and to know the dynamics that are expected to operate and to use them to predict the future kinematic.

The discussion then moved on to considering the different data requirements for the two types of models used by

organisations i.e. the internal organisational model and the external environmental model.

And finally, in meeting the needs for data about the external system, a Way of Life concept was introduced, as a means of considering all the relevant aspects of the environment that are likely to affect the organisation.

SYSTEM DYNAMICSIntroduction:

Part I of this thesis finished with a consideration of a Way Of Life concept and indicated that a causal looping approach provided a useful means of determining and analysing the Way of Life. This chapter considers the attributes of the System Dynamics approach (of which causal looping is a part), the attributes that will facilitate the compilation of a Way of Life and the discernment of its dynamics and hence implications.

The Unique Event:

By definition, the unique event has not occurred before and is not expected to occur again. Its effects will not be able to influence a subsequent occurrence of the event because there will not be a subsequent occurrence. Its effects, will however, affect other events.

In other words, there will be an open chain of cause and effect, through time.

The Optional Event:

By definition, the optional event can occur again, and because of this, its effects will be able to influence a subsequent occurrence of the event as well as affect other events.

In other words, there will be, initially, a closed chain of cause and effect through time. The word initially, has

been used to allow for the possibility that the effects of the first or any subsequent occurrence, may be such as to cause actions to prevent any further occurrence of the event. (E.g. killing the last female/male of a species prevents the occurrence of that species again, i.e. the killing constitutes a unique event and as a result an open chain of cause and effect will flow through time, from that unique event.)

#### Reason For The Distinction:

The distinction has been made because of the need to make adequate provision for the impact of individuals, and the development of specific technology, upon the evolution of the Way of Life as these tend to be "unique" events. For example, the impact of national leaders and the advent of computers.

The belief that an event is not expected to occur again is useful, in that it prevents the wasted allocation of resources to deciding how to adjust to another occurrence.

Similarly, the knowledge that an event can occur again, implies that it might be useful to allocate resources to deciding how to adjust to it. In particular, it implies that the event will be affected by the effects of the initial occurrence.

#### Causal Loops - Cycle and Occurrence Time:

The optional event that is expected to recur over the foreseeable future, permits the construction of closed causal

loops. The closure take place through time, not at an instant in time, and consequently the loop has a cycle time associated with it, or in the System Dynamics terminology, a delay. (Cycle time is more useful, because it does not have the connotation that delays are bad.)

Each individual loop, therefore has a cycle time associated with it, the time between the occurrence of the initial event and the event in the future that is affected by the effects of the initial event. Of importance here, is the fact that the cycle time does not have to match the time between occurrences of the event, i.e. more than one occurrence of the event can occur before the effects of the first loop back.

If the cycle time and the occurrence time are synchronised, then the loop in question, has a discrete characteristic, in that the next occurrence waits until the full effects of the first are available for influencing the next occurrence. For example, a competition archer will not loose his next shot until he has seen where the first one went. I.e. these are the conditions for a batch process.

The two times provide a measure of the sensitivity to control of a loop when they are expressed as a ratio of cycle to occurrence; the closer to unity, the greater the degree of control that can be exerted upon the event and its effects. But faster control can lead to prevention of loop settling into its natural stability.

The absolute values of the cycle and occurrence times are also important, as they give an indication of the response times that might be required in order to adapt to the system.

The cycle and occurrence times within a closed loop provide measures that facilitate deciding whether action can be taken "in time" i.e. the absolute values, and whether there will be a rapid response in terms of event occurrence, i.e. the sensitivity to control ratio.

#### Loop Polarity:

Causal loops differ in terms of polarity, i.e. loops are defined to be of positive polarity if the effects reinforce subsequent occurrences of the event and negative if the effects counter the subsequent occurrences of the event.

Positive loops are characterised by either exponential growth or else the decay mode of exponential decline. Without any other factors affecting a positive growth mode loop, there will be no limit to tangible growth. In the case of a decay mode loop however, the approach to and attainment of a zero value will tend to stop the loop even though it is possible to envisage negative values. This is because, in physical terms, negative values tend not to have any significance, e.g. at some stage urban decay will reach a value whereby the city no longer exists in physical terms.

In terms of analysis therefore, it is likely to be use-

ful to determine when a decay loop expires.

Negative loops are control loops. They exhibit goal seeking characteristics and either try to reach an imposed goal or else seek to reach the natural goal of the system. They are the determinants of stability within a system and act to control positive loops or the positive tendencies within parts of a loop.

In goal seeking, the loops will either be stable, i.e. they will have oscillations of a decreasing amplitude or else they will be unstable and have oscillations of increasing amplitude. In each case the oscillations are about the goal of the loop.

In terms of analysing the environment, and in particular, in trying to determine what the goals are, a close study of the behaviour of negative loops should at least give an indication of the nature of the goals being sought.

Negative loops are a source of stability, and in social terms, this can mean the suppression of change. A study of negative loops with a view to assessing what sought of positive loop would be needed to permit change to occur can provide a means of determining where to look for the existence of positive loops.

For example, if a loop is showing a tendency to hold the output of doctors at a constant level, it might be worthwhile to look for signs of positive loops that could disturb that goal. In other words, given a goal seeking



negative loop, consider what sort of events, in the form of positive growth (or decay) that could disturb that goal and then look to see if it is in existence or likely to arise.

Similar actions should be instituted with positive loops, especially growth loops, such as "unlimited" markets for a product. Consider that a negative goal determining loop could arise to control the positive loop. The nature of the positive loop will reveal where control is most likely to have the greatest impact. With that data look for the seeds of a negative loop.

Positive loops have another characteristic arising from their exponential character. If the loop has levels with very low initial values, then it is possible that the loop will have little significance but that does not mean that it has little relevance. With no change in the structure of that loop, merely the expiration of time, the loop can adjust levels to values of considerable significance. Goodman, in "Study Notes in System Dynamics" illustrates this very clearly on page 25. The point is, in assessing the significance of a positive loop, look to the characteristic of the dynamic that is operating as well as the level values. For example, a political group with only 1,000 members might not be worthy of interest, but if it is doubling every 3 months then some consideration might be given to its future impact.

#### Flow Diagramming:

The previous discussion was about causal loops by them-

selves and looked at the chains linking cause and effects. System Dynamics however, goes further, it looks at the structure of the loop in terms of levels that are operated upon by rates, the distinction being that only levels exist when the system is at rest. The earlier discussion about models used Thom's terminology of "kinematic" and "dynamic," these terms being roughly equivalent to "levels" and "rates."

In discussing positive loops, the dynamic was stressed as being of some relevance even though the level was insignificant.

In social terms, levels are probably the more readily determined part of a loop, in some cases quite specific values can be attached, and because of this, it is possible to lose sight of the more difficult to determine rate or dynamic that is operating to adjust the level.

A flow diagramming analysis emphasises the existence of the dynamics between the various levels and it is this emphasis that is important.

The use of flow diagramming emphasises the structure and because of this, facilitates the construction of a model that is eminently suited to the requirements for planning, i.e. the present and desired future states (levels or kinematics) are provided for, as are the dynamics (rates) that operate upon the states.

## Systems

So far the discussion of the applications of System Dynamics to the Way Of Life concept has concentrated upon individual loops acting independently of one another, although indications were given that the loops might not be independent.

The purpose of that approach was to emphasise the amount of information that can be extracted from a study of a loop in itself. However, the concept of the Way of Life is a system of inter-related chains of cause and effect. The system is not limited to closed chains or causal loops because the effects of unique events, whilst not part of a loop, can affect parts of other chains of events that are parts of loops.

A system of chains of cause and effect is generally given a boundary, a frame of reference, that limits the scope of the study. The creation of this boundary, of itself, raises new problems of cross-boundary transactions and acts to freeze the values of external levels into "constants" used by the internal part of the system and to freeze the relationships of external rates into "table functions" or "look up" devices.

A continual review of the extent of the boundary, is therefore, necessary in order to form a view as to whether the values of those "frozen" items are still appropriate.

The Way of Life concept involves very wide boundaries

indeed, but even then, there will be the need to provide for freezing values and relationships of events occurring outside those boundaries.

#### System Time:

Just as individual loops had a cycle time, so too with the system. The cycle time of the system will be defined here, as the minimum time taken for every loop within the system to complete at least one loop cycle, i.e. this permits the full effects of an initial event to cycle once throughout the system.

Because individual loops will have different cycle times, the completion of one system cycle will involve some loops commencing or completing more than one cycle, i.e. the different cycle times of the individual loops provides part of the basis for system continuity.

The other part, relates to the system itself, in terms of whether the system permits all loops to commence at the same time, or else the system has a partial sequential start up of individual loops. (It is this aspect that prevents the system cycle time from being the sum of the loop cycle times.)

This has implications for the start up and shut down of systems and is exemplified by the start up of a refinery or any other device that uses pipelines -- the system has to be filled before the system can operate. This involves

an increase in the systemic cycle time, unless the sequential parts of the system are primed first, in the case of start-up or simultaneously drained in the case of shut-down.

#### Loop Dominance:

A system of loops, which will generally be a mixture of positive and negative loops, raises the question of loop dominance within the system. Does the system show growth/decay characteristics or goal seeking characteristics? What leads to shifts in loop dominance?

