Chapter 3

A HIGH LEVEL ANALYSIS OF THE HARD SYSTEMS APPROACH

"It isn't that they can't see the solution".
"It is that they can't see the problem".
G.K. Chesterson

3.1 INTRODUCTION

The 'hard' systems approach as adapted from Checkland **[29]**, presupposes that real world problems can be addressed on the basis of the following four assumptions:

- There is a desired state of the system, $\mathbf{S_1}$, which is known.
- There is a present state of the system, $\mathbf{S_0}$.
- There are alternative ways of getting from $\mathbf{S_0}$ to $\mathbf{S_1}$.
- It is the role of the systems person to find the best means of getting from $\mathbf{S_0}$ to $\mathbf{S_1}$.

This is supported by Habermas cited by Jackson **[80]**, who is of the opinion that hard systems is a manifestation of the technical interest in the prediction and control of natural and social systems. Furthermore, according to Habermas, hard systems methodologies seek as far as possible to follow the empirical analytical methods employed in the natural sciences.

In addition to the references cited in this thesis, the author acknowledges the fact that the hard systems methodology is an established concept with contributions over the years made by, amongst others: Hitch, Hall, Quade, Machol, Chestnut, Jenkins, Lee, De Neufville and Stafford, Miles, Chase, Daenmzer, and Wymore **[29]**. The problem solving methodologies specifically selected for their appropriateness to this research and included within the context of this chapter are, Systems Engineering and Systems Analysis as categorised by Checkland **[29]**, with Jackson **[80]** adding Operational Research, and Management Cybernetics to the list. In addition, Systems Dynamics pioneered by J.W Forrester concludes the list.

The analytical process followed thus far, is graphically depicted in Figure 3.1, which places the chapters in context with the overall thesis objectives, and furthermore indicates the relative positioning of this chapter.

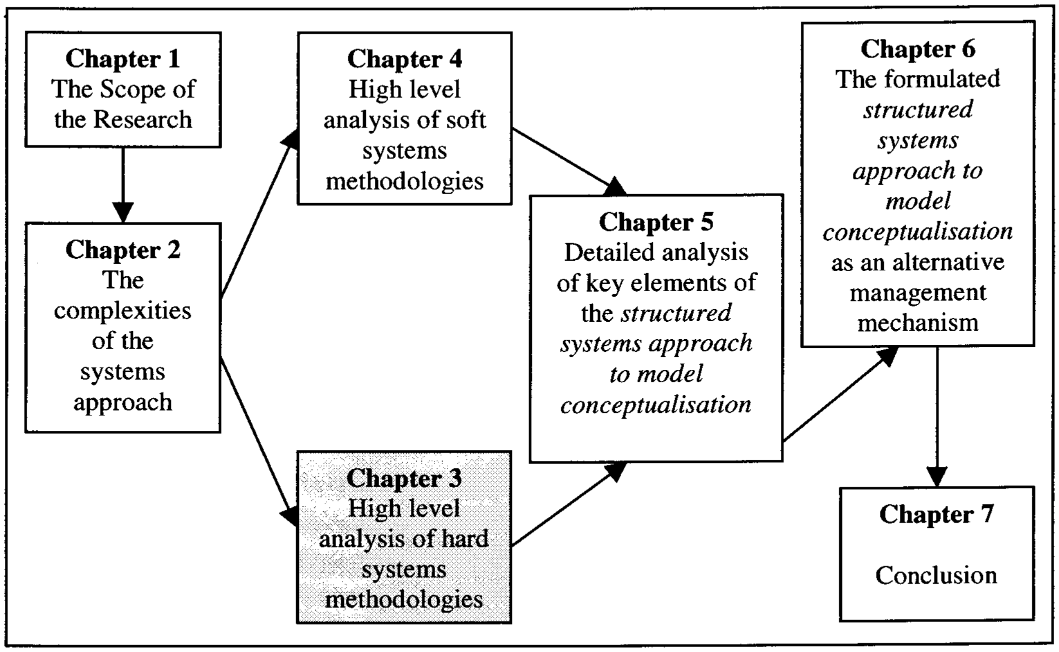

Figure 3.1: Chapters in context of the overall research

An analysis of Figure 3.1[1], shows Chapter 1 as the overall research approach to the thesis. Chapter 2, contains a number of key elements (complexities), which are explained in lieu of the high level analysis of hard systems contained in this chapter, and the high level analysis of soft systems, (contained in Chapter 4). Key elements from the high level analysis of hard systems and soft systems methodologies, will serve as preliminary input mechanisms to Chapter 5, where the elements will be further analysed in detail to ultimately culminate in a formulated *structured systems approach to model conceptualisation.* Chapter 6 will depict the *structured systems approach to model conceptualisation* as an

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[1] Arrows in Figure 3.1 represent 'information flows' (inputs) from one chapter to the other.

alternative management mechanism in practice, while Chapter 7 will contain a summary of the thesis content.

To ensure that the entities under discussion are not only appropriately placed within context of hard systems, but also within context of the overall research of this thesis, the classification of systems falling within the ambit of the systems approach depicted in Figure 2.2, is repeated here as Figure 3.2 for ease of reference.

Referring to Figure 3.2, Frame 3.2 pertains to problem solving of 'real world' phenomena having two distinct components namely:

- The hard systems approach.
- The soft systems approach.

