SYSTEMS: CONCEPTS, METHODOLOGIES, AND APPLICATIONS

Brian Wilson

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To My Family

In a world that is rapidly changing, organizations need to become more adaptable and to better learn to manage change. From a systems point of view, change is enormously complex and can come from inside or outside the boundaries of the system. A major key to managing change is proper diagnosis of problems and situations, keeping in mind that the performance of the whole is not the sum of the individual parts, but is a consequence of the relationship of the performance between the parts. Thus problems cannot be solved separately, since they are interdependent.

Huse (1980)

Preface

The word 'system' is open to many interpretations. It is used in everyday language to describe 'the Establishment', our particular part of the Universe, the arrangement of pipework that extracts exhaust gases from a car engine, and even a procedure for placing bets on the race-course. In the technical literature, it appears in book titles as systems engineering, systems analysis, and systems dynamics. Any one of these may refer to the subjects of communications, control theory, computers, or a particular modelling language.

It is clear, given the above confusing range of meanings, that, if the concept 'system' is to be used as the basis for a modelling language, as is the case here, its interpretation must be made explicit and a definition must be derived which makes sense when related to all other interpretations.

Recently, Peter Checkland produced a book entitled *Systems Thinking, Systems Practice* (Checkland, 1981). This represented an account of his learning experience since joining the Department of Systems at the University of Lancaster in 1969. His aim was to make clear the interpretation of the word 'system' and the activity of 'systems analysis' as it had emerged from the 'action research' programme within the Department, and also to place the work done at Lancaster within the context of the various underlying philosophies of science and the systems movement as a whole.

It is not my aim to reproduce the same material in different words but, in presenting the results of my own experience in using systems ideas, I hope to assemble a coherent account of their development and application together with the relationship of particular systems methodologies and concepts to the nature of the kind of problems encountered. Thus the context in which this work is cast is not one of philosophy but is that of problem-solving in general. Since the basic concepts used are the same as those discussed by Professor Checkland, there will inevitably be some duplication of the ground already covered, but that is necessary if this account is to be coherent.

The audience for this material is the student, or would-be practitioner, of systems concepts and methodologies and it is my hope that this reflection on the particular experiences that I have enjoyed since joining the Department in 1966 will be of interest and of use to them. It is my style of writing to avoid, whenever possible, the use of the impersonal pronoun 'one'. I must add lest I be accused of male chauvinism that, except where a specific reference is being made, 'he' should be read as 'he or she'.

I am indebted to the many organizations and students with whom I have collaborated over the past 16 years, but they are too numerous to mention individually. However, I would like to express my appreciation to British Airways, to the Central Electricity Generating Board (Southern Region), to Glaxochem, to Ponderosa Industrias SA of Chihuahua, and to Materias Primas Monterrey SA, who gave me permission to refer specifically to projects carried out within their organizations. I gratefully acknowledge the contribution made to the development of systems ideas by all the members of the staff of the Department of Systems at Lancaster and its associated consultancy company, ISCOL Ltd. The action research activity has been a collaborative effort and, without continuing critical debate, many of the lessons would have been lost. I am particularly grateful to Gwilym Jenkins, who founded the Department and who provided me with the opportunity of taking part in such a rich learning experience, and to Peter Checkland, with whom I have collaborated in teaching systems ideas to both masters degree students at Lancaster and to representatives of many companies in the UK and abroad.

I would like to thank Mr M. J. Whitmarsh-Everiss for permission to reproduce Figures A10 and A11 of Appendix I, and the McGraw-Hill Book Company for permission to reproduce Figures 24 and 25. Also the *Journal of Systems Engineering* for permission to reproduce the paper 'A systems study of a petrochemical plant' which appears as Appendix II, I also wish to acknowledge the contributions of Dr T. R. Barnett and Chris Pogson who produced the Albion Exercise in Appendix III. Finally, my grateful thanks go to Mrs Sue Jarman, who converted the original manuscript into legible typescript with both accuracy and speed.