Shifts in loop dominance are of considerable importance in terms of this thesis, because they demonstrate that discontinuous behaviour can arise from the inter-actions of continuous behaviour. It is in this area in particular, that the work of Thom and Zeeman (on Catastrophe Theory) has its greatest relevance, because it provides a rigorous analysis of the transition in behaviour.

The classical picture of a shift in loop dominance is demonstrated by the sigmoidal curve, whereby there is a period of exponential growth that gradually switches into an asymptotic approach to a goal.

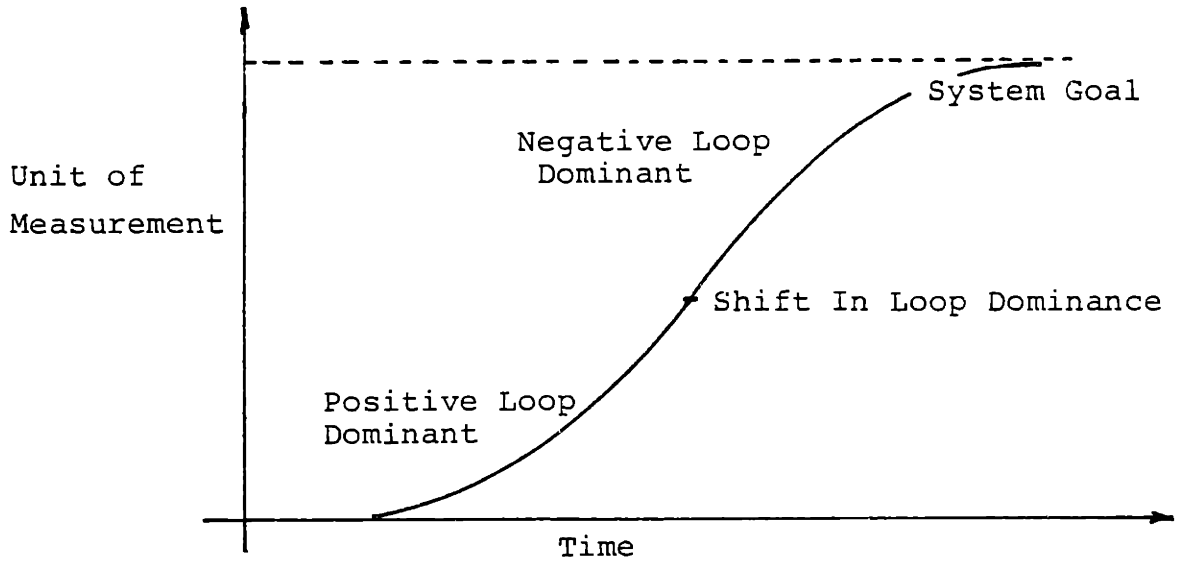


Diagram 3: Sigmoidal Curve - Change In Level  
(Characterised by initial growth and then stability)

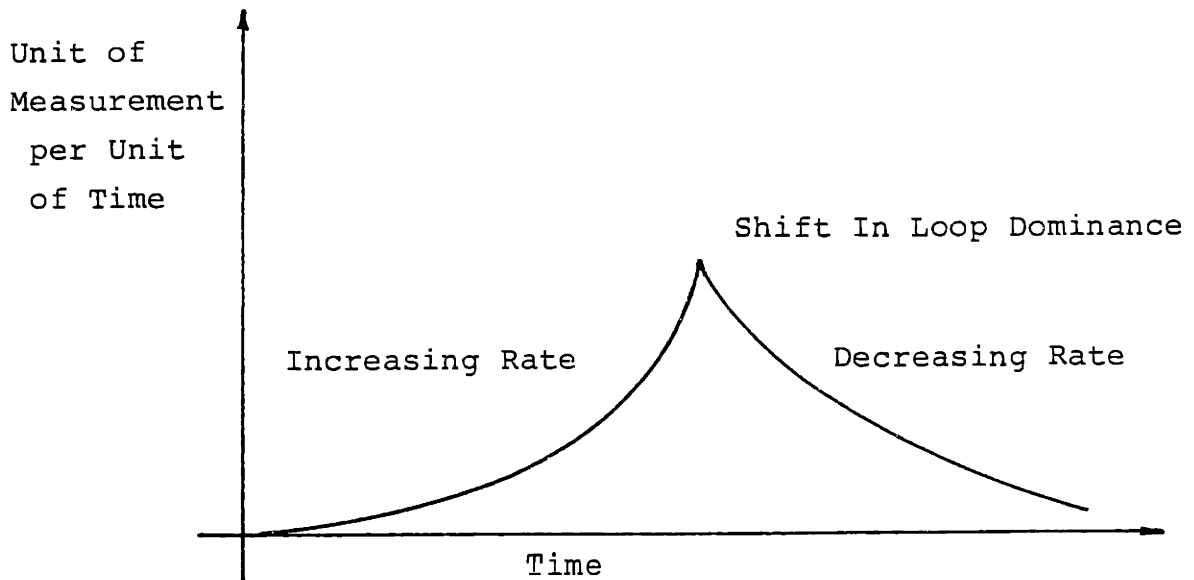


Diagram 4: Rate Curve - Change in Rate  
(Produces Sigmoidal pattern of Change in Level)

In many instances within system dynamics, this sigmoidal pattern is generated by using a table function that produces a rate that grows and then decays, as a short cut way of depicting the full structure of two loops inter-acting upon the level in question. In other instances, the combination of positive and negative loops within a system generates the sigmoidal pattern, i.e. it is a system feature.

The sigmoidal pattern is so important to the analysis of the Way of Life concept that the initial short cut of a table function is not advocated because it obscures the underlying dynamics

The sigmoidal pattern is important, because it effectively implies that there is a structural limit upon the variable in question. It is important to know whether the system is in a growth phase or a goal seeking phase because the actions to be taken, if any, are liable to be different. In particular, action might not need to be taken to "control" a positive system because a goal seeking loop might already be in existence -- in fact in those circumstances the action might lead to preventing stability.

#### System Complexity:

A two or three loop system with a limited number of levels and corresponding rates might be capable of assessment on an inspection basis, but System Dynamics has shown that the complexity of the inter-actions within real life

systems is such that the system can only be understood adequately by the use of simulation -- the step by step production of system levels and determination of the characteristics of the changes in the rates over time.

It is in this area that computer simulation comes into its own, but it is also in this area that difficulties arise with regard to analysing the Way of Life. In order to determine what the system is doing, and how it is likely to evolve, initial levels and the characteristics of the rates have to be quantified in order to make use of the computer to do the simulation.

The problem is surmountable, because the causal loop and flow diagram approach in particular isolates the areas that need intensive study in order to quantify the system adequately i.e. it at least identifies the haystack that the needle is hidden within!



Summary:

The chapter reviewed some of the characteristics of System Dynamics that make it a useful and powerful tool for analysing the Way of Life. The tracing of cause and effect provides the set of inter-relationships that is so important in assessing the impact of actions and proposed actions.

The analysis of the resulting causal loops provides a series of pointers to features of the system, such as polarity with its exponential, or alternatively its goal seeking, characteristics.

The further analysis of the causal loops into their structure of levels and rates (kinematic and dynamic) matches precisely the requirements of predictive models.

In considering the combination of loops into systems, attention was drawn to the need to have boundaries of some sort (frame of reference) and how the very use of boundaries "freezes" parts of the now external systems -- an area that needs careful control in terms of continuing relevance.

System time was considered, and attention was drawn to the way that individual loop cycle times, when placed within a system, provide part of the basis for system continuity. Start up and shut down times were referred to in the context of sequential parts of a system having different characteristics to simultaneous parts of the system.

Loop dominance was briefly looked at as the area in which continuous functions interact to produce discontinuous

behaviour. The sigmoidal curve was referred to and in particular, the importance of analysing it into its underlying structure, of a positive and negative loop interacting upon a level. The importance of consideration or restraint in taking action in such a case was stressed -- i.e. the system is self-correcting if there is adequate time to let the system progress into the negative loop dominated part of the "cycle."

Finally, the chapter referred to the need to use the computer to undertake the simulations required to reveal the behaviour of the system and how this requires quantification that the Way of Life analysis might not be able to generate easily. It was believed that this is not an insurmountable problem because the System Dynamics approach narrows down the areas requiring detailed analysis in a structured way that permits a better appreciation of the importance of the detail.

The chapter indicated that the area of shifts in loop dominance provides the link to an approach to discontinuities called Catastrophe Theory. The next chapter will consider this theory and its application to the Way of Life concept.

CATASTROPHE THEORYIntroduction:

The simplest introduction to Catastrophe Theory is given, in layman's language, by Woodcock and David. The quotation is given at length as it portrays the concepts in a useful manner.

"A catastrophe, in the very broad sense Thom gives to the word, is any discontinuous transition that occurs when a system can have more than one stable state, or can follow more than one stable pathway of change. The catastrophe is the 'jump' from one state or pathway to another. In the landscape envisaged by Waddington, it could be represented as a passage of an object from one to another, or as a flow of water from one channel into another. The transition here is discontinuous not because there are no intervening states or pathways, but because none of them is stable: the passage from the initial state or pathway to the final one is likely to be brief in comparison to the time spent in the stable states."

