# M253 Resource Sheet

## *The systems approach*

### 1 Overview

The purpose of this Resource Sheet is to introduce you to systems ideas as a useful and potentially powerful way of looking at problem situations, and to give you some ideas about the sort of questions that you will need to ask (and answer) as you start the process of understanding the situation that you have been given as a case study.

### 2 Systems thinking

When we want to solve real-world problems we need a general framework within which to operate. A paradigm that became increasingly popular in the latter half of the 20th century was that of systems thinking. Engaging in systems thinking is a way of imposing some sort of order on the world around us. This is either to help us to understand how things are organised (in order to understand how they operate), or how they need to be organised (in order to control them). To some extent, therefore, a particular system is something fairly arbitrary – what we define it to be – rather than something that necessarily exists in its own right. We choose to look at some specific aspects of the world around us in a particular way that helps us to make sense of it, or helps us to manage it more effectively.

As with so many words in everyday use, the word ‘system’ is overused, and not all the everyday uses relate to ideas that we want to consider here. We need to be rather more specific about our intended meaning. Looking at dictionary definitions of the word ‘system’ we see that it is used in so many different situations that there is little agreement on exactly what a system is, or how one should go about defining or designing one. Even when we restrict our investigation to the more scientific and technical literature, we still find many uses of the word ‘system’. There are hard systems and soft systems; open systems and closed systems; biological systems, social systems and ecosystems; control systems, computer systems and information systems. We read about Systems Engineering, Systems Analysis, Systems Management, Systems Theory and Systems Methodologies.

### 3 What is a system?

So what, for our present purposes, makes a system a system? Can we say anything about the insights into the nature of systems in general that will help to clarify the situation, even if our main interest is in man-made systems and, in particular, in computer-based information systems? Well, here is one possible definition to start us off on our discussion: ‘A system is a bounded entity which, in its environment, achieves a definite objective through the interaction of its component parts’.

If we take the various concepts involved in this definition, and expand on each of them in turn, we can perhaps get a better overall view of what constitutes a system.

### 3.1 A system has a boundary

Firstly we have the phrase ‘bounded entity’, which is included in the definition to ensure that what we are dealing with is finite and manageable. There have to be limitations on what is regarded as being included inside any given system and what is regarded as being outside it. There must be some **boundary** within which the system exists and operates – a conceptual line that can be drawn around a system, defining what constitutes an essential part of the system and what is not included in the system. Deciding where this boundary should be drawn is possibly the most important, and at the same time the most difficult, aspect of defining a system.

In the case of many biological and technological systems there may well be a physical boundary within which the system is contained. However, in the wider context of information systems, operating across a communication network and involving a variety of interactions between people and computers, the concept of a physical boundary is less important than the concept of a functional boundary. In such situations, although it may be possible to specify the physical limits of the system in terms of the specific terminals or machines from which it can be accessed, and which servers and routers are used in transmitting and processing the information handled by the system, it is possibly the functional boundary of the system – the divide between what the system can and cannot do – that is more relevant than the physical nature of the mechanism by which that functionality is delivered.

There will be inputs to the information system, passing in data from the outside world across the system boundary. There will be outputs from the system, passing data back to the outside world across the system boundary. Inside the boundary, in order to carry out the purposes (the functionality) for which the system has been created, there will be appropriate internal transformation and storage of the data.

### 3.2 A system has an environment

Whatever the nature of the boundary, the very existence of a boundary implies that there is something outside that boundary. This is what is generally referred to as the system **environment**. This term is generally used in a much wider context than just the physical environment in which the system operates, such as location, temperature, humidity. We could, for example, be talking about organisational, political, social, economic or cultural aspects of the environment within which a system operates. It is often the case that the environment of the system in which we are interested can itself be regarded as another system, or even a group of overlapping systems.

There is an assumption that a system and its environment interact but that, whereas a system may be affected by events occurring in its environment, the environment is not affected by events occurring in the system.

### 3.3 A system has components (subsystems)

The phrase ‘through the interaction of its component parts’ should be seen in the light of our earlier comment that the environment of a system may in fact be another system. In handling complex situations it is always useful to try to group together elements that appear to go together physically or logically, so that we can handle the situation more simply by viewing these groups of related elements as separate **components**. In the context of systems, we can look for identifiable **subsystems** which, when taken together, form the system as a whole. Subsystems are considered to be wholly contained within the system under consideration. Subsystems may even be complex enough for us to think about them as having their own subsystems.