Overview

The material in this book is presented in five chapters together with three appendices. Following an introduction, which describes the kind of research that has led to the particular systems ideas used and some brief comments on the nature of problems and the organizations in which they reside, Chapter 1 seeks to survey the kind of modelling languages appropriate to various parts of a problem spectrum. This spectrum extends from the well defined (hard) problems, in which the modelling language may be mathematically oriented, to soft, ill structured problems in which a modelling language is required which is capable of a richer description of the real world than mathematics can provide. Such a language is that based upon the concept of a human activity system. In a supporting appendix (Appendix I), examples are given which merely aim to illustrate the many techniques available for modelling, for problems which can be precisely defined, though the reader is referred to selected references if a deeper understanding is required. These may be of interest to the reader who is concerned with developing a capability for modelling over the entire problem spectrum. The emphasis in the book, however, is towards the development of a modelling language, and its application, which is relevant to the 'soft' end of the problem spectrum. Chapter 1 aims to provide the context in which this further development can be placed. Chapter 2 therefore concentrates wholly on a description of the human activity system, which is the basic element within this modelling language. Modelling in these terms consists essentially of two phases. Firstly, it is necessary to derive a definition of the system to be modelled, and secondly, to develop a model of the system so defined. Ways of doing both phases are described in detail in this chapter. Although such models may look very different to those developed as descriptions of situations at the 'hard' end of the problem spectrum (in that they are in words rather than symbols), in principle they are no different. A differential equation is an intellectual construct used to describe the phenomena underlying the behaviour of a physical system involving hardware. In the same way a human activity system is an intellectual construct used to investigate the behaviour of a situation involving people. Chapters 1 and 2 therefore concentrate on the activity of modelling prior to a discussion of how such models can be used within the general activity of problem-solving. In discussing these ideas I have maintained a complete separation between their description and their use. In an analogous situation, I would argue that before a serious analysis of French literature can be undertaken the analyst should, at least, understand the French language.

Chapter 3 begins to examine methodology using systems ideas but, as in Chapter 1, a brief survey of methodologies in general is included to provide the context for this discussion. The development of systems methodology at Lancaster started from a particular set of ideas and Appendix II is included to illustrate an application of our initial problem-solving approach to a situation that could be described as relatively 'hard', in relation to its position within the problem spectrum.

Chapter 4 continues a discussion of systems methodologies and their relation to specific kinds of problem situations within the spectrum as a whole. This discussion takes place through the description of a number of actual cases in which the specific methodologies and associated concepts were used. They concern a problem of the design of a services complex, an operational system, service systems, and a problem related to testing an hypothesis (more usually associated with scientific investigation).

Chapter 5 continues the discussion but is related entirely to the area of management control and information systems analysis. Within this chapter, a number of projects are described which illustrate, and emphasize, the particular methodologies developed during the projects. They relate to reorganization as well as to information systems planning and development and two techniques in particular are described, namely organization mapping and the Maltese cross. Because the area of information systems analysis contains a number of other approaches, this chapter is concluded by a brief discussion of the relationship of a systems-based methodology to those others available.

Finally, Appendix III contains a number of exercises. The reader may wish to tackle these as a means of starting to develop a capability in using this particular set of systems ideas. What I have described in the book is really a way of thinking about problem situations. As such it cannot be taught, it can only be learnt. I would liken it to swimming. You may read a book which describes to you how to swim, but having read it, you will not be an accomplished swimmer. It will be necessary to get into the water. Similarly, an accomplished systems thinker is one who practises it. The exercises are graded and extend from giving practice in picture building (a necessary activity if you are to understand relationships) to problem-solving assignments. All the excercises are open-ended; i.e. there are a number of possible answers and no one answer can be regarded as the correct one. For this reason, and also because the exercises are used within our own teaching programme, specimen answers are not given.

I hope that you find the contents of the book interesting and thought-provoking. I have found the ideas invaluable in my own consultancy activity and I hope that you will also find them of use.