"The elementary catastrophes are the seven simplest ways for such a transition to occur. They can be illustrated by graphs that show the stable states as sets of points -- lines or surfaces -- in a 'behaviour' space. As long as the system 'occupies' one of those points, its behaviour is continuous -- but when it leaves the line or surface, it is unstable and must return, sometimes at a point far distant from the initial point. The graphs of the seven elementary catastrophes depict seven topologically distinct arrangements of the profits representing stable states. Within certain limits, moreover, they are the only possible arrangements. So they are, in a sense archetypes: the most basic models for many processes that are very different in quantitative terms and in their internal workings. The graphs allow us to incorporate a great deal of information about causes and effects in a clear descriptive diagram. They are geometrically rich, with structural features that are not immediately apparent. Often, if a process is modelled with one of them because its behaviour corresponds to some features, we can

study the model to see what other, less obvious types of behaviour it suggests." (page 32)

(underlining my emphasis)

Thom, in his Classification Theorem, provided the proof that there were only seven elementary catastrophes by proving that there was structural stability in morphogenesis.

Zeeman designed a small "machine" that, using rubber bands and a pin or two permits one to accurately model the dynamics of a catastrophe; the catastrophe is the "cusp catastrophe" which has two "control" factors and one behaviour pattern. The following quote and diagram is in terms of energy levels and serves to illustrate two of the features of a catastrophe, the sudden transition from one stable state to another and the hysteresis cycle that occurs.

"The state  $x$  starts in the unique minimum; nothing happens when a second minimum appears at  $Q_1$ . The second minimum eventually becomes deeper, but the state stays in the first minimum, held there stably by the dynamic. Eventually at  $Q_2$  the stability of the first minimum breaks down as it coalesces with the maximum, and the state has to jump (or more precisely is swiftly carried by the dynamic) into the second minimum, which has now become the unique minimum. On the reverse journey the roles of  $Q_1$  and  $Q_2$  are reversed; the state stays in the right hand minimum until  $Q_1$ , where it has to jump into the left hand minimum again. This is called the hysteresis cycle."

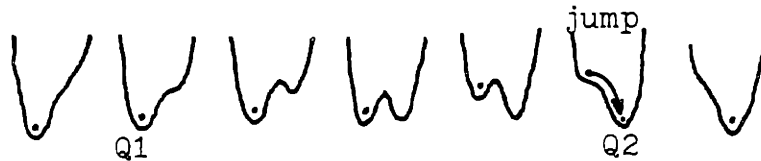


Diagram 5: Changes in the energy graphs explaining the jump at Q2  
(Zeeman)

The above graph illustrates how a continuous function can result in an abrupt change in position from one local minimum to another local minimum.

The Classification Theorem:

Zeeman provides a simplified statement of part of Rene Thom's general Classification Theorem that deals with structural stability in morphogenesis. In particular, Zeeman's simplified version applies to the cusp-catastrophe.

"Theorem: Let  $C$  be a 2-dimensional control (or parameter) space, let  $X$  be a 1-dimensional behaviour (or state) space, and let  $f$  be a smooth generic function on  $X$  parameterized by  $C$ . Let  $M$  be the set of stationary values of  $f$  (given by  $\frac{df}{dx} = 0$ , where  $x$  is a coordinate for  $X$ ). Then  $M$  is a smooth surface in  $C \times X$ , and the only singularities of the projection of  $M$  onto  $C$  are fold curves and cusp-catastrophes."

In elaborating upon some of the terms used, Zeeman goes on to say;

"...what the theorem really says is that qualitatively Figure 4 (Diagram 6 in this thesis) is locally the most complicated thing that can happen to a graph. That is why the cusp catastrophe can be used with such confidence

in so many different fields, whenever a process involves 2 causes and 1 effect."

The mathematics is a problem. It is in a difficult field for the more general mathematician and is in a field almost totally alien to the requirements of the businessman. However the basic concepts can be illustrated by relatively simple diagrams, and by using examples that are deliberately chosen to demonstrate the power of the theory. For the serious mathematician, Thom's book is a necessary starting point, necessary in order to capture the rationale for the theory's development, whilst the simplest (!) full proof (65 pages) of the theory is contained within a paper by a collaborator of Zeeman's, namely David Trotman.

The diagrams of the behaviour surface and its projection are the areas best suited for the non-mathematician as, in general, he will lack specific quantified data with which to use in the various formulae -- the theory is therefore liable to be used as a paradigm.

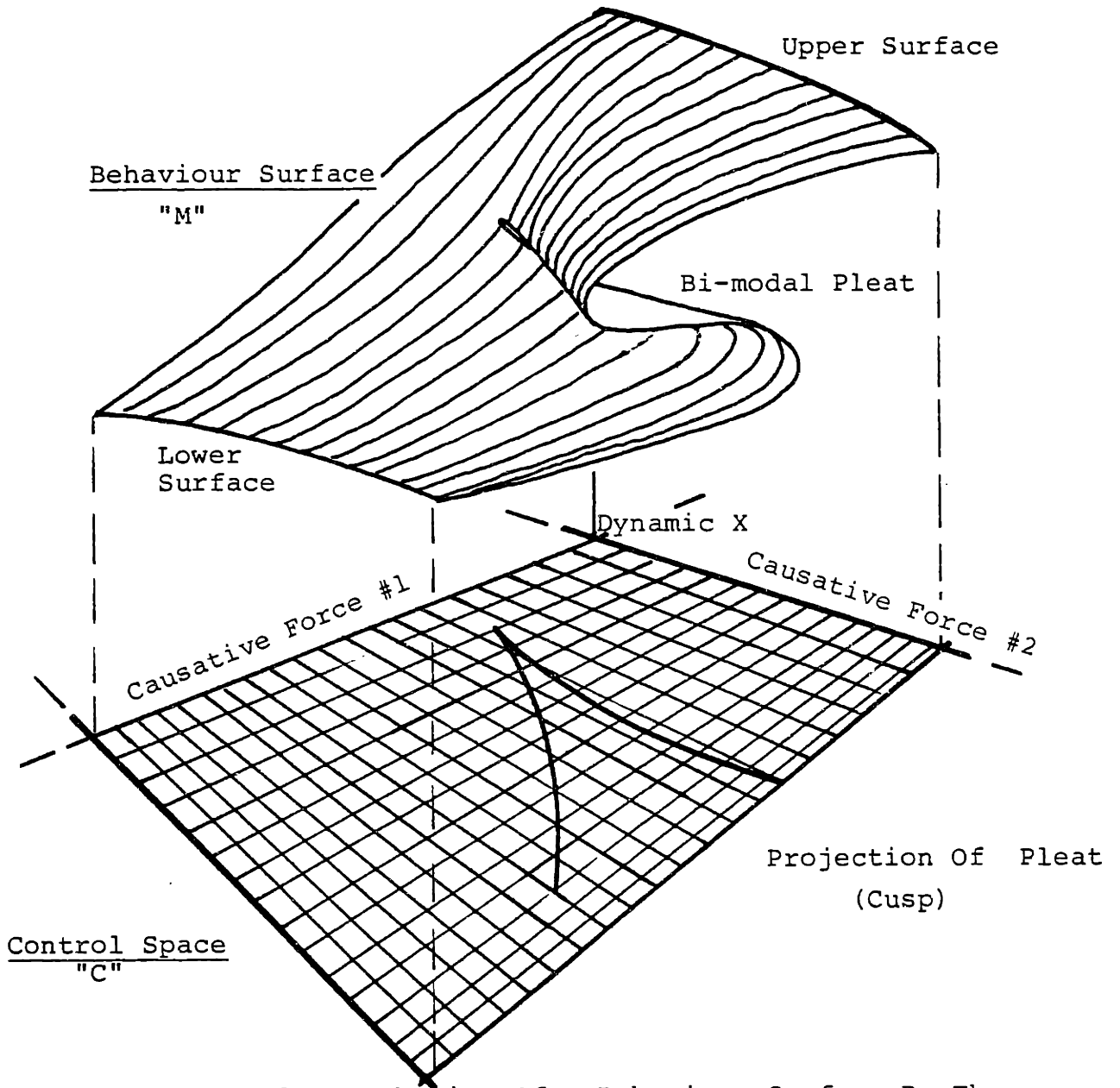


Diagram 6: Local Perturbation Of A Behaviour Surface By The Cusp Catastrophe

### The Cusp Catastrophe:

The previous graph shows the behaviour surface that the quote from Woodcock refers to, and the projection of that surface or differential; in this case a three dimensional behaviour surface -- the cusp catastrophe -- and the projection onto the plane of the pleat in the behaviour surface. The projection of the pleat give this archetypal surface its name of cusp.

Each point within the surface represents a stable pattern of continuous behaviour resulting from the interaction of two causative forces. Some points have equally likely behaviour patterns and these points are represented on the upper and lower edges of the pleat and are the points where a line normal to the plane is tangential to the pleat. When one of these points is reached, the behaviour shifts abruptly from the upper to lower surface or vice versa -- i.e. equivalent to the "jump" shown in the Zeeman graphs on the preceding page. The projection of these points is the cusp shown on the plane. The middle surface of the pleat is the region of least likely behaviour and is generally ignored.

Equation Of The Behaviour Surface  $X^3 = (\alpha - \beta) + X(\alpha + \beta)$

Equation Of The Cusp  $27(\alpha - \beta)^2 = 4(\alpha + \beta)^3$



The behaviour surface has some important characteristics. Firstly, it is possible to have behaviour evolve and move from upper to lower surfaces without any abrupt changes in behaviour e.g.