3.2 SYSTEMS ENGINEERING

In his description of the nature of systems engineering, Checkland **[29]**, views the concept as:

> *"a set of activities which together lead to the creation of a complex man-made entity and/or procedures and information flows associated with its operation"*

Jackson **[80]**, cites Jenkins (1972) who defines systems engineering as:

> *"The science of designing complex systems in their totality to ensure that the component subsystems making up the system are designed, fitted together, checked and operated in the most efficient way"*.

For Jenkins (1972), the purpose of systems engineering is to ensure the optimal use of resources, the main ones being men, money, machines, and materials. This can be achieved through a methodology incorporating four basic phases namely:

- Systems analysis.
- Systems design.

- Systems implementation.
- Systems operation.

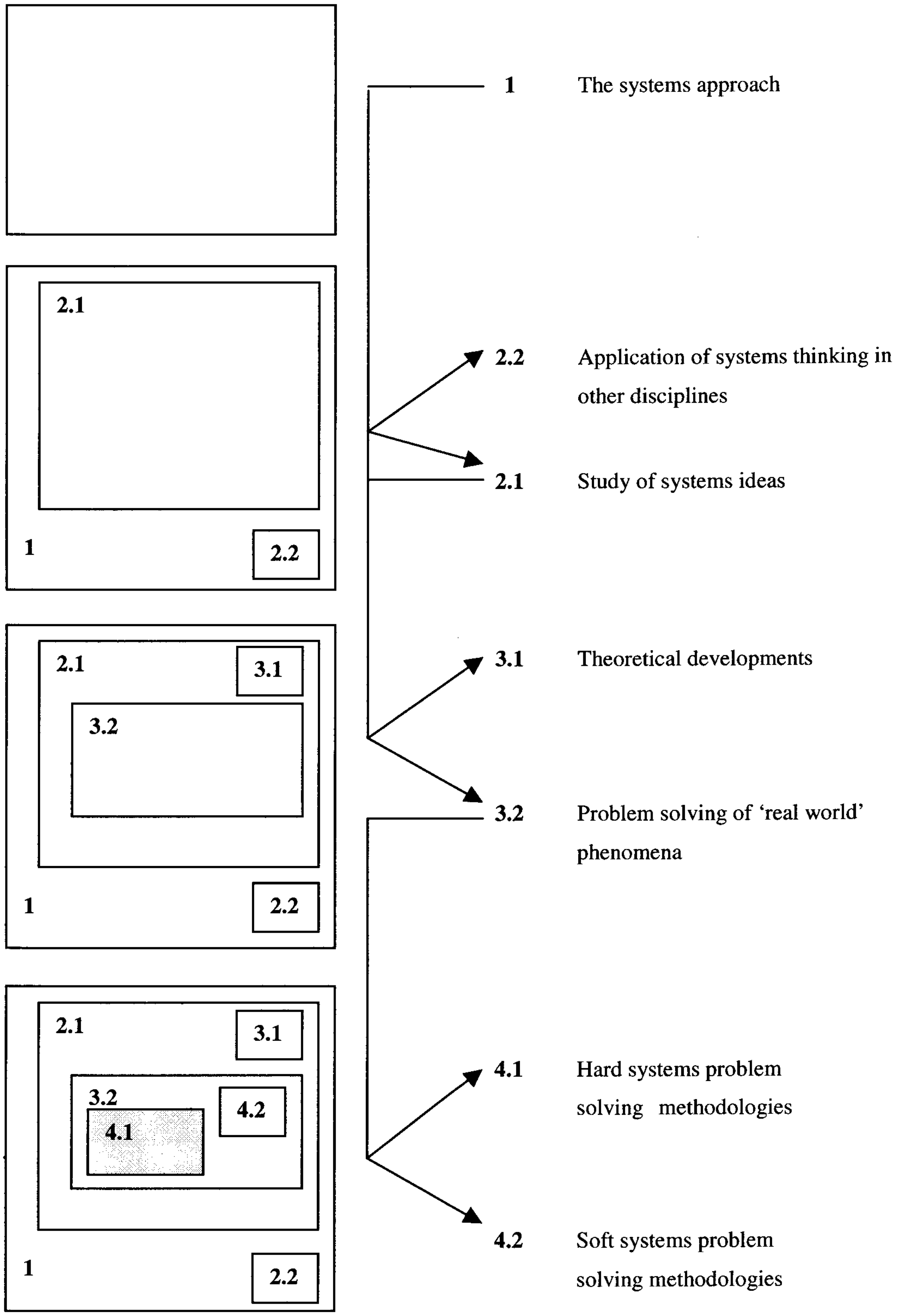

Figure 3.2: Classification of systems falling within the context of the systems approach

Systems analysis:- In this phase, the real world is taken to consist of systems and is examined in systems terms. The problem is formulated and the system in which it exists is defined and analysed in terms of important subsystems. Thereafter, the interactions between these subsystems are studied.

Systems design:- In this phase, the future environment of the system is forecast. The system is then represented in a quantitative model that simulates its performance under different operational conditions. The particular design that optimises the performance of the system in pursuit of its objectives is then chosen. The model therefore is an aid in the prediction of the consequences that follow from adopting alternative designs. Furthermore, a control system is incorporated in the design of the optimum system.