Contents

Introduction

Problems and Problem-solving

The most basic statement about the content of this book is that it is about problem-solving. To make that statement, however, is to make a gross over-simplification. The idea of a problem is, itself, highly complex and the notion that a solution can be found which removes the problem represents a naive view of the activity of problem-solving. There are, of course, situations in which a problem can be defined in simple terms; for example, if your car has a flat tyre, then your problem can be defined very easily and a solution will be recognized as such when the desired pressure is maintained in the tyre. This kind of easily defined problem represents one extreme of a problem spectrum which extends to the kind of problem facing the British Government at the present time, i.e. what to do in Northern Ireland? It is difficult to envisage a solution to that situation which will be recognized as a solution by all of the concerned parties.

The emphasis in this book will be on that class of problems generally termed 'management problems' which lie towards the latter end of the above spectrum. Later discussion will aim to clarify what is meant by the term 'management problems'.

The activity of problem-solving consists of, first of all, finding out about the situation in which the problem is believed to lie and then, through some analysis leading to decisions about what to do, taking action to alleviate the perceived problems. Our concern here is with the terms in which such analysis can be undertaken.

The questions, 'What are management problems?' and 'In what terms can management problem-solving be undertaken?' have been the stimulus for a major research programme carried out by the staff and postgraduate students of the Department of Systems at Lancaster University, and this has led to a particular process of analysis based upon the use of a particular concept: the human activity system. This is a crucial concept in the analysis of the highly complex area of management problem-solving, and considerable emphasis will be given to its derivation and use later in the book. First, it is worth describing a little of the background to the development process undertaken in the research programme.

The Department of Systems at Lancaster (formerly Systems Engineering) accepted its first intake of students in 1966. It was established as a post-graduate department and its central activity was a twelve month course leading to a master's degree. This is still the case, though postgraduate activity extends to a doctoral programme and some undergraduate teaching of systems forms an input to other courses within the university.

The specific aim of the Department was to extend the methodologies of engineering design and 'hard' systems engineering (Goode and Machol, 1957; Williams, 1961; Hall, 1962; Chestnut, 1965) into the area of management problem-solving in general. The philosophy of the Department has always been to undertake this development through involvement in real-world problems. Here the distinction is made between problems in the real world and problems in the laboratory. In the laboratory the analyst has the freedom to define the problem and to control the environment. Thus he can allow certain variables to affect the process under investigation and to constrain others so that they do not. In the real world such freedom does not exist. The analyst has to accept whatever influences the situation under investigation. The mechanism chosen to carry out this development therefore was 'action research' (Foster, 1972; Warmington, 1980). It has been our practice to do both the teaching and the research in this mode and this has demanded that our students should, in the main, be mature postgraduates (to date the average age has been 30), as it is difficult to be effective in this process of learning and development if the students do not already have an appreciation of how organizations function and of the kinds of problems faced by real managers when undertaking the task of real management. In addition to the use of joint staff–student teams on client-sponsored studies, the Department formed a management consultancy company so that this work could be supported through studies unconstrained by the time and resource limitations of the master's degree programme; this was registered as a limited liability company, ISCOL Ltd, in 1970. Experience from both sources will be used to illustrate the development of concepts and methodology in Chapters 3, 4 and 5.

Action Research

The concept of action research is that of simultaneously bringing about change in the project situation (the action) while learning from the process of deriving the change (the research). Over 200 such studies have now been completed in both the Department and ISCOL Ltd and these have led to the particular systems language and methodologies which form the basis of our teaching and consultancy work.

The process of action research can best be seen as a learning cycle illustrated by Figure 1. The process is initiated by the existence of situations in outside organizations in which there are perceived to be problems. In order to undertake analysis of these problem situations, the analyst must have available, or develop, ways of describing them (i.e. models) together with modelling languages. The initial expertise within the Department (related to the previous industrial experience of the members of staff) was in the area