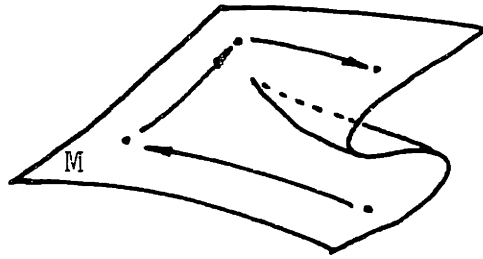


Diagram 7: Smooth Evolution of Behaviour

Secondly, a very small change in one of the causative forces can lead to quite different behaviour, again without any abrupt change in behaviour. This is shown below by the divergence around the cusp point.

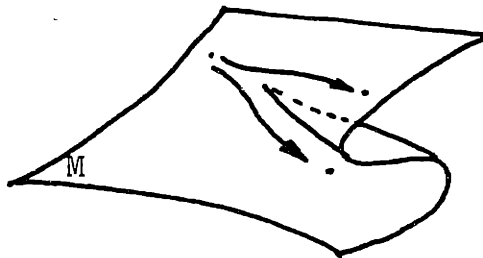


Diagram 8: Divergence Around The Cusp Point

Thirdly, there is the bi-modal character of the behaviour surface; this is represented by the upper and lower surfaces and is best shown with the central fold of the pleat deleted.

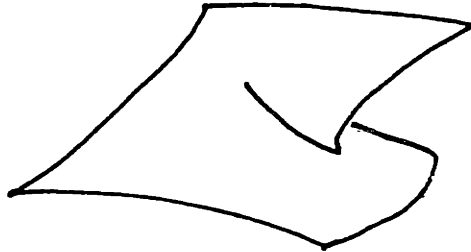


Diagram 9: Bimodality of Behaviour Surface

Fourthly, there is the hysteresis cycle which is portrayed by a cross-section of the pleat and, in the drawing is shown by the leading edge of the surface. Of very great importance here is the increasing length and height of the cycle as the surface evolves, this implies that the abrupt change, when the causative forces produce a point upon the lip of the pleat, becomes more dramatic as the pleat evolves. (In fact this point provides a beautiful geometric portrayal of the old adage "that a stitch in time saves nine").

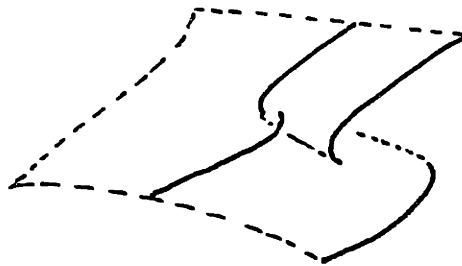


Diagram 10: Hysteresis Of Pleat

Fifthly, the surface shows that the shift in behaviour is dependent upon the initial state. This follows from the hysteresis cycle, in that being on the lower surface and reaching the pleat lip means a jump up to the upper surface and if on the upper, a jump down to the lower surface.

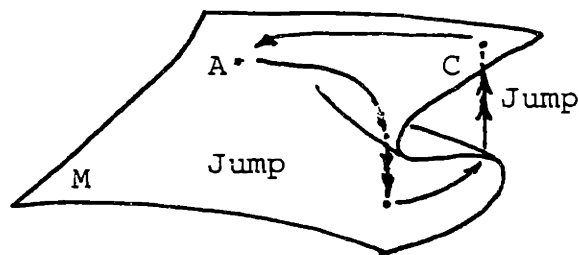


Diagram 11: Sudden Jumps or Catastrophes

The position of the axes and the starting point of the evolution of stable continuous systems influences when and whether the cusp boundary will be crossed.

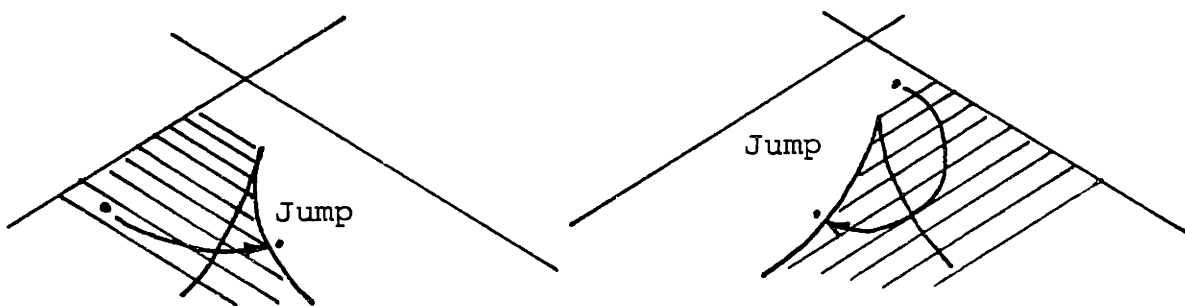


Diagram 12: Projection of Sudden Jumps

In the above diagrams, the shaded areas represent the lower and upper surfaces respectively and it is not until the system passes through the shaded area and crosses the cusp boundary that the catastrophe occurs. I.e. a rough knowledge

of the position and shape of the cusp indicates the likelihood of a catastrophe, without having to know or determine either the third dimensional dynamic or the specific shape of the behaviour surface.

If the axes are aligned with the cusp, i.e. one is the cusp axis and the other normal to it; the following diagrams result. These diagrams have the axes named "normal" and "splitting" respectively, because for values greater than zero the splitting axis splits the behaviour surface into the upper...

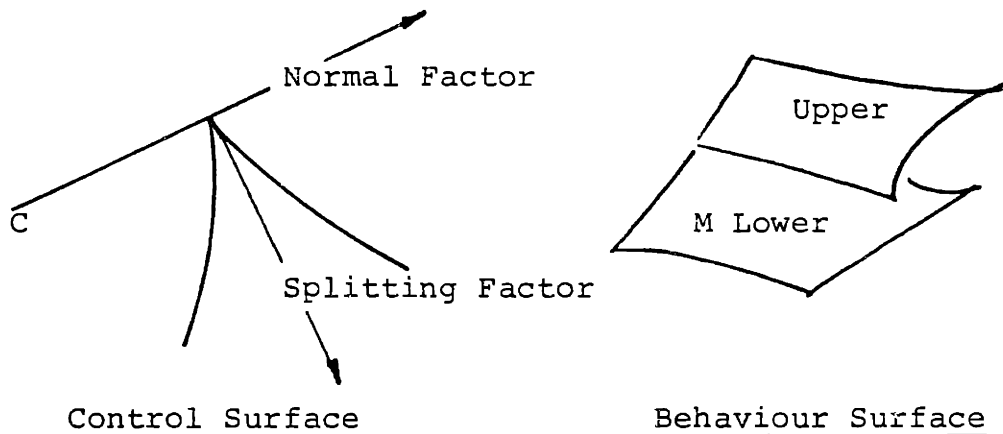


Diagram 13: Normal and Splitting Factors

and lower sheets. Of more importance to this thesis however, is the ability to portray an accepted form of behaviour as being at the origin of the cusp on the normal axis. It will be apparent that any departure from the norm, in either direction, is liable to result in discontinuous rather than continuous transition to the new state of behaviour.

Behaviour that results from having the axes to its control surface follow the splitting rather than conflicting pattern will demonstrate greater readiness to make discontinuous jumps -- even to the point of setting up a regular cycle such as bull/bear markets with a crash in between. Knowledge of how the control factors inter-relate provides valuable insight into the system being studied.

#### The Importance of Catastrophe Theory:

Catastrophe theory has an intrinsic importance in terms of mathematical development and its natural philosophical implications -- later quotes from authors in the field of catastrophe theory will demonstrate this, and also demonstrate that there is considerable controversy about the applications of the theory.

But catastrophe theory is also a model that has considerable power in explaining how and why things occur the way that they do. It is in this regard that catastrophe theory has its greatest benefit to the analysis of the Way of Life and hence the greatest benefit to understanding

the likelihood of and the assessment of discontinuities.

Zeeman provides a good description of this model strength;

"...the cusp catastrophe shows that the five qualitative features of bimodality, inaccessibility, sudden jumps, hysteresis and divergence are all interrelated. And the deep classification theorem of catastrophe theory permits us to enunciate the general principle that whenever we observe one of these five qualities in nature, then we should look for the other four, and if we find them we should check whether or not the process can be modelled by the cusp catastrophe. Indeed our verbal usage in ordinary language of pairs of opposites frequently indicates a bimodality that has grown smoothly out of some unimodality and which may be modelled by the upper and lower sheets of a cusp catastrophe surface."