Systems implementation / Systems operation phases:- These phases involve the construction, operation and testing of the system in the real world. Hall (1962, 1969) cited by Checkland **[29]**, sees systems engineering as part of 'organised creative technology' in which new research knowledge is translated into applications meeting human needs through a sequence of plans, projects, and 'whole programs of projects'. Hall offers the following explanation of the concept:

> *"Thus systems engineering operates in a space between research and business, and assumes the attitudes of both". "For those projects which it finds most worthwhile for development, it formulates the operational, performance and economic objectives, and the broad technical plan to be followed".*

The following problem-solving sequence is suggested by Hall:

- Problem definition.
- Choice of objectives.
- System synthesis.
- System analysis.
- System selection.
- System development.
- Current engineering.

According to Checkland **[29]**, there is a need to import the concept of '*Weltanschauung*' into systems engineering in order to cope with human activity systems. This is based on the fact that hard systems is only concerned with a single '*Weltanschauung*'[2], a need is defined or an objective is stated, and an efficient means of meeting the need or reaching the objective is needed.

3.3 SYSTEMS ANALYSIS

Jackson **[80]** cites Quade (1963) who defines systems analysis as:

> *"Analysis to suggest a course of action by systematically examining the costs, effectiveness and risks of alternative policies or strategies – and designing additional ones if those examined are found wanting".*

According to Jackson **[80]**, systems analysis developed out of wartime military operations planning, and during the 1940's and 1950's applications were mainly military, involving work on weapons systems and strategic missile systems. At that time the approach was closely associated with the Rand Corporation, a non-profit body in the advice giving business that was set up in 1947 and came to embrace systems analysis as its favoured methodology. As a result of the Rand Corporation's association with systems analysis, the latter became to be known as Rand ('research and development') –style analysis.

The Rand-style analysis is best described in the following, rather lengthy description thereof by Quade and Boucher (1968) cited by Checkland **[29]**:

> *"One strives to look at the entire problem, as a whole, in context, and to compare alternative choices in the light of their possible outcomes". "Three sorts of enquiry are required, any of which can modify the others as the work proceeds". "There is a need, first of all, for a systematic investigation of the decision-makers objectives and of the relevant criteria for deciding among the alternatives that promise*

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[2] Refer to Chapter 2, Paragraph 2.8.

> *to achieve these objectives". "Next, the alternatives need to be identified, examined for feasibility, and then compared in terms of their effectiveness and cost, taking time and risk into account". "Finally, an attempt must be made to design better alternatives and select other goals if those previously examined are found wanting".*

From the above description, Checkland **[29]** draws the analogy that the establishment of systems analysis is a way of tackling complex problems of resource allocation in defence, thus becoming inevitable that it should be advocated as a methodology for business managers, who face problems of a similar kind. According to Ways **[179]**, "systems analysis involves ways of arranging ends and means so that decision makers have clearer ideas of the choices open to them and better ways of measuring results against both expectations and objectives". This analogy is supported by Schoderbeck *et al* (1975) cited by Checkland **[29]**, who define systems analysis as:

> *"The organised step-by-step study of the detailed procedures for the collection, manipulation and evaluation of data about an organisation for the purpose of not only of determining what must be done, but also of ascertaining the best way to improve the functioning of the system".*

While the systems approach is more synthesis than analysis, the following abbreviated rendition from Johnson **[81]** clearly, by example, demonstrates the distinctive differences between the entities systems analysis and systems synthesis:

- **Analysis:-** In terms of analysis, the first step to understanding a system is to take it apart. Consider a University, for example. If we wanted to use analysis to define a University, we might first say that it consists of colleges, in turn, contain departments, and departments are made up of students, faculty, and areas of study. We would continue to reduce the University in this way until we arrive at its indivisible elements. Then we would try to build up our understanding of these elements into an understanding of the entire University.

- **Synthesis:-** With synthesis, the opposite of the process followed in 'analysis' apply. To define a University using 'synthesis', we would first try to determine the larger system of which the University is a part; in this case, education. As a second step, we would try to understand the larger system as a whole. Finally, we would refine our understanding of the University by identifying its role or function in the containing system of which it is a part.

Flow tracing is a dimension which Strümpher **[165]** adds to the concept 'analysis', and makes the following comparisons between 'analysis', 'flow tracing' and 'synthesis':

- **Analysis:-** Strümpher **[165]** is of the opinion that analysis cannot explain the dynamics of a system, but it can help identify and explain static relationships, i.e., structure. As such the primary knowledge product of analysis is information and the process involves the following steps:
  - Break the thing (system) to be understood into its logically constituent parts.
  - Explain the parts.
  - Assemble the explanation of the parts into an explanation of the whole.
- **Flow tracing:-** This methodology is used to obtain insight, i.e., knowledge about the process dimension, which is a generalised approach of that which is called 'systems analysis' in the computer world. Flow tracing involves the following steps:
  - Starting at either the input or output points of the system, trace the sequence of matter/energy or information flow through the system.
  - Regard process points as points where matter/energy or information flows enter and are transformed into new matter/energy or information flows, thus describing the transformation that takes place.
  - Assemble an integrated process diagram, which describes the matter/energy or information flows, their confluence's and the transformations.

Synthesis:- Neither flow tracing nor analysis can form understanding, which requires explanation of the function(s) fulfilled by the system with respect to a containing whole. To form understanding one requires synthetic thinking, which follows the following process:

- Place the entity (system) to be understood within a containing whole.
- Explain the containing whole.
- Explain the item of interest by explaining the function(s) that it fulfils with respect to the containing whole.