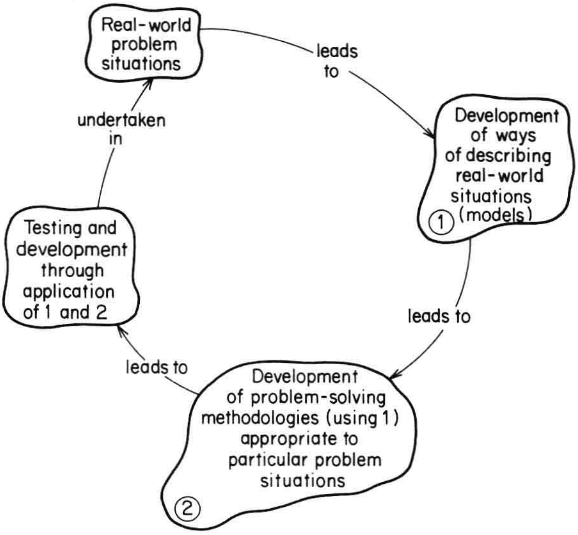

Figure 1. An action research cycle

of process modelling and hence the modelling language was, in the main, based upon the use of mathematics.

The methodologies available for problem-solving within the Department, at that time, were those related to process design, process control, and optimization and those of the Hall and Rand 'systems engineering' variety (Quade and Boucher, 1968). Thus, armed with this initial expertise, the learning cycle of Figure 1 was operated and the modelling process and methodologies extended, adapted, and created to cope with the variety of problem situations encountered. Since the cycle is completed by application, the development remains problem oriented and the output is usable problem-solving methodologies capable of practical application.

Problems and Organization

Since the development process referred to above has been undertaken in outside organizations and has effectively been driven by the kinds of problems encountered within those organizations, it is useful briefly to examine the nature of such problems. This will help to explain the view taken later of the nature of the problems within the problem spectrum and the relationships of these problems to the particular methodologies used in their analysis.

A broad classification of problem types can be derived by taking the extremes of a spectrum which extends from 'hard' to 'soft' and by considering the distinction between questions which are concerned with *how* an activity should be undertaken as opposed to *what* the activity is. In this context, the well defined problem of the flat tyre, referred to previously, is a hard problem, whereas the situation in Northern Ireland is extremely soft.

A 'hard', or structured, problem is one which is exclusively concerned with a 'how' type of question. This can be exemplified by considering the problem confronting Brunel when faced with the need to span the Avon Gorge. There was no doubt in Brunel's mind as to what he wanted to do; the problem was how to do it. This kind of problem is the domain of the design engineer who seeks effective and economic answers to the 'how' type of question.

A 'soft', or unstructured, problem is one which is typified by being mixtures of both 'what' and 'how' questions. In the area of production, for example, a particular manager may be faced with the problem that production performance could be better. This statement of the problem gives no guide to *what* he should investigate to identify areas for potential improvement, or *how* he could then introduce change to realize that improvement. At the level of what he needs to do, he could (a) improve raw material to product conversion; (b) improve plant maintenance; (c) redesign production planning and scheduling methods; (d) improve marketing to production communications. Having decided on one or more of the above areas, he has then to determine *how* to bring about the improvement desired. This example is typical of 'management' problems and hence any methodology, which is aiming to help managers tackle the problems of management, needs to be capable of structuring the problems, i.e. of converting them from mixtures of 'what' and 'how' into problems only of 'how'. Thus a major output of the action research programme has been the change in emphasis towards the development of methodologies to structure problems and away from the development of techniques to 'solve' problems.

The concept of 'problem' is also one that has been found to be inappropriate. The notion that a problem can be defined suggests that a solution can be found which removes the problem. This is not unreasonable at the 'hard' end of the problem spectrum, but at the 'soft' end problems do not occur in a way which enables them to be readily isolated. It is more usual to find sets of problems which are highly interactive and it has been found to be more useful to examine, *not a problem, but a problem situation*, i.e. a situation in which there are perceived to be problems.

Adopting this stance enables a highly significant aspect of any management situation to be taken into account, namely the multiple perceptions of the various managers who may be involved in the particular area of concern. At the strategic level in an organization, for example, some managers may see the primary aim of the organization to be the satisfaction of a market need while others may see it as the need to make most efficient use of the productive resources. In reality, of course, some balance must be maintained between these two extremes. Exactly where that balance lies may be seen to be very different by different managers and hence any problem-solving methodology which is to be effective in an organizational context