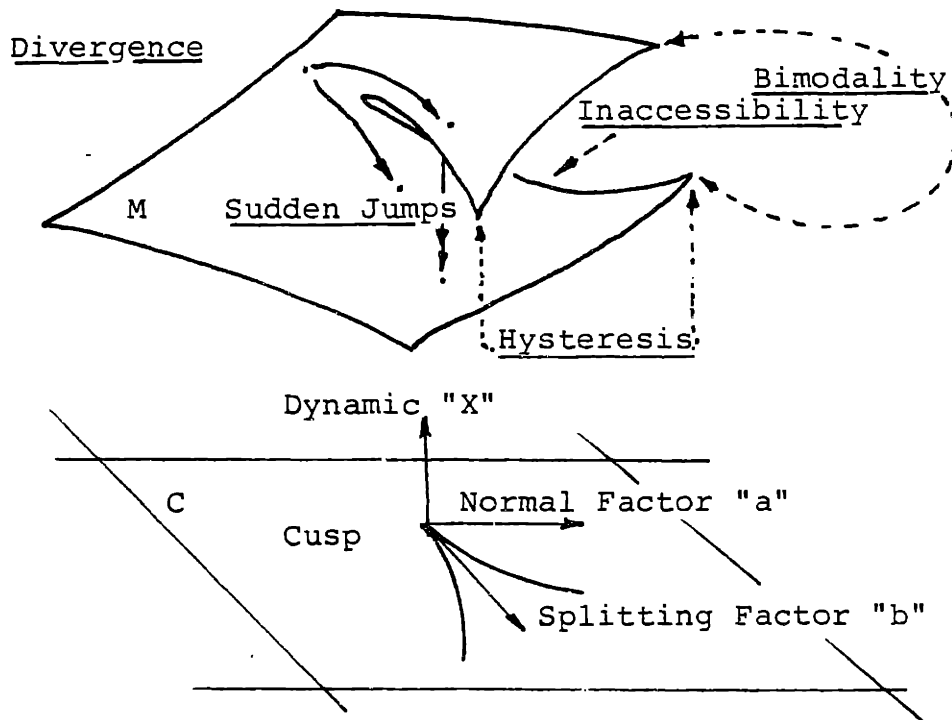


Diagram 14: The Five Factors of The Cusp Catastrophe

Just as the application of a system dynamics approach provides a means towards asking illuminating questions about the cause and effect relationships, so catastrophe theory provides a model for posing further illuminating questions about the way continuous behaviour is liable to evolve. In particular, it provides the detailed model of what occurs when there is a shift in loop dominance.

#### The Significance Of The Cusp:

The cusp determines the shape of the pleat in the behaviour surface, i.e. it determines when the movement of the control factors will result in a catastrophe -- a jump from one surface of the behaviour sheet to another.

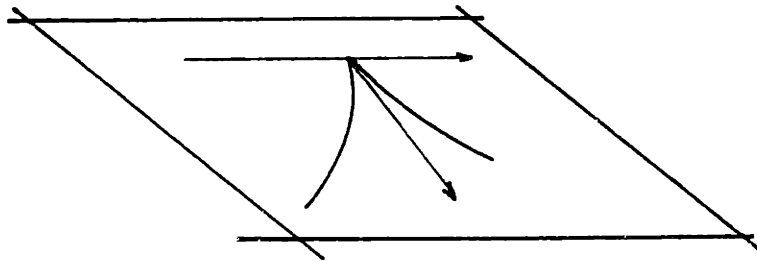


Diagram 15: The Cusp

In social terms the cusp will tend to be determined by the accepted norms of the society. At some point of departure from the norm, the society will react in a discontinuous manner. The shape of the cusp and the position of the behaviour relative to it will determine the extent of the allowable departure from the norm and the extent of the change in behaviour. For example, a wide cusp, a rapidly diverging pair

of lines will permit large movements away from the norm before there is a discontinuity, but the discontinuity, when it arises will result in significantly different patterns of behaviour. In addition, the three dimensional nature of the pleat permits the consideration of the magnitude of the jump i.e. its depth or intensity. For example a deep jump has a different connotation to a shallow jump. An economic example might serve to illustrate this more clearly, the jump from a mild recession to a mild recovery is a lot more likely than a jump from a major depression to a major boom and a lot less disruptive.

A parallel can be made to System Dynamics when there is a switch in loop dominance. A secondary loop often feeds from the dominant cause to the behaviour and thus governs the intensity of the behaviour. For example to use an illustration from Zeeman, a very scared dog will generally flee, but if its made angry as well it is liable to attack. The degree of anger will determine how viciously it attacks.

In summary therefore, the nature of the pleat, as portrayed by the projection of it, and an assessment of its depth, will determine the likely behaviour pattern if the control factors are moving -- evolving -- in a perceptible manner.

#### Catastrophe Theory and System Dynamics:

Both disciplines study cause and effect relationships;



both study areas of activities that include qualitative rather than quantitative aspects; both study continuous behaviour and the events that lead to the break in behaviour that is labelled a discontinuity. It was this similarity of study that drew my attention to using both disciplines as a means of expanding upon the nature of the other and then as a means for aiding the analysis of the discontinuities that prove to be so disconcerting to the unwary organisation.

System Dynamics provides the discipline to analyse the cause and effects that Catastrophe Analysis (my term for the applied side of Catastrophe Theory) relies upon to explain the evolution of continuous behaviour in either a stable or unstable manner.

In particular, the two disciplines are seen at their closest in the analysis of shifts in loop dominance, especially with regard to the sigmoidal curves of initial exponential growth switching to a goal seeking curve. The transition point from one loop to another is generally characterised by a table function that shows a reversal of behaviour from increasing to decreasing, a movement from one side of the inflection point to the other results in a behaviour change that is of a discontinuous nature, and this inflection point is equivalent to the point at which behaviour makes the jump to a new point of local stability. I.e. it is the pattern demonstrated by Zeeman's energy level model illustrated on page 85.

The table function in System Dynamics even has the same shape as the projection of the pleat in the cusp catastrophe -- i.e. a cusp. In fact, the table function represents the projection of the three dimensional behaviour surface, with the variables of the table function being the "control factors" of catastrophe theory.

Just as in System Dynamics -- with the need for empirical observation in order to construct the table function -- so to in catastrophe theory in order to construct the shape of the cusp.

Controversy And Implications of Catastrophe Theory:

C. H. Waddington, in writing the Foreword to the English translation of Rene Thom's book "Structural Stability and Morphogenesis," concludes with the following sentences;

"I am convinced that Thom's book is one of the most original contributions to the methodology of thought in the last several decades, perhaps since the stirrings of quantum and relativity theories. In the particular field of embryological morphogenesis, which is so central to it, it is in my opinion more important than D'Arcy Thompson's great work, 'On Growth and Form.' Thompson's contribution was to apply well-known types of mathematical thinking where they had not been applied before, whereas Thom invents not only the applications, but the mathematics as well. Just as much of the detail in D'Arcy Thompson has turned out to be invalid, or at best incomplete, so it is likely that not all Thom's suggestions will prove acceptable; but in neither case does that constitute any reason to overlook the importance of the new insights which these authors have given us."  
(1975), (page xvii)

Alexander Woodcock and Monte Davis, in their popular book, "Catastrophe Theory" have the following to say;

"Catastrophe Theory (in particular its essential concept of structural stability) is really a paradigm rather than a theory. It has attracted so much attention and generated so much argument because its scope and application appear to be virtually unlimited. But so much hangs upon the phrase 'appears to be' that one should distinguish, as physicist Michael Berry does, among the different ways the theory has been applied to date. First, there are the true applications of the theory -- those such as Berry's own work in optics, where the theory has made correct predictions and led to advances in understanding. Second, there are the illustrations -- cases in which the theory produces in a new way results that have already been obtained by existing methods (as when Thompson and Hunt realised when they correlated catastrophe theory with their analysis -- via bifurcation theory -- of elastic buckling). Third, there are what Berry calls 'invocations' of the theory -- those in which the identification of the potential and the control factors remains tentative, so that the theory is employed 'because of the suggestiveness of its images in the hope that its axioms might eventually be shown to apply.' The third category takes in nearly all the uses of catastrophe theory to date in biology, and all of those in the social sciences and psychology." (page 142)

As can be gathered, there was and still is a degree of controversy about catastrophe theory and the preceding book summarises that controversy rather well -- including the capture of some of the more pointed remarks. The controversy seems to revolve around the application and presentation rather than around the mathematics, which seem to have undergone some considerable development and increase in rigour since Thom's book. The most publicised articles about the theory have come from E. C. Zeeman who has taken catastrophe

theory a long way -- to the extent that there is now some controversy between Zeeman and Thom.

It is perhaps unfair to use the following quote made in a little dialogue written by Zeeman in Catastrophe Theory Selected Papers 1972 - 1977, but the comment is illustrative of the faith being placed in the theory. The dialogue is between an informed reader and a mathematician;

"...If function is to influence form, then it must do so through the intermediary of some storage system, and Thom is suggesting that the natural language for such a storage system is catastrophe theory. At the first of Waddington's conferences at Serbonelli on theoretical biology Crick\* suggested that the three great unsolved problems of biology were evolution, development and the brain, and now Thom has re-posed them as a single problem, in a rather unexpected form.) (page 655).

\*(Crick was one of the two men responsible for unravelling the structure of DNA).

Summary:

The chapter has endeavoured to present a very simple outline of the basic features of Catastrophe Theory that will be of use in analysing the Way Of Life.

The approach was to concentrate upon the visual richness of the 3-dimensional behaviour surface and its differential, the 2-dimensional parameter or control space, as a model for explaining the evolution of continuous parameters, especially when that evolution results in an abrupt change in behavior -- i.e. when it goes bimodal.

An abridged form of the classification theorem was stated to justify Zeeman's statement that locally, the cusp catastrophe was the most complicated thing that could occur, given two control factors and one behaviour space. The importance of this was the resulting ability to apply the theory to all forms of behaviour. It was this feature that so admirably suits catastrophe theory to the analysis of the qualitative events that comprise the Way Of Life.