Capra **[27]** summarises the functionality of the two entities by using the analogy that 'analysis' means taking something apart in order to understand it, and synthesis[3], means putting it into the context of a larger whole.

3.4 OPERATIONAL RESEARCH

The first textbook on 'operational research' appeared in 1957 and was written by Churchman *et al* entitled *'Introduction to Operations Research'* **[29]**. According to the authors **[29]**, operational research as an established concept emerged during World War II, when military management called on scientists in large numbers to assist in solving strategic and tactical problems. Many of these problems fell in the category of 'executive-type problems'. Scientists from different disciplines were organised into teams, which were addressed initially to optimising the use of resources and thus becoming the first operational research teams.

One of the objectives of operational research as it emerged from this evolution of industrial organisation, was to provide managers of the organisation with a scientific basis for solving problems involving the interaction of components of the organisation in the best interest of the organisation as a whole. Such decision would become known as the 'optimum decision', while the best relative to the function of one or more parts of the organisation would be known as a 'sub-optimum decision'. The problem of establishing criteria for an optimum decision, would prove in itself to be very complex and technical. In summary, the objectives of operational research were to find the best decisions relative to a large portion of a total organisation as is possible. One of the earlier views (1960) on the purpose of operational research is provided by Ackoff **[2]**, who was of the opinion that operational research is concerned with increasing the effectiveness of

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[3] The original text used by Capra **[27]** refers to the concept 'systems thinking', as opposed to the word 'synthesis' as used within context of this thesis.

operations of organised man-machine systems, and according to Ackoff and Rivett **[5]**, based on three essential characteristics namely:

- Systems orientation.
- The use of interdisciplinary teams.
- The adaptation of scientific method.

Jackson **[80]**, identifies seven phases of an operational research project, while Ackoff and Sasieni **[6]** identifies five stages, combined here for completeness as follows:

- Formulating the problem.
- Identifying, designing, and screening alternative responses.
- Building and using models for predicting the consequences of adopting particular responses.
- Comparing and ranking alternative responses.
- Evaluating the analysis.
- Decision and implementation.
- Evaluating the outcome.

Ackoff with co-author Sasieni **[6]**, provides the following as a useful basis for understanding the nature of operational research namely:

> *"The understanding of scientific method by inter-disciplinary teams to problems involving the control of organised (man-machine) systems so as to provide solutions which best serve the purposes of the organisation as a whole".*

The Operational Research Society's official definition for operational research as cited by Jackson **[80]**, is the following:

> *"Operational Research is the application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business, government and defence". "The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors*

> *such as chance and risk, with which to predict and compare the outcomes of alternative decisions, strategies and controls". "The purpose is to help management determine its policy and actions scientifically".*

Interpretation of this definition and its applicability as a viable solution in solving complex phenomena of the real world is provided by Checkland **[29]** as follows:

- The definition of operational research applies the methods of science to parts of the real world, as opposed to artificial situations created in the laboratory. It is interesting to note that engineers apply the same solution: To carry out 'experiments', not on the real world object of study, - which is usually not available – but on a model of it, if possible a quantitative model.
- The strategy of operational research, is to build a model of the process concerned, one in which the overall performance is expressed in some explicit measure of performance (often economic), then to improve and optimise the model in terms of the chosen performance criterion, finally to transfer the solution derived from the model to the real world situation. This equates to an attempt to be scientific in the real world as opposed to the laboratory. Beer **[21]**, is of the opinion that when the operational research scientist sets about the task of making a particular model rigorous, he is using the tool called General Systems Theory[4].
- The strategy obviously ought not to be pressed unless the model can be shown to be valid. In the case of a well defined production process, this may not be too difficult – if the model, when fed with last year's demand, can generate last year's output, then we may feel reasonably confident that it reflects reality, however, these instances are extremely rare.
- No single performance criterion can possibly unite within itself the myriad considerations, which actually effect decisions in social systems.

From the above interpretation, Checkland **[29]** draws the analogy that what operational research can provide is one crucial contribution to a management decision, a rational story of the form: "If you adopt *X* as the measure of

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[4] As described in Chapter 2, Paragraph 2.3.

performance, then you may optimise with respect to *X* by the following actions …, but it can hardly generate the kind of irrational decisions which, in a management situation, often turns out to be a good one".

The criticism levelled at operational research by Checkland **[29]**, is echoed by Jackson **[80]** who is of the opinion that:

> *"Operational research largely abandoned any pretence of taking a 'systems approach' or of being interdisciplinary in nature". "It failed to establish itself at the strategic level in organisations and become associated with a limited range of mathematical techniques".*

It is of interest to note that Ackoff **[2]**, as early as 1960 saw that systems engineering and operational research was converging into one entity, namely 'systems research'.

3.5 MANAGEMENT CYBERNETICS

The ultimate solution for addressing unstructured complex phenomena, will in this thesis not be limited to a single set of problem solving methodologies. While management cybernetics falling within the ambit of the hard systems approach, (as opposed to organisational cybernetics, a soft systems approach, which will be discussed in Chapter 4), do not form part of the core of the thought processes to address the research problem, the building blocks thereof however requires high level scrutiny. These building blocks of management cybernetics according to Jackson **[80]** include:

- The 'black box technique', which is used to deal with issues of extreme complexity.
- 'Negative feedback', which is used for the management of self-regulation.
- 'Variety engineering', which is used for probabilism yields.

