# Chapter 2
# Systems Concepts

**Abstract.** First of all, we will define and explain the most important, basic concepts from the systems approach. We readily admit that this is the most tedious chapter but knowledge of these concepts and their mutual interaction is absolutely imperative to be able to apply the systems approach and to think in terms of systems and processes in practical problems. The concepts of "system", "element" and "relation" will be sharply defined, together with the concepts derived from these definitions. In order to describe a system completely, the concepts of "structure" and "behaviour" are required. Furthermore, subsystems and aspectsystems are distinguished; this distinction is required for the correct modelling of systems. We will also define the key items of our approach: "function" and "task". Finally, the system boundary will be discussed.

## 2.1 System

The word "system" is a very general term. It is derived from the Greek verb meaning "to compile". The literature harbours dozens of definitions, as follows:

- A system is a collection of mathematical relations whereby a composition of physical objects is described
- A system is a man-made "whole" of interactive factors, variables (Lievegoed 1993)
- A system is a purposeful, ordered, coherent "whole" of related items and their constituent parts (dictionary; Koenen-Endepols)
- All that is not chaos is a system (Boulding).

The problem with all these definitions is that they all contain inherent limitations. The first definition confines itself to mathematical relations and to physical objects. A composition of non-physical objects is therefore not a system. In addition, the relations must be determined using mathematical formulae. The second definition requires human intervention in order to be able to speak of a system. Systems formed by nature are therefore not considered systems. The third definition demands that an arrangement must exist and that this arrangement must contribute to a certain goal. Groups of related parts, for which we cannot determine the goal, are thus not regarded as systems.

All of these definitions have two essential features in common, namely:

1. A collection of elements
2. Interaction between the elements.

We can discern the group of interacting elements within a greater whole. In the total reality, there are even more elements, elements which we do not acknowledge when studying the discerned group of elements. These latter elements can however be related to the elements in the total reality. We can thus *discern* a system within the total reality but we cannot *dissociate* the system from the total enveloping reality. Should we dissociate the group of related elements from the total reality, we run the risk of severing important relations with this reality. The group of elements we choose to study as a system within the total reality depends on the research requirements or on the researcher's own interests. The term "system" is therefore a way of thinking, *a way of looking at things*, that is dependent on the purpose for which we intend to use it. The definition must allow for this.

**Definition**

A *system* is, depending on the researcher's goal, a collection of elements that is discernable within the total reality. These discernable elements have mutual relationships and (eventually) relationships with other elements from the total reality. This definition introduces concepts that require further explanation.

**Elements (Objects, Components, Entities)**

These are the smallest parts considered by a researcher in view of his goals.

For this particular problem, they are not considered to be composed of even smaller building blocks. The sociologist, who studies a company as a system, will regard the company's people and machinery as elements. The company doctor, concerned with research into the effects of dust on the incidence of sick leave, will regard the dust particles, the lungs and, where necessary, other organs in the human body as elements. The engineer, charged with designing a new machine for a company, will regard the machine parts as elements. The material scientist, charged with advising on the choice of materials for these parts, will view atoms as elements of his system.

In mathematical systems thinking, it is common to refer to "objects". This is, in our opinion, too limiting. In many systems, not just *ob*jects but also *sub*jects, inert and living elements respectively, play a role. That is why we use the term element here, which can account for both. In addition, elements can be both material and non-material. With material elements such as the components of a machine or human organs, the system is *concrete*. Here, "concrete" means that it actually exists, is tangible and can be observed. The opposite of concrete is abstract. "Abstract" means separated from the material; intangible. Systems also exist where the elements are concepts; for example, capacity and resistance. These concepts have a mutual relationship that can sometimes be expressed in formulae. The related conceptual apparatus in itself can also be seen as a system. These are *abstract systems*, just like systems of services, of natural numbers in a numbering system or of feelings in a system of feelings. The concepts in this book also form an interrelated whole and are, as such, also an abstract system.

### Content

We refer to the sum of the collection of elements as the content of the system. This is directly comparable to a "parts list" of a drawing that provides an overview of all of the parts that will appear in the drawing.

### Attributes

The elements have certain properties. These can be physical, geometric, aesthetic, social, etc. An individual taken as an element has properties such as length, a face, and a character.

Seen qualitatively, an attribute often has different facets. The face can feel rough to the touch or look sympathetic, etc. The size is also one of the facets, and size has a certain *value*: the length of the individual is 1.85 m, and the face is very friendly.

### Relationships

Relationships exist between elements. These relationships denote a particular interaction between the elements. In an abstract system, these are conceptual interactions. In a concrete system there is dynamic exchange. The elements influence each other. These influences can be mutual or one-sided. But what is the nature of this influence? This means that the characteristics of one element can change the values of the characteristics of another element and eventually vice versa. Characteristics that a particular element did not possess in the first place (had a zero value) can obtain a value other than zero under the influence of another element. We can say that the initial missing element is cultured. This distinction, that a property can have a zero value, can be important in gaining a clear insight. When rearing children, we try to reduce or suppress those characteristics we consider to be rated undesirable by society and preferably assign them a zero value, whilst encouraging the expression of or teaching other desirable characteristics, and increase their value through, for example, education. The term "relation" can also imply the positioning of the elements with respect to each other.