The graphs of the behaviour and control surfaces were portrayed and some of their features were indicated. The important features result from the explanatory power of the graphs, i.e. the pleat, the projection of the pleat (the cusp), the hysteresis cycle, divergence, and the actual catastrophe -- the jump from one surface to another. The power of the theory comes from the determination that all the above characteristics are inter-related and thus if one or more

occurs in nature, then it behoves the student to look for the others. I.e. the power results from providing the ability to ask the right questions.

The importance of the shape of the cusp was stressed, as it determines when and where on the control surface that the related behaviour will cross the cusp boundary and result in a catastrophic jump between the upper and lower levels of the pleat in the behaviour surface.

Catastrophe Theory was related to System Dynamics, especially in the area of shifts in loop dominance. Catastrophe Theory and System Dynamics should be merged into one comprehensive system for the explanation of the development of continuous behaviour and abrupt change.

It is in this area that significant developments could arise in the study of abrupt change.

Finally, the chapter considered a little of the controversy arising from the ascribed merits of Catastrophe Theory and gave an indication of its believed potential.

From the above, it is concluded that the explanatory power of the Catastrophe Theory models, particularly the cusp (though the higher orders are also useful when the number of dimensions needs to be increased) is of tremendous benefit in assessing whether a discontinuity is liable to arise, and the sort of discontinuity that will arise.

The model provides an analytical tool for studying where change should occur, i.e. if there is a form of behaviour that

it is believed should be broken, catastrophe theory can indicate the direction of evolution that is required to achieve the desired catastrophic change. (In this regard a study of the practical applications by Zeeman is well worth undertaking -- especially the paper on Anorexia Nervosa.)

Finally, it is concluded that Catastrophe Theory and System Dynamics are so very closely inter-related, that the linkage of the two models should be considered seriously.

DISCONTINUITIESIntroduction:

The underlying theme of this thesis has been the subject of the discontinuity and its effect upon the plans that organisations make in order to move towards their goals. Those plans are frequently upset by the occurrence of the unexpected, the abrupt change in behaviour, or if the change was thought about and planned for, its startling nonoccurrence.

The financial effects of discontinuities that are unexpected can be quite severe, but the need to then take rapid corrective action, often under considerable pressure, can set in train a series of effects that of themselves are more damaging than the original discontinuity. An example is the set of actions put in train by the original reaction to the Watergate disclosure. That first denial probably caused Nixon more trouble in the long run, not to mention the impact upon America with regard to foreign and national confidence.

The Nixon Case and the Iranian Crisis raise another, often overlooked feature of all discontinuities, they are precipitated by real people. The events do not occur by themselves, they focus upon an individual, be it a Ralph Nader in consumerism, an ayatollah in Iran or a professor in a university (A recent article by Walter Karp (Harper's May 1980) draws pungent attention to the way that history teaching is being de-personalised, that "faceless social forces" make our



history.' It is this feature that can arise from the study of the Way of Life, broad wave fronts of social development sweeping on into the future. The study of the discontinuity, however, the thing that changes the shape and direction of the broad wave front, is dependent upon individuals.) The determination of the specific individual around whom a discontinuity will occur is a subject that must be left to the future to develop on a rigorous basis; the determination of the social forces and their dynamics that create the opportunity for that individual to precipitate the discontinuity is possible now and given adequate analysis, can be used now.

#### Aspects of Discontinuities:

Some of the following aspects of discontinuities have been discussed in earlier parts of the thesis, but there is some merit in drawing them altogether.

The first aspect is the continuous behaviour that is interrupted. A study of this behaviour and the forces controlling it will give some indication of the impact that a discontinuity of the behaviour will have upon other parts of the system. In this area, a rigorous System Dynamics type study will provide the greatest benefit.

The second aspect is the behaviour, continuous or not, that causes the interruption of the other continuous behaviour. Again, a rigorous study of the cause and effect chain will elucidate the features of this behaviour and the impact that it could have.

Thirdly, there is the interruption itself. The nature of the interruption will be determined by the topology of the pleat in the behaviour surface. The breadth of the hysteresis loop and its depth will indicate the magnitude of the effects and the extent to which the control factors will need to be changed in order to achieve the interruption. A study using the Catastrophe Theory model will provide the best insight here.

Fourthly, there is the resumption of continuous behaviour after the interruption. What sort of behaviour will it be and what will be the effects throughout the system in which the interruption occurred. This aspect requires the combined benefits of System Dynamics and Catastrophe Theory to be applied to the system.

It is interesting to note that the study of discontinuities requires the study of continuous behaviour. Both Jay W. Forrester and E. C. Zeeman stress this fact in their works; Forrester from the System Dynamics point of view, and Zeeman from the Catastrophe Theory view. For example Forrester warns about discreteness as follows:

"The beginner tends to be carried away by his knowledge of the discreteness of various decisions and actions...In actual systems, pressures build up gradually, leading progressively over a period of time to awareness and action." (page 453)

and

"Real systems are more nearly continuous than is commonly supposed." (page 64)

(Both quotes from 'Industrial Dynamics')

Zeeman, in discussing Catastrophe Theory in his 1976 paper put it this way:

"(Catastrophe Theory)...is particularly applicable where gradually changing forces product sudden effects. We often call such effects catastrophes, because our intuition about the continuity of the underlying forces makes the very discontinuity so unexpected..."(pagel)

Approach To Discontinuities:

Discontinuities can be approached in two, inter alia, ways. The first is to analyse the forces directing events and to project their evolution so that it becomes apparent that, as things stand, a discontinuity will or will not arise, i.e. the approach is to see what happens.

The second is, after seeing what is expected to arise, to work back to what would need to occur to achieve or prevent a discontinuity.

In terms of cause and effect chains, the first approach relates more readily to the event that will recur, the closed loop approach. The second approach provides a means of assessing the impact of the 'unique event,' or open chain of cause and effect that could burst upon the system.

Both approaches enable discontinuities to be assessed in terms of their likely occurrence; both approaches provide a basis for assessing the characteristics of the discontinuity; and both approaches go a long way towards predicting the occurrence of discontinuities.

### The Impact of Ideas:

Ideas have been mentioned in earlier chapters and some indication of their importance has been given. The search for new ideas is of considerable importance for organizations in the technological field, they depend upon a continual generation of them for their organisations continued existence. In this context, ideas precipitate change from a future of stagnation to one of growth.

But ideas can alter, and do alter the speed of evolution of the social forces at hand. The impact of a new technological advance can have effects that alter the probability of discontinuities occurring elsewhere in the system under consideration. For example, seminal works such as those by the leaders of the thought of the day such as Hamilton, had an enormous impact upon the future of the United States, and the framing of its Consitution. Similarly, the ideas that led to the development of the digital computer have revolutionised the data handling world.

In other words ideas can precipitate or alter the otherwise expected pattern of evolution of a system.

The other side of the coin is of more interest however. An analysis of the expected evolution of a system provides the opportunity to study the effects of changing that evolution, (something that is done regularly in any System Dynamic's study). But the analysis has more potential than that. It provides the chance to ask what sort of things need to be

developed in order to effect the desired changes, i.e it provides a source of 'ideas' for development, a source that could be of considerable use to the technology industry.

Not only is it a source of ideas, but such analysis puts the impact of the idea into proper perspective-the effects are taken into account at the outset, and can be adequately planned for.

#### Control of Discontinuities:

The preceding chapter on Catastrophe Theory gives the impression that it only requires the adjustment of the evolution of one or both of the control factors in order to prevent or alternatively, precipitate the catastrophic jump from one level of the pleat to the other. This is true, but it is not the only way. The other way is to alter the shape of the pleat, the cusp-projection. In the social areas, the shape of the cusp is generally a function of social norms and is of itself, evolving. For example, landmark cases in the Supreme Court can and do alter what the allowable norms will be, i.e., there are cause and effect relationships that determine the shape of the pleat itself.

Interference with any of those relationships-their rate of evolution, provides scope for the control of the behaviour surface, and in real life that interference is a continuous function in itself, i.e., that nice three dimensional graph of the behaviour surface is actually a continuously writhing and undulating surface that has local not global stability.

The earlier chapter on System Dynamics placed heavy reliance upon the system of inter-related causal loops. There is another aspect of those systems; because they are inter-related they have an inherent stability, in that change has to adjust quite prodigious amounts of activities before it becomes adequately embedded within the system. This is similar to the growth of the mutual dependency links in the organisational life and the similar links in the Way of Life, i.e. these links facilitate the continued existence of the organisation and the Way of Life by making change more difficult - its effects more widespread.

The above paragraphs create the impression that change is difficult to control, not that change will not occur. A close study of the forces at hand however, and an understanding of their inter-relationships enable the pin-pointing of the areas where change is amenable to control. An earlier example was lobbying, where desired change can be set in train by choosing the topic, time, place and person for lobbying. A study such as advocated here, that sets up the cause and effect relationships and considers the shape of the cusp curve, could well improve the effectiveness of lobbying. Other examples of attempts to make controlled change in the social arena appear to have been undertaken by the CIA in Chile. In fact, it could be said that diplomatic representation is an example of; firstly the acquisition of data about the Way of Life of a given nation; secondly, a device for effecting change at the

crucial points in the nation (e.g. the meetings between Robert Kennedy and the Russian Ambassador during the Cuban Crisis); thirdly that the diplomatic approach seems to use the avoidance of abrupt change in peaceful times, and the precipitation of abrupt change in times of stress. (e.g. the advocacy of boycotting the 1980 Moscow Olympics is designed to bring about an abrupt change, namely the reversal of the Soviet presence within Afghanistan.)