3.5.1 BLACK BOX TECHNIQUE

Exceedingly complex systems, which are so complicated that they cannot be described in any precise manner or detail, are commonly known in cybernetic terms as 'black boxes' **[38]**. The complexity of such systems according to Schoderbek *et al* (1985) cited by Jackson **[80]**, is the combined outcome of the interaction of four main determinants namely:

- The number of elements comprising the system.
- The interactions among these elements.
- The attributes of the special elements of the system.
- The degree of organisation in the system.

It is interesting to note that Sterman **[161]**, consider certain computer models as being black boxes, due to the fact that these devices operate in completely mysterious ways.

The way 'not' to proceed in approaching an exceedingly complex system – a black box – according to Ashby **[17]**, is by analysis. Instead of analysis, the black box technique of input manipulation and output classification should preferably be employed. According to Jackson **[80]**, faced with a black box, a manager does not have to enter it to learn something about it. Instead, the system is investigated by the collection of a long protocol, drawn out in time, showing the sequence of input and output states. The manager can then manipulate the input to try to find regularities in the output. Initially, if nothing is known about the black box, random variations of input will be as good as any. As regularities become established, a more directed program of research can be conducted.

Caution regarding the use of this technique is provided by Ashby **[17]** and Beer (1979) cited by Jackson **[80]**. According to Ashby **[17]**, there are problems with the black box technique, as when a particular experiment changes a system to such an extent that it cannot be returned to its original state for further experimentation. According to Beer (1979), it is very important not to jump to conclusions about the behaviour of a system, without observing it for a sufficient length of time.

3.5.2 NEGATIVE FEEDBACK

According to Jackson **[80]**, exceedingly complex probabilistic systems have to be controlled through self-regulation. To understand what such self-regulation cybernetics can provide, it is important to understand the following two concepts:

- It is the existence of mechanisms bringing about self-regulation that gives a degree of stability to the environment of organisations.
- Due to the fact that managers lack 'requisite variety' to all the decisions that will have to be made, managers should understand the nature of self-regulation they wish to induce in the organisation they manage. Furthermore, according to Beer **[22]**, managers are required to make their organisations 'ultra-stable' due to the fact that they will not be able to accurately determine what types of environmental disturbance their organisations will face.

The work of Wiener (1948) cited by Jackson **[80]**, has established that the way to ensure self-regulation is through the negative feedback mechanism. The feedback control system is characterised by its closed-loop structure. It operates by the continuous feedback of information about the output of the system. This output is then compared with some predetermined goal, and if the system is not achieving its goal, then the margin of error (the negative feedback) becomes the basis for adjustments to the system designed to bring it closer to realising the goal. Churchman **[34]**, defines negative feedback as:

> *"A situation in which information coming to the manager arrives at the right time for him to take the appropriate course of action".*

Four distinctive elements are required for negative feedback to function optimally, namely:

- A desired goal, which is conveyed to the comparator from outside the system.
- A sensor (a means of sensing the current state of the system).
- A comparator, which compares the current state and the desired outcome.
- An activator (a decision-making element that responds to any discrepancies discovered by the comparator in such a way as to bring the system back toward its goal).

This kind of control system is extremely effective, since any movement away from the goal automatically sets in motion changes aimed at bringing the system back onto course.

3.5.3 VARIETY ENGINEERING

Executive management are faced on an ongoing basis with complex phenomena, which are invariable unstructured and unexpected, resulting them to live with probabilistic systems. In this respect, Ashby **[17]**, provides some understanding of such difficulties and ways in which they should be dealt with from a cybernetic point of view using 'variety engineering'. According to Ashby **[17]**, variety of a system is defined as:

> *"The number of possible states it is capable of exhibiting".*

It is therefore, a measure of complexity. The problem for executive management, as Ashby's 'Law of Requisite Variety' has it, is that only variety can destroy variety, thus in order to control a system, we need as much variety available as the system itself exhibits. When faced with massive variety, the variety must either be reduced (variety reduction) or increased (variety amplification), a process according to Beer **[22]**, which is known as 'variety engineering'. From this follows the analogy that since the variety equation initially seems to place executive management at a disadvantage, they will require all the skills availed to them by 'variety engineering' to balance varieties and (following the law of requisite variety) achieve control.

Beer **[22]**, provides comprehensive tables, which highlights the techniques that executive management can employ to reduce external variety of both kinds (operational and environmental) and amplify their own variety. An abridged extract of Beer's tables to illustrate the techniques is reproduced here from Jackson **[80]** as follows:

To reduce the external variety, managers can use:

- Structural (e.g. divisionalisation, functionalisation, massive delegation).
- Planning (e.g. setting priorities).

- Operational (e.g. management by exception).

In amplifying their own variety, executive management can employ the following methods:

- Structural (e.g. integrated teamwork).
- Augmentation (e.g. recruit experts, employ consultants).
- Informational (e.g. management information systems).

The following extract from Beer **[22]**, provides and incumbent summary of the concept variety engineering: "The output variety must (at least) match the input variety for the system as a whole, and for the input arrangement and the output arrangement considered separately". This is a vital important application of Ashby's Law of Requisite Variety, which determines that control can be obtained only if the variety of the controller, (and in this case of all the parts of the controller) is at least as great as the variety of the situation to be controlled.