### 3.4 A system has an interface

The existence of a boundary and a surrounding environment imply that there must be a set of rules for how a system interacts (communicates) with the environment in which it operates, and in this context we refer to the system's **interface**. There is usually an assumption that subsystems will interact with each other within the boundary of the overall system of which they form a part. Such **interactions** take place across the boundaries of the interacting subsystems and in such a context we talk about the interfaces between these subsystems. We are generally interested in the rules governing the interactions that take place at the interface between a system and its environment.

### *3.5 A system has structure*

The identification of appropriate subsystems is one of the ways in which we can make the handling of a complex situation more manageable. It allows us to think at different levels of **abstraction**, and to avoid getting bogged down in too much detail in the early stages of our analysis. When we are thinking about the system as a whole, at the top level, we can just refer to the way it is made up of appropriately identified subsystems. Some of these subsystems will themselves be complex in their own right, but we can put off thinking about their internal complexity until later in our analysis, and just concentrate on their interfaces and their interactions with other subsystems.

There will possibly be a whole hierarchical **structure** of subsystems within a given system. The characteristic of a system however is that – although it can be divided into subsystems – it functions as a whole in order to achieve its objectives.

### *3.6 A system has synergy*

We should at this point also make the observation that the way a system behaves as a result of the interactions between its subsystems is often more than might be expected from an analysis of the behaviour of the individual subsystems of which it is composed. In this context we sometimes talk about **holistic** behaviour: the way in which the combined subsystems behave as a whole. Another word used in this context is **synergy**, which describes the enhancement effect arising from the collaboration between components of a system, and in this context we recall the phrase 'the whole is greater than the sum of its parts'. When talking about the unexpected or unpredictable effects arising from such collaboration we also use the term **emergent** to describe the resulting behaviour.

However we should remember that not all the interactions between subsystems necessarily lead to positive outcomes at the overall system level, and we may well find there are unexpected negative consequences that need to be taken into account, especially when we attempt to enhance an existing system by adding a new subsystem to it.

### *3.7 A system has a purpose (objective)*

Finally, in discussing the given definition of a system, we note that – particularly in the context of man-made, as opposed to natural, systems – the system has a purpose, a reason for its existence, a set of defined **objectives**. A system does not exist in a vacuum but has been created, or has evolved, in order to achieve some goal(s) – it does something, usually for someone (an owner or a client), making optimal use of available resources (such as money, manpower, machines and materials), usually under some constraints and involving some trade-offs between the efficiency and effectiveness of the component subsystems and also between the needs of the various stakeholders who have an interest in the system.

Ultimately, we need to remember that when we talk about a system we are talking about nothing more than a personal and subjective ordering of reality, a way of looking at some aspect of the world and imposing a structure on it in order to give it some meaning. The meaning which it is given may well depend on who is looking at the system and why they are looking at it. There are no 'right' answers in this context, only more or less useful ways of getting to grips with a problem which needs to be solved.

### *3.8 An example of a system*

To clarify some of the ideas introduced earlier in this section, we will use the human body as an example. If we regard the human body as a system it is reasonably straightforward to define the physical boundary of the system: we exist inside our skin! The environment within which this system exists is both complex and changeable, and how we describe it will vary with the context of our study, even if we restrict ourselves to physical aspects such as place and time. We can identify a number of major subsystems of interest, such as the circulatory system, the respiratory system, the digestive system, the skeletal system, the neural system, and the reproductive system, all of which interact with each other in an extremely complex physical structure. Each of these subsystems can be studied and described in its own right (and possibly broken down into further subsystems) but the overall human system certainly exhibits behaviour that is more than would be expected from just considering the sum of the properties of these separate parts. The interface where the overall system interacts with its environment includes taking in fresh air, and returning the used air, taking in food and returning the waste products, and taking in information and returning information. It is not so easy to define the purpose of the system, except perhaps in terms of some evolutionary objective such as survival of the species. In the context of activities such as heart, liver or lung transplants, whether donated from other humans or provided as artificial equivalents, we can observe that although we may replace a faulty subsystem by what appears to be a functionally identical item having the same interface features, unexpected interactions with the rest of the system can often lead to rejection of the transplant.

## 4 Systems approaches

Given the overall concept of a system, in terms of its composition, relationships and intent, the question arises as to how this can help us when we come to the analysis of a particular real-world system of interest to us. We will restrict ourselves here to the consideration of designed as opposed to natural systems – to systems that involve human activity and that contain purposeful elements. Where there is a will to understand and to improve the situation in which we find ourselves, what we need is a means of using systems ideas to structure problem situations in order that we can exercise that will.