The debate and discussions that national State Departments engage in with one another is equivalent to the determination of the cause and effect relationships of actions upon their respective Ways of Life. It is this exploration and understanding that then determines what can be done to delay or precipitate discontinuities upon a national level.

In terms of altering the shape of the cusp curve, recent actions to change the use of energy at the family level, such as decontrol, are one example. A second attempt to control the shape of the cusp curve is demonstrated by the rhetoric of the politicians who are endeavouring to gain political office. The attempt to swing the populace from say Democratic to Republican is equivalent to altering the shape of the curve because it alters the limits to accepted political behaviour.

Precipitation of a discontinuity is elegantly demonstrated by Zeeman in his paper upon Anorexia Nervosa which was shown to be a cycle of behaviour involving the regular occurrence of discontinuous behavior. The analysis of the cycle, using

Catastrophe Theory, showed the most effective point at which the cycle could be broken. Subsequent treatment used that knowledge with some considerable degree of success.

Within organisations, control of change takes place when specific individuals are moved in order to allow the incoming person to effect change. Similar instances abound throughout the organisation.



Summary:

This chapter has looked at discontinuities from several directions in order to broaden the scope of the discussion and in order to draw out some of the more important aspects more clearly.

First, consideration was given to the effects of hasty reactions to discontinuities, in order to highlight the benefits of trying to plan for, or at least react in an orderly manner to, discontinuities.

Second, attention was drawn to the way that discontinuities focus upon individuals, that the broad sweep of history is changed by the actions of focal people, in order to draw out that the sweep of events can be analysed and predicted to some extent, but that the prediction of the specific individual is not so likely.

Third, the chapter focussed upon the fact that an analysis of discontinuous behaviour depends upon an analysis of the continuous behaviour that is interrupted.

Fourth, the two approaches to discontinuities (and any field for that matter) can each shed some light on the phenomena in question.

Fifth, the impact of ideas was considered, firstly as an instigator of discontinuities, and secondly through the ability of a study of the factors liable to cause a discontinuity, to generate ideas.

Sixth, control of discontinuities was discussed in terms of controlling the control factors and in terms of altering the shape of the cusp. Examples were given of every day uses of this action, and an indication was given to the improvement that could result from a structured analysis using System Dynamics and Catastrophe Theory.

A RETURN TO PLANNINGIntroduction:

A return to the subject of the planning process will enable the threads of the previous discussions to be brought to a focus and from that enable the conclusions to be drawn more clearly.

There are several key threads that run through the discussion, of which the first is the distinction between the organisation and its environment. The distinction is real, but it goes hand in hand with the factors that embed the organisation within its environment. Without these factors and their development, the organisation serves no environmentally useful purpose and its continued existence becomes subject to serious doubt. The embedding factors are those that lead to what I have called the 'mutual dependency links,' the cross boundary transactions.

The second key thread is the approach to be taken in understanding the environment. The need for a total approach leads to the Way of Life concept and how the evolution of the Way of Life will affect the mutual dependency links.

The third key thread arises from the nature of the problem, and that is the analysis of future effects from current or expected actions. This has required a cause and effect analysis to be necessary and from this, has determined the sort of tools that are required for the analysis.

The fourth thread also arises from the nature of the problem, the need to better handle discontinuities. This has again led to the determination of the analytical tool best suited to resolving the problem namely Catastrophe Theory.

The fifth thread relates to the people doing the planning, setting the goals and assessing the options. The discussion has indicated that broad experience is a necessary supplement to analytical abilities.

This chapter will therefore look at these areas in the context of planning.

#### Mutual Dependency:

The basic question is quite simple, what are the mutual dependency links of the organisation?

This topic commences with a need to know what it is that the organisation is doing, not what it should be doing, though that is vital later. For example, what are the obligations created by dealing with specific customers and suppliers? What are the effects of changing those obligations? Who depends upon the organisation? (This is the real core because the answer might be surprising and at variance to the stated goals of the organisation. e.g. the provision of jobs may be of fundamental importance to the society to the extent that it over rides the profit goal).

Mutual dependency therefore requires the planners, the strategists, the goal setters, to understand the mutual obligations that have arisen. The approach to determining

this can range from highly structured questioning of the operating staff to the odd random question of key people e.g. why does George always purchase from John Doe?

It is suggested that consideration should be given to keeping track of the mutual obligations to a far greater extent than merely keeping up with legal obligations and specific contractual relationships.

How is this to be done?

The planning process in the larger organisations is normally fairly structured in terms of data handling and standardised input. The basic approach could be for those preparing the data and those reading it, to keep asking, why are we doing this? What is relevant about doing this? It becomes a frame of mind that will ascertain whether a structured approach such as formal meetings and analysis is appropriate. The key is to keep in mind, the picture of the cross boundary relationships, those links that create the mutual dependency

#### Way of Life:

The Way of Life has already been discussed in some detail, but how do you determine it? Tools exist already, under the general topic of Environmental Scanning, and highly sophisticated systems can be and are set up to gather and process the information necessary to analyse the environment. Depending upon the organisation, specific units can be set up to do the work and draw the conclusions. Units such as policy planners,

governmental affairs, economic analysis, public relations. But again the approach depends upon an attitude of mind, that of being prepared to look at the total way of life, to consider that events other than economic can have an impact upon the organisation.

The choice of people here is critical, there is the need for the generalist, the person with a more 'classical' background as opposed to the 'narrow' specialist.

The access to data is critical, separation of data upon functional lines of the sort outlined above is invaluable at one level, provided it is supplemented by someone responsible for looking at the whole picture, so that the pattern of the events can be discerned.

There are considerable data available in this field of the environment. For example the foreign departments of international banks, the country booklets prepared by the international accounting firms, the studies prepared by the United Nations and its organisations, the informed reports in the more reputable weeklies and monthly journals, the editorial pages of the better newspapers and most importantly, the advice and knowledge of the diplomatic community.

The essential feature in this area is the integration of the available data; the organisational structure best suited to that will depend upon the problems to be resolved and the structure of the organisation itself.

### The Tools:

Environmental scanning has been separated from the heading of the tools because it is problem specific and because it is subsumed within the "tool" of the Way of Life concept.

The tools being considered here are the powerful models of systems. The analysis of cause and effect that uses the System Dynamics approach and the powerful model of Catastrophe Theory.

How does an organisation use these tools?

If the problems have a strong quantifiable bias, then the organisation can use them in a quantifiable manner, e.g. using DYNAMO in System Dynamics and the mathematics of Catastrophe Theory to produce specific predictions and specific analysis. In many instances though, the problems will not be quantifiable and the tools will provide an indication of the picture rather than a specific map. Again, from an organisational viewpoint, the structure to do this will depend upon the specific organisation.

The importance of the "tools" arises from their ability to permit analysis in a clear and structured manner; in their ability to alter the way a problem is perceived and in their ability to elucidate the complexities of the problem at hand.

Accordingly, organisations will gain the greatest initial benefit by exposure to the concepts behind these two tools. This raises an issue of training in order to obtain that exposure and it is a thorny issue because the topics are

sufficiently complex to require more than a seminar or two.

However, the tools are amenable to very effective visual presentation and it is probably in this area that the initial exposure will take place, leading on to, perhaps, more rigorous training.

### The People:

In the first instance, the people need to have integrative abilities, to be lateral thinkers, to have had exposure to a lot of variety and yet to have the ability to understand in depth when necessary.

Second, there is the need for a full understanding of the organisation, its present position, its intended position and its relationships with its environment.

Third, there is a need for a very good knowledge of world events and national development over time.

Fourth, there is a need for a high degree of intelligence, as the concepts are not easy to apply.

Fifth, there is need for specific training in the two models of System Dynamics and Catastrophe Theory (at the very least, training in the concepts that they employ, if not in the models themselves).

Whether all these requirements can be or should be met in one individual is a moot point. But whatever organisation is set up it should have access to people with the above skills and in particular, they must be exposed to one another in order to achieve the integration that is so vital.



It would seem therefore that planning for discontinuities will have effects upon organisational training programmes and upon personnel selection policies.

Summary:

This chapter has had a difficult task, in that the topic of changing the approach to planning in order to handle discontinuities is specific to the type of problems liable to be encountered by the organisation and the organisation itself.

Accordingly, the chapter has concentrated on drawing out the changes in attitudes that planning for discontinuities requires, the need for the global approach, the need for structured analysis of cause and effect relationships and the need to use the richness of the concepts of the models of System Dynamics and Catastrophe Theory.

Stress has been laid upon the requirements for the people doing the planning and how this will have an impact upon training and selection policies.

CONCLUSIONS

This thesis set out to explore our abilities to

1. Determine what events are significant to the organisation.

It is concluded that events that lead to:

- (a) goal conflict between the organisation and its environment,
- (b) diminution of mutual dependency links,
- (c) unexpected occurrence of discontinuities,

are separately and together of significance to the organisation because they have the ability to lead to the downfall of the organisation.

2. Discern social forces sufficiently early to predict that the probability of a discontinuity arising is high and requires planning.

It is concluded that

- (a) social forces can be discerned by the rigorous application of an environmental scanning approach that considers the total environment - the Way of Life concept,
- (b) that the social forces can be discerned sufficiently early by understanding the significance of the available data through the discernment of patterns of behaviour and that the patterns of behaviour are facilitated by models that reduce

the amount of data needed and that permit the judicious use of partial data,

- (c) that the use of cause and effect analysis and the compilation of systems of causal loops permits the determination of where and when loop dominance is liable to shift and where abrupt change is likely to occur.