3.6 SYSTEMS DYNAMICS

The 'systems dynamics' approach of Forrester **[59a]**, has its roots in the following four traditions:

- Advances in computer technology.
- Growing experience with computer simulation.
- Improved understanding of strategic decision making.
- Developments in the understanding of the role of 'feedback' in complex systems.

While systems dynamics according to Richardson **[131]**, is not linked to the General Systems Theory, it is of importance to note that Senge **[152]**, identified systems thinking in the systems dynamics tradition as the fifth of five disciplines of the learning organisation **[132]**.

According to Sahin **[143a]**, the systems dynamics approach to modelling social systems, appears to be gaining rapid acceptance as a legitimate tool of management science even as it still evokes controversy. Sahin **[143a]**, is of the opinion that the controversies might have been caused, not so much by the methodology itself, but by the areas to which it has been applied (e.g. world dynamics), and the manner in which it has been applied (e.g. using possibly heroic assumptions or building on partly impressionistic data).

The systems dynamics approach according to Richardson **[133]**, involves:

- Defining problems dynamically, in terms of graphs over time.
- Striving for an endogenous, behavioural view of the significant dynamics of a system, a focus inward on the characteristics of a system that themselves generate or exacerbate the perceived problem.
- Thinking of all concepts in the real system as continuous quantities interconnected in loops of information feedback and circular causality.
- Identifying independent stocks of accumulation (levels) in the system and their inflows and outflows (rates).
- Formulating a behavioural model capable of reproducing, by itself, the dynamic problem of concern – the model is usually a computer simulation model expressed in non-linear equations, but is occasionally left un-quantified as a diagram capturing the stock-and-flow/causal feedback structure.
- Deriving understandings and applicable policy insights from the resulting model.
- Implementing changes resulting from model-based understandings and insights.

While systems dynamics is categorised in this thesis as belonging to a hard systems approach, it is acknowledged that recent interest has grown in systems dynamics as a soft modelling methodology. This soft approach to systems dynamics according to Morecroft **[113]**, is being spearheaded by Wolstenholme (1983) and Wolstenholme and Coyle (1984). Furthermore, Checkland **[29]**, also supports the soft approach to systems dynamics.

3.6.1 PHILOSOPY OF SYSTEMS DYNAMICS

Underpinning Jay Forrester's systems dynamics is a theory of information feedback and control as a means of evaluating business and other organisational and social contexts. A systems dynamics view is one that places emphasis on structure, and the processes within that structure, assuming that this is how dynamic behaviour in the real world can best be characterised. Systems dynamics considers behaviour as being principally caused by structure, it is a theory of the structure of systems and dynamic behaviour. Structure includes not only the physical aspects of plant and production processes, it also importantly refers to the policies and traditions, both tangible and intangible, that dominate decision making. Thus, systems dynamics assumes that analysis of a situation can be undertaken from an external objective viewpoint and that the structure and dynamic processes of the real world can be recreated in both systems diagrams and mathematical models.

The tendency is to evaluate the applicability of methodologies only from a private sector perspective, while the public sector management and policy is equally fraught with many of the same problems encountered in private sector applications, but the path to the implementation of insights is even more difficult **[132]**. It is in this arena that systems dynamics proves to be most appropriate from a modelling perspective as demonstrated in Table 3.1.

Public Sector Application	**Authoritative reference**
Forecasting.	Sterman and Richardson **[164]**.
Conservation policy.	Ford and Bull **[58]**.
Efficiency standards.	Ford **[57]**.
Energy policy planning.	Naill **[116]**.
Solid waste disposal.	Mashayekhi **[98]**.
Social organization underlying poverty and hunger.	Saeed **[142]**.
Rangeland destruction.	Mashayekhi **[97]**.
Social program management.	Richardson *et al* **[134]**.
Medical technologies.	Homer **[78]**.
Community care.	Wolstenholme **[184]**.
Cocaine prevalence.	Homer **[77]**.
Policy analysis.	Richardson and Lamitie **[135]**.
School finance reform.	Andersen **[12]**.

Table 3.1: Public sector applications of the systems dynamics model

3.6.2 PRINCIPLES OF SYSTEMS DYNAMICS

The philosophy of systems dynamics emphasises model structure, which supports an interest in prediction and control, and so these will be the main principles of analysis. Structure is seen as having four significant characteristics, which amount to the focal concerns of any systems dynamics analysis, which are:

- Order.
- Direction of feedback.
- Non-linearity.
- Loop multiplicity.

3.6.3 MODEL AND METHODOLOGY OF SYSTEMS DYNAMICS

Sahin **[143a]**, is of the opinion that the most widely used approach in constructing 'initial' systems dynamics models, is to identify the feedback loops and depict them as a causal loop diagram[5]. This is supported by Richardson **[133]**, who confirms that, "conceptually, the feedback concept is at the heart of the systems dynamics approach".

Morecroft **[112]**, provides the following description of a systems dynamics model:

> *"A systems dynamics model is descriptive of the way a company functions; it does not contain idealized decision-making processes". "It shows the division of responsibilities, the goal and reward structure of the organization, as well as the inconsistencies of policy that are a part of any real organization".*

By their own admission, Flood and Jackson **[56]**, admits that there are many versions of how a quality model can be formulated, hence the approach to provide a model developed from their own work, which consist of the following elements:

- Identification of the organisational problem, which focuses the attention of the decision-makers, and leads to their purposeful activity.