Relationships also have characteristics, but we will not delve deeper into this area here. Much has been published on this topic, particularly in the discipline of sociology.

### Structure

The enumeration of the collection of relationships is referred to as the structure of the system. The parts list of the drawing provides the content; the actual drawing provides information on the structure, such as place and form relationships.

### Universe

Here we refer to the total reality, i.e. all elements and relationships, known and unknown, in reality.

According to the definition, a system is a group of elements that the observer distinguishes within that universe. The elements of the system have interrelationships but can, according to the definition, also have relationships with other elements in the universe. Not all elements in the total reality will have relationships with the elements of the system. We thus distinguish the meaning of "environment".

### Environment

The environment belonging to the system under consideration is comprises those elements from the universe that influence the characteristics, or the value of the characteristics, of the system's elements; or in reverse, are influenced by the system. When we consider a company as a system, the elements of the prevailing society form a system of higher order that influences the company and the elements within. Society therefore forms a definite part of the environment of the company's system. On the other hand, the planet Saturn, which is also an element of the universe, probably does not influence the company's system and therefore does not belong to its environment. This is really unclear for a particular company on another continent. This can or cannot influence the company. The actual components of the system's environment are often difficult to determine.

In principle, the system's environment is the collection of objects and subjects in the universe that influence the elements of the system but are not constituents of the system. The environment is part of the universe.

We therefore make a distinction within the definition of "structure". All interelement relationships within the system form the *internal* structure. All relationships with elements from the environment form the *external* structure.

**Emergence**

Emergence is the principle that whole entities (groups, elements) display characteristics that are only meaningful when they are assigned to the whole and cannot be reduced to the individual elements. For example, the odour of ammonia or the image that appears as we progress with the piecing together of a jigsaw puzzle. Each model of a system of human activity displays, as a complete entity, characteristics that emanate from the activities of the system's elements and its structure, but which are not retraceable to these. These are *emergent characteristics* of the whole (Checkland and Scholes 1990; Hitchins 1992).

**Summary**

Universe (the total reality)

- Environment (the elements of the universe that have relationships with elements of the system)

System

- Concrete (tangible)
  - Content (summing up of the elements)
  - Structure (summing up of the relationships)
    - Internal (the inter-element relationships within the system)
    - External (the relationships between some elements within the system with elements from the environment)
- Abstract (intangible)
  - Content
  - Structure
    - Internal
    - External

## 2.2 Subsystems and Aspectsystems

In order to obtain a clearer insight into a complex system, it has been shown to be extremely useful to differentiate the system into subsystems and aspectsystems. (De Leeuw 2000).

A system is composed of elements and relationships. We can therefore use two methods to differentiate partial systems: subsystems and aspectsystems.

### 2.2.1 Subsystem

**Definition**

A *subsystem* is a partial collection of the elements in the system whereby all the original relationships between these elements remain unchanged.

We therefore think of a division into subsystems as a division into groups of elements whereby all the original relationships between the elements of such a group, and their relationships with the other system elements, retain their original properties.

A subsystem completely conforms to our definition of a system. A subsystem is a system whereby the original system forms an important part of the environment of the now differentiated subsystem; for example the starting motor of a car engine. The motor can be considered to be a subsystem of the car. The car forms the environment of the motor. Nevertheless, at one stage lower the starting motor forms a subsystem of the motor whereby the motor and part of the car form the starting motor's environment. In technical systems, we usually differentiate subsystems as those groups of elements that collectively assist or aid in the greater system. In a company's system or organisation, the division between what we want to differentiate as a system or subsystem and what is the environment is often less obvious than in technical systems. Depending on the problem definition, it is often recommended that those subsystems of an organisation should be chosen that form a more or less independent part or that fulfil a certain process function in the whole.

### 2.2.2 Aspectsystem

**Definition**

An *aspectsystem* is a partial collection of the relationships in the system whereby all the original elements remain unchanged.

The relationships within an aspectsystem are generally of a singular type. The aspect we wish to examine determines the type of relationships that we distinguish in the partial collection.

The remaining relationships are not considered here. As such, we could separate the following aspectsystems in a motor:

- The thermodynamic aspectsystem, such as the conversion of chemical energy into kinetic energy, resulting in heat transfer and material expansion
- The kinematics aspectsystem: the predicted movements that the parts must make with respect to each other
- The tribology aspectsystem: the mutual friction of the moving parts and the lubrication required

- The spatial aspectsystem: the positioning of the compulsory parts with respect to each other
- The control aspectsystem: the controlled progression of the process
- The strength aspectsystem, such that the parts can tolerate the apparent forces in action
- The maintenance aspectsystem: the approachability, the ability to replace and the life expectancy of the different parts.