3. Analyse discontinuities in terms in discernible social forces.

It is concluded that

- (a) discontinuities can be analysed in terms of social forces by studying the continuous behaviour that is interrupted by the discontinuity; the behaviour that leads to the discontinuity; the discontinuity itself; and the behaviour that follows from the discontinuity.

4. Indicate the approximate degree of seriousness of the foreseen discontinuity, its time and place, by using the models for analysing discontinuities created by Catastrophe Theory.

It is concluded that

- (a) the combined application of System Dynamics and Catastrophe Theory permits the discernment of the nature of the discontinuity in qualitative data, the precise timing and precise magnitude of the discontinuity is not readily attained at present. It is added that the power of the models is such

that given precise data, the specific nature can be quantified,

- (b) the analysis afforded by Catastrophe Theory is powerful and illuminating as an explanatory mechanism leading to a better understanding of the problem at hand,
- (c) the seriousness of the catastrophe can be gauged by a study of the approximate shape of the cusp, that the evolution of the behaviour in relation to the position of the cusp provides an indication of the degree to which the control forces have latitude to move before a discontinuity arises and hence some approximation of timing can be determined,
- (d) the analysis affords a mechanism for understanding where action can be taken to control or prevent/precipitate a discontinuity and that many examples of this abound in every day life.

5. Use and develop existing analytic tools for the above purposes.

It is concluded that

- (a) the extension of the Environmental Scanning approach into a total Way of Life approach provides the mechanism for ascertaining the force at work,
- (b) System Dynamics is an inherently suitable tool for analysing the Way of Life particularly in terms of the knowledge gained by analysing each causal

- loop as well as the entire system,
- (c) notwithstanding the complexities of the proofs of the theorems behind Catastrophe Theory, the models resulting from that theory are so powerful and match the use of Systems Dynamics so well, that Catastrophe Analysis is a necessary requirement to understanding and interpreting the occurrence of discontinuities,
  - (d) the use of the tools is not limited solely to the prediction of discontinuities, but has applications in their control.

## RECOMMENDATIONS

This study has revealed several areas that could prove of interest to follow up by more detailed analysis and study.

The first is the mathematics of the shifts in loop dominance. There appears to be a striking similarity between the shift in dominance and the cusp catastrophe to the extent that the mathematics of the cusp catastrophe could explain the transition which occurs in the shift.

The second area relates to determining the relative significance of different parts of a system with regard to their amenability to the exercise of control. An indication of this was given in the discussion of the ratio between cycle time and occurrence time within a single loop. If simple measures are available, they could help pinpoint the most effective areas for overcoming the inherent stability of complex systems and further add to the ability to control discontinuities.

The third area relates to measures for social forces. The selection of suitable surrogate measures means that the more quantifiable aspects of both System Dynamics and Catastrophe Theory could be used more fully.

The fourth area relates to the seven elementary catastrophes themselves and the need to have a simpler method of appreciating their full power without the necessity of a complex course in the mathematics of topology. Adequate appreciation of the 3-dimensional cusp catastrophe is readily come by, but the richness of the butterfly and swallowtail is

difficult to appreciate without the mathematics. The usefulness seems to be considerable in terms of handling some of the more complex social interactions.

The fifth area relates to the dissemination of the features of the two models. They are powerful explanatory devices and need more use to be made of them.

It is recommended that all the above areas be the subject of further study.



BIBLIOGRAPHY

1. Robert N. Anthony and John Dearden, Management Control Systems Text and Cases 3rd ed. Irwin, Illinois, 1976.

The definition of strategic planning, on page 10 and implementation programming on page 396 are useful and clear.

2. Jacob Bronowski, A Sense of the Future, M.I.T. Press, Cambridge, 1977.

This collection of essays provided a rich source of inspiration regarding creativity and set in train some thoughts about the importance of ideas.

3. Daniel Chirot, Social Change in the Twentieth Century, Harcourt Brace Jovanovich, New York, 1977.

This text was not used very much, but it provides an example of the types of in depth studies that are being done in the field of social change.

4. C. Roland Christensen, Kenneth R. Andrews and Joseph L. Bowen, Business Policy Text and Cases, 4th ed., Irwin, Illinois, 1977.

The chapters on the concept of corporate strategy, the company and its environment and the accomplishment of purpose are particularly useful reading.

5. Fred Emery, Futures We Are In, Martinus Nijhoff, Leiden, 1977.

Whilst not used extensively, this text provides a good example of the approaches taken to forecast the future. It has particular relevance to the methodology of the Way of Life Concept.

6. Jay W. Forrester, Industrial Dynamics, M.I.T. Press, Cambridge, 1961.

Industrial Dynamics introduce the study of feedback systems to management and laid the foundations for the, by now renamed, System Dynamics. Parts one and two are of particular relevance and the Appendices provide the necessary detail for gaining a better knowledge of the mechanics of the model. A useful book and gives a good insight into what Forrester had in mind in using a cause and effect type of analysis for management.

7. Michael R. Goodman, Study Notes In System Dynamics, Wright-Allen Press Inc., Cambridge, 1974.

The study notes are very useful in providing technical detail about the principles underlying the casual loops, both positive and negative, of Systems Dynamics. It is a very useful book but presumes that it accompanies a course in System Dynamics.

8. James H. Hayes, Patterns Plain and Fancy, Rand Paper Series P-6278, 1979.

This paper provides an interesting discussion upon the problems of seeing the overall pattern contained within large accumulations of data. The paper is based upon a military example but has much wider implications for data handling and the construction of models. The paper emphasises that small units act similarly, (i.e. similar to Forrester's comments that many discrete events form a continuous flow); that only in the aggregate do doctrinal differences (patterns) show, and that there is a justification for abstraction. A very useful paper and full of intriguing ideas.

9. W.M. Jones, Predicting Insurgent and Governmental Decisions: The Power Bloc Model Project Rand, RM 6358 PR, 1970.

The Power Bloc Model creates 7 categories of power within a nation and determines 4 types of power. The model is particularly useful as a framework for use in assessing the Way Of Life. The most important point however, is its recognition that one has to consider all opposition forms of power as well as the 'legitimate' form of power. Application of this model would have detected the immense importance of the Ayatollah (and in military terms, probably did).

10. Stephen J. Kobrin, Foreign Direct Investment, Industrialisation, and Social Change Journal of Conflict Resolution, London, 1976, Vol. 20 #3.

This paper provides an excellent example of the way some of the characteristics of the Way Of Life can be approached in a quantifiable manner.

11. Guy J. Pauker, Sources Of Instability in Developing Countries, Rand Paper Series #P-5029, 1973.

This paper discusses instability in the context of a population's view of the legitimacy of its government. It is a delightful paper to read especially in terms of the humanity of the author.

12. Edward B. Roberts (Editor), Managerial Applications Of System Dynamics,  
The M.I.T. Press, Cambridge, 1978.

This text was the basic text in the Sloan Fellow's course in System Dynamics. Of particular value were the chapters on the basic concepts, the chapter on Market Growth (the course exercise) and the applications to social problems contained in part six. The book forms a good starting point for the first time exposure to feedback systems and provides a graded move to the more complex applications.

13. Edgar H. Schein, Organisational Psychology 3rd ed.  
Prentice Hall, New Jersey, 1979.

This little book expands and elaborates upon the field of behaviour in organisations. The book is written in the context of dealing with dynamic matters, evolutionary developments and is thus particularly useful as an insight to the internal dynamics of the personnel side of the organisation.

14. Rene Thom, Structural Stability And Morphogenesis,  
W.A. Benjamin, Inc., Reading, 1975.  
(Translated from the French by D.H. Fowler)

This text is the seminal text for Catastrophe Theory and includes two useful chapters upon models and form. The text raises a series of implications of structural stability that take the topic into natural philosophy and other areas that have been and are being hotly debated. There is an excellent series of photographs that illustrate the occurrence of the various catastrophes in nature. The book does need to be read with either a good grasp of the mathematics of topology or else after reading a primer in the topic that draws out the implications of the mathematics in laymens terms.

15. R. Wesson and F. Hayes Roth, Dynamic Planning: Searching Through Time And Space,  
Rand Paper Series, P-6266, 1979.

This paper discusses problems associated with air traffic control, but does so in a System Dynamics way. The paper emphasises an approach of varying granularity to the time and event steps so as to maintain concentration upon the significant events at all times.

16. Alexander Woodcock and Monte Davis, Castastrophe Theory, Avon Books, New York, 1978.

This little paperback is written by a biologist and a science writer who between them manage to give a lay explanation of the theory that is very useful. The book provides also, the story of the development of the theory and its subsequent involvement in controversy. Non-technical but essential background reading.

17. E.C. Zeeman, Catastrophe Theory, Selected Papers 1972-77, Addison-Wesley Publishing Company, Reading, 1977.

Zeeman has done a considerable amount to draw the theory to the attention of the public. The first paper in the book is the best primer to the subject and is a longer version of the paper that appeared in 'Scientific American' in April, 1976. The book contains examples of the applications of Catastrophe Theory and two further sections that are worth perusing. The first is the complete minimal (sic) proof of the theory by Trotman and the second is a discussion about the future of the theory with Thom.