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[5] Refer to Chapter 2, Paragraph 2.9.

- Carry out 'task formulation' to assist in determining the appropriate way forward. A methodology, which typically can be used for task formulation is the 'Total Systems Intervention' described in Chapter 4, Paragraph 4.7.
- Set modelling purposes which determine in unitary fashion the essential characteristics of the model to be formulated.
- Pragmatic review extant models.
- User assessment.
- Model construction (starting with the drawing up of a model development sub-methodology).
- Introduction of a validation sub-methodology.
- Model formulation:
  - Conceptualising.
  - Formulation
  - Simulation.

3.6.4 MODEL UTILISATION OF SYSTEMS DYNAMICS

According to Meadows cited by Flood and Jackson **[56]**, there are three stages in a decision making process to which systems dynamics must contribute:

- First, is to appreciate in a broad sense, the situation of concern and to develop a non-precise understanding of the dynamics.
- Second, this broad understanding needs to be translated into ideas about how to improve problematic aspects, which requires deeper investigation into the structure that underlies behaviour, although exact precision is not necessary.
- Third, is the need for detailed implementation where precision is vital

The type of 'systems thinking' which has emerged from the concepts of systems dynamics, is concerned with assisting the process of strategic debate by developing transparent models, which at the qualitative phase, facilitate knowledge capture and pluralistic exploration of process, structure and strategy, and at the quantititative phase, are capable of being developed into computer-based micro-worlds and archtypes, by which insights can be disseminated in a 'hands-on' framework **[184]**.

3.6.5 TESTS FOR BUILDING CONFIDENCE IN SYSTEMS DYNAMICS MODELS

Confidence in systems dynamics models can be increased by a wide variety of tests **[60]**. The following serves as examples:

- Tests of model structure.
  - Structure verification test.
  - Parameter verification test.
  - Extreme conditions test.
  - Boundary adequacy test.
  - Dimensional consistency test.
- Tests for model behaviours.
  - Behaviour reproduction test.
  - Behaviour prediction test.
  - Behaviour anomaly test.
  - Family member test.
  - Surprise behaviour test.
  - Extreme policy test.
  - Boundary adequacy test.
  - Behaviour sensitivity test.

3.7 CRITICISM OF HARD SYSTEMS THINKING

We are now in a position to consider the criticisms that have been levelled at the hard systems approach. The catalogue of points that follow, has been compiled from a variety of sources namely:

- Checkland **[29]**.
- Hoos **[79]**.
- Watkins **[177]**.
- Jackson **[80]** citing:
  - Ackoff (1977, 1979a, 1979b).
  - Checkland (1978, 1983).
  - Churchman (1979b).
  - Hoos (1976).

- Lilienfeld (1978)
- Rosenhead (1981, 1989b)

First there are criticisms that suggest hard systems thinking has a very limited domain of applicability. Hard approaches demand that objectives be clearly defined at the very beginning of the methodology process. In the vast majority of managerial situations, however, the very definition of objectives will constitute a major part of the problem faced. Involved parties are likely to see the problem situation differently and to define objectives according to their own worldviews, values, and interests.

A second kind of criticism relates to the failure of hard system approaches to pay proper attention to the special characteristics of the human component in the socio-technical systems with which they sometimes aspire to deal. People are treated as components to be engineered just like other mechanical parts of the system. The fact that human beings possess understanding, and are only motivated to support change and perform well if they attach favourable meanings to the situation in which they find themselves, is ignored. This deterministic perspective in hard systems thinking, which puts the system before people and their perceptions, extends to the ability of humans to intervene in their own destiny.

The third group of criticisms concerns the demand for quantification and optimisation in hard systems methodologies. When highly complex systems are involved, the building of a quantitative model is inevitably a highly selective process and will reflect the limitations of vision and biases of its creator(s). Far from recognising this and demanding that the assumptions made in building the model be made explicit, hard systems thinking seems to acquiesce in the concealment of assumptions and to treat the model readily as synonymous with the reality. The model, which is of course far more easily manipulated than the real world, becomes the focus of attention and the generator of 'optimum' solutions. It is convenient and cosy to play with the model, but the result is solutions that are out of date answers to the wrong questions. Furthermore, another consequence of the demand for quantification and optimisation is the tendency to ignore those factors in the problem situation that are not amenable to quantification or, perhaps even more seriously, to distort them in the quest for quantification. Different aspirations or matters subject to differing value interpretations are forgotten or ground down on the wheel of optimisation.

Fourthly, the degree to which hard systems thinking offers succor to the status quo, and to the already powerful, is frequently noted. It goes without saying that the best way to ensure the continuance of a consultancy project, and the implementation of the proposals, is to privilege the objectives of the most powerful stakeholders. Having inevitably been forced into making such political choices, hard systems approaches seek to cover their tracks by encouraging 'depoliticisation' and 'scientisation'. The complicated mathematical modelling discourages ordinary people from believing that they might have anything useful to contribute to decision making. It also suggests that difference of opinion and interest, can be rationally dissolved by experts using the latest tools and techniques. Thus conflict is hidden. Furthermore, since conclusions emerge from a computer model programmed by white-collar scientists, they take on an air of objectivity that is, of course, entirely spurious.