The basic proposition of a systems approach is that it is reasonable and useful to view the world around us as a complex of interacting systems. General Systems Theory provides us with an understanding of the fundamental nature of systems, but little guidance as to how this might be used in practical situations. The Systems Analysis movement, which grew up alongside the widespread introduction and use of computers to solve technological problems, was more concerned with developing a methodology for engineering large complex systems (often referred to as 'hard' systems). More recently, as the use of computers has spread into wider and wider areas of human activity, there has been a need for a more general application of systems ideas to handle so-called 'soft' systems, which are typically less well understood, defined and delimited.

There are nearly as many approaches to the analysis of systems as there are systems analysts. Describing and designing systems has given rise to a vast range of notations, diagramming techniques and methodologies, each with its own set of enthusiastic supporters. It is not our intention to describe any of these in detail, but rather to give an indication of the questions to be asked and the activities to be undertaken in order that we make some useful progress in solving our perceived problem.

### *4.1 Checkland's Soft Systems approach*

The following discussion is influenced by the work of Professor Peter Checkland, who was responsible for the **Soft Systems** approach. He defined (Checkland 1972) soft systems – by contrast with the 'hard' systems traditionally handled by industrial design engineers – as those in which 'objectives are hard to define, decision taking is uncertain, measures of performance are at best qualitative and human behaviour is irrational'.

Checkland pointed out that many of the proposed systems analysis approaches/ methodologies stem from a design engineering view of the world, and start from the assumption that *what* is required has already been clearly defined and that the problem is to examine *how* this can best be provided – the design engineer's problem is, essentially, a structured one in which a need can be clearly defined, or objectives can be clearly stated, in such a way that a system can be engineered to achieve them.

However, as indicated earlier, real world problems are often unstructured. They are *problems* precisely because there is no agreement on needs, objectives or measures of performance. The lack of agreement is not simply due to lack of understanding or information, but arises from the different world views brought to the problem by the various individuals or groups involved, or because ongoing relationships are seen as more important than ends and means.

Checkland's view was that 'problem solving is dependent on problem structuring' and his methodology attempted to provide – using systems ideas – a way of seeing diffuse, ill-structured problems in a patterned way, without distorting the original problem in the process. For the present discussion we shall consider only the initial stage of the process, in which we try to define and delimit our problem. To answer the overall question '*what* is the system about?' we need to start by providing answers to a number of important subsidiary questions. Only when we have expressed our problem clearly can we proceed to the next stage, of formulating possible solutions.

The initial phases of Checkland's methodology investigate the problem situation in the 'real world' prior to any modelling of the situation in the 'system world'. They involve gathering factual material and presenting it in such a way that it provides an overview of the underlying complexity of the situation. It is recommended that simple diagrammatic representations, referred to as **rich pictures**, are employed in order to capture important aspects of the structure, processes and concerns that have been identified in these initial investigations.

Following on from the initial phases of the investigation, we enter the system thinking world and construct a **root definition** of the system. This describes 'what the system is and what it aims to achieve taking into account the persons who could be affected by it and defining the transformations that could be taking place and the environment that surrounds this particular (human activity) system'. To ensure all the relevant aspects of the system needed in the root definition are present the mnemonic **CATWOE** is used, where the letters each represent an important aspect of the system that has to be considered:

| | |
|---|---|
| C | Client |
| A | Actors |
| T | Transformation |
| W | World view |
| O | Owner |
| E | Environment |

If you are interested, you can find out more details about the Soft Systems Methodology in the books and web links that we have included in the *Further resources* section of this document. What we have provided for you here is only intended to put you in the right context to begin your investigations into the scenario which we have provided as the basis for your project activities on the course.

## 5 Questions to ask

Although we do not expect you to adopt a fully fledged Soft Systems approach to the problem your team is being asked to investigate, we hope that you will have absorbed some of the ideas we have presented and that you will be ready to ask the right sort of questions. The following sections provide a few questions to start you off on the process.

### *5.1 Who is your system for?*

In approaching what Checkland calls **human activity systems** – those that involve purposeful human activity – the first assumption is that a product should be designed to fulfil customers' actual needs. Your first step therefore is to determine who the customers are, what their needs are, and how they will be expecting to interact with the system? You have to answer questions like: Who are the actors? What are their roles?

How do they perceive the system? By 'customer' we are not just referring to the client for whom the system is being built – the person who will be paying for the development – but to anyone involved in the operation and maintenance of the system. Often there will be a number of different groups of **stakeholders** – individuals or organisations interested in, or affected by, the operation of the system, and their interests and priorities may not coincide. You will need to identify any potential clashes of interest, as this may well affect decisions that you have to make later on in the design and implementation of the system.