Fifthly, the naïveté of the hard systems approach to complex socio-technical problems can be accounted for, at least in part, by its roots in the engineering tradition and the 'trained incapacity of engineers' to see systems as anything but things governed by predictable laws. The survival of such naïve orientation, is more difficult to explain. A feasible argument offered is that systems theory of this ilk should be regarded as 'ideology'. It flourishes because of the service it renders to the scientific and technocratic elite. Presenting as it does, a view of systems as entities to be manipulated from the outside on the basis of expertise, hard systems thinking justifies the position and privileges of the elite.

3.8 POSITIVE ASPECTS AND FEATURES OF HARD SYSTEMS

It is important to put the criticisms highlighted in the paragraph above in context by emphasising some of the positive achievements and features of hard systems. The following positive aspects of hard systems are identified by Jackson **[80]**.

- The problem solving characteristics of hard systems constitute an advance over *ad hoc* thinking about the executive management task.
- Mathematical models used to aid decision making in addition allowed for predictions to be made about the behaviour of real world systems without the attendant risks and costs of intervening in the actual system of concern.
- There is recognition in the interactive nature of systems parts and of the need to draw the boundaries of any investigation wide so as to include all-important influences on the system. This allowed the problem of sub-optimisation to be identified and avoided.
- The practice of hard systems has often been rather better than the precept. Indeed, this could hardly fail to be the case. For were operational research, for example, to be simply the set of techniques described in many of the textbooks, then it could hardly have survived in modern organisations, and yet there are examples in British industry of very successful operational research groups.

This section dealing with the positive aspects and features of hard systems was necessary in order to put the criticisms of the concept into context. The hard systems has registered some significant achievements, practitioners are more sophisticated than written accounts of hard methodologies suggest, and the hard tradition is not static- changes are taking place that show an awareness of some of the concerns evinced by the critics.

3.9 HARD AND SOFT SYSTEM METHODOLOGIES COMPARED

At this particular point in the research, where the reader has been exposed to hard systems thinking in this chapter, and is about to be introduced to soft systems thinking in the next chapter, it is most appropriate to compare the main differences between the two concepts, details of which is contained in Table 3.2.

HARD SYSTEMS METHODOLOGIES	**SOFT SYSTEMS METHODOLOGIES**
Concerned with the system dimension of the system of systems methodologies **[80]**.	Concerned with the dimension dealing with people and their perceptions, values and interests (the participants dimension) **[80]**.
Ignores issues of subjectivity **[80]**.	Admits there are multiple perceptions of reality **[80]**.
Hard systems are goal-directed, in the sense that a particular study begins with the definition of the desirable goal to be achieved **[29]**.	Soft systems work within real world manifestations of human activity systems in which something was perceived to be a problem **[29]**.
Hard systems are suitable to address issues pertaining to 'structured problems' - problems which can be explicitly stated in a language which implies that a theory concerning their solution is available **[29]**.	Soft systems are suitable to address issues pertaining to 'unstructured problems' – problems, which manifest in a feeling of unease, but which cannot be explicitly stated without this appearing to oversimplify the situation **[29]**.
Hard systems methodology is concerned only with a single *'Weltanschauung'* **[29]** .	In soft systems methodology, we are forced to work at the level at which *'Weltanschauungen'* are questioned and debated **[29]**.
The hard approach can stand by asking: What system has to be engineered to evolve this problem, or what system will meet this need, and can take the problem **[29]** ?.	The soft approach has to allow completely unexpected answers to emerge at later stages **[29]**.
The hard methodology is seen to be 'special cases' **[29]**.	The soft methodology is seen to be the 'general cases' **[29]**.

Table 3.2: 'Hard' systems and 'Soft' systems compared.

The most important difference between the two concepts is the fact that in hard systems thinking, the end result would be to implement the designed system, while in soft systems thinking, one would implement the agreed changes **[29]**.

3.10 CONCLUSION

It is of interest to note, that the soft systems approach, the subject under discussion in Chapter 4, emerged as a result of the dissatisfaction with the development, content and limitations of the hard systems approach, in spite of the positive aspects thereof listed in Paragraph 3.7 above.

In this chapter, the major hard systems methodologies, selected especially for their particular applicability to the research in this thesis have been contextually analysed at a high level in terms of literature reviews. The analysis covered the following hard systems methodologies:

- Systems engineering.
- Systems analysis.
- Operational research.
- Management cybernetics.
- Systems Dynamics.

Included in this chapter and in lieu of Chapter 4, which will deal with the soft systems approach, hard and soft systems methodologies were compared to add to the conceptual understanding of the reader of the two concepts. Furthermore, to provide a balanced analysis, the hard systems approach was analysed to highlight its major criticisms, positive aspects and features.

In Chapter 4, the major soft systems methodologies, selected especially for their particular applicability to the research in this thesis will be contextually analysed at a high level in terms of literature reviews. The analysis will cover the following soft systems methodologies:

- The Viable Systems model of Beer (organisational cybernetics).
- Churchman's Social Systems Design.
- Checkland's Soft Systems Methodology.
- Ackoff's Interactive Planning.
- Mitroff and Mason's Strategic Assumption Surfacing and Testing Methodology.

As in the case of Chapter 3 to provide a balanced analysis, the soft systems approach will be analysed further to highlight its major features.