When you consider how people interact with a computer based information system, you need to determine the level of expertise that may be expected in terms of their familiarity with the information technology aspects of the interface and with the domain of information that the system handles. An increasingly important consideration that you need to consider is the issue of access to the system by people with disabilities.

## *5.2 What does your system have to do?*

You need to clarify the purposes/goals/functionality of the system. What is the problem that the system is required to solve? In making your initial lists of what you want the system to do, it is probably useful to take a fairly wide view of what functionality might be included in the system, with the intention of later reducing this to a manageable amount before the design and implementation stage.

Some functionality that you identify may turn out to be a cluster of related sub-functionalities that can be regarded as a single area of functionality at the top level of your system. Identifying such groupings should form part of your attempt to manage system complexity by using the idea of levels of abstraction – allowing you to concentrate on the most important aspects and pushing the consideration of details further down in the system.

Reduction may also occur because you decide that, at least in setting up the initial system - you do not want to provide some of the identified areas of functionality. There are advantages in any system in keeping things as simple as possible, and not overcrowding the system with everything that you can possibly think of, whether or not it is really necessary. Always remember the **KISS** principle: '**k**eep **i**t **s**imple, **s**unshine'.

There may also be areas of functionality that you have identified as relevant, even desirable, but for which you may decide that you cannot afford the time or money to provide that functionality at present. Functionality falling into this category can always be put on a 'pending' list for possible enhancements of the system at a later date, but its early identification may be useful in determining how you construct your system so that it is flexible enough to facilitate such enhancement when further resources become available.

## *5.3 What is the context of the system?*

You also need to place the system in its wider context. What is the environment within which the system will operate? What are the boundaries of the system? What other systems will it need to interact with? How, if at all, will the environment in which the system is deployed affect its use? Are there aspects of the environment – factors outside your control – that impose constraints on your system? Are there events arising from the environment that could cause the system to fail? As we indicated earlier, determining the boundaries of a system is always a difficult process. Some further reductions in your initial list of desired functionality may occur because you are able to identify functionality that can be provided by interaction with other systems that already exist outside the boundary of your proposed system. There is rarely any benefit in re-inventing the wheel.

## 6 Summary

There is an old saying that 'facts are not given, they are gotten'. You have to get out and find out about the situation in which you are interested. What you find out is inevitably selective (we know it is impossible to cover every possible aspect) and subjective (we know that as individuals we bring our own understanding, norms, values and beliefs into play in our investigations). Working as a team is one way of improving this situation. By bringing together a group of people with a range of different experiences and attitudes to focus on the same problem, able to share and combine their insights, it is possible to achieve a more complete understanding of a problem and a more satisfactory solution.

What is important is that, at the end of this stage of the process, you have a clear definition of what overall functionality your system has to provide, to whom and in what context, which avoids obvious overlaps and does not leave any obvious gaps. It is unlikely that your first attempt at defining the problems that your system is intended to handle will be satisfactory, and you may need several iterations of this stage before you feel ready to move on to the next stage of the process, which involves developing in more detail various aspects of the solutions to the problems that you have identified.

The links in the section below are provided for anyone who wants more details on the issues and approaches to systems that have been introduced and discussed in this Resource Sheet.

## 7 Further resources

One of the early papers written by Checkland on Soft Systems, which is still worth reading for an overview of his approach, is:

> Checkland, P. B. (1972) 'Towards a systems-based methodology for real-world problem solving'. *Journal of Systems Engineering* Vol. **3** No. 2.

More developed expositions of the detailed activities involved in applying the Soft Systems Methodology can be found in the books:

> Checkland, P. (1981) *Systems Thinking, Systems Practice*. Chichester, Wiley.
>
> Checkland, P. and Scholes, J. (1990) *Soft Systems Methodology in Action*. Chichester, Wiley.

If you want to read more online about systems theory, soft systems, rich pictures, concept maps, and so on, then you may find a useful starting point for your search at:

> http://www.icra-edu.org/page.cfm?pageid=anglolearnsyslinks

which provides a useful collection of links to relevant documents.

In particular, follow the links to:

the Operational Research Society's "Introduction to Soft Systems Methodology" at

> http://www.orsoc.org.uk/about/teaching/StrategicProblems/m_s_3frs.htm

and the paper on using rich pictures by Howard and Monk, from the journal ACM Interactions, at

> http://www.ics.uci.edu/~wscacchi/Software-Process/Readings/RichPicture.pdf