In a company, it is possible to distinguish the following aspectsystems:

- The technological aspectsystem, e.g. the rows of machinery in a production line
- The economical aspectsystem, i.e. the cash flows or the value added flows
- The social aspectsystem, i.e. the relationships between the workers and between the workers and the machinery
- The spatial aspectsystem, i.e. the physical positioning of the departments within the factory walls or of people and machinery within a department
- The information aspectsystem, i.e. the flow of the planning and control data between the departments or the employees
- The political aspectsystem, e.g. where is the balance of power and the political influence with respect to decision-making?

The above-mentioned relationships and more can be found in both a motor and a company. Each type of relationship can be studied as an aspectsystem.

Relationships also exist between the individual aspectsystems. Such relationships are termed *inter-relationships*. Our knowledge of these latter relationships is limited. We often omit the word "*aspect*". We usually only describe certain aspects of a system, certain relationships between the elements. This omission presents a real danger. In the long term, we forget that we have excluded, without reason, various other relationships that are present. We base our conclusions and decisions only on that which we have studied by that one aspectsystem. This can have disastrous consequences: for example, buying a digitally controlled milling machine but neglecting to instruct one of the workers (element) in its use (relationship) or forgetting to adjust the work preparations. Here, one has defined a systems limit that is too narrow, namely, only around the machine itself.

Sometimes an aspectsystem is also referred to as a partial system (De Leeuw 2000). In mathematical, partial differentiation, one assumes that the remaining relationships are constant. In an aspectsystem, we go further and completely exclude the remaining relationships. The danger of such action has already been pointed out. In order to avoid any confusion with respect to this point, the term "aspectsystem" will continue to be used. It is perhaps unnecessary for us to point out that the term "social aspectsystem" does not have the same meaning as the term "social system" as used in sociology. A social system in sociology is a system where some or all of the elements are people. Also, in this respect, we cannot omit the word "aspect". In this book, the term "social aspectsystem" refers to all relationships between people who belong to the system we are studying.

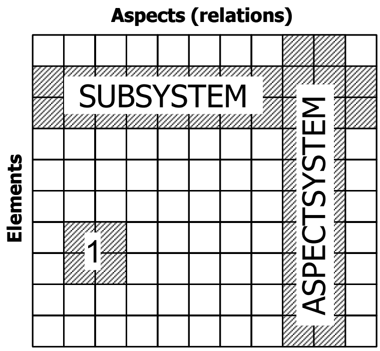


**Fig. 2.1** Subsystems and aspectsystems

**Summary**

In subsystems, we distinguish groups of elements whilst retaining all the relationships between the elements.

In aspectsystems, we distinguish relationships whilst retaining all the elements. Both approaches can occur simultaneously such that we view some aspects of a subsystem (1 in Fig. 2.1), an aspect-subsystem, or sub-aspectsystem. The matrix in Fig. 2.1 depicts this.

In his attempts to understand the universe, man mainly studies subsystems within aspectsystems. The number of relationships between all elements that together form the universe is, after all, unimaginably large for the limited capacity of the human mind.

So:

System

- Subsystem (a group of elements retaining all relationships)
  Aspect-subsystem (a group of elements within which we only look at certain functions)
- Aspectsystem (certain relationships retaining all elements)
  Sub-aspectsystem (certain relationships, but now only within a group of elements).

**Examples**

Take a group of students in a lecture theatre as a system. The system's boundary lies at the walls of the theatre. If we consider all of the relationships between the students in the left half of the theatre only, then we are looking at a subsystem. On the other hand, if we consider only certain relationships between the students in the entire theatre—for example, their positions with respect to each other and their eventual memberships of a student society—then we are studying an aspectsystem. Now, if for the whole theatre we draw the system's boundary around those students that are members, and then we get one or more aspect-subsystems. If we take only the left half of the theatre and look at their memberships, then we have a sub-aspectsystem.

Consider another example. If we consider a building a system, then the subsystems are, among others, a floor, a room and a stairwell. The aesthetic appearance of the building is an aspectsystem just as much as the colours. This is the architect's domain. The civil engineer looks at other aspectsystems such as weight, strength and measurements. The business specialist will look at the transport aspectsystem, among others. The communications technician looks at the telephone aspectsystem, a part of the communication aspectsystem.

## 2.3 State, Process and Behaviour

Each of the elements in a system has certain characteristics. These characteristics have certain values. The elements can mutually influence each other such that one or more characteristics change in value. We then speak of relationships between the elements.

### *2.3.1 State*

We can, for now, define the state of a system at a defined time as the value of the properties at that time in the system.

An *event* occurs when the value of the property of an element changes; that is, when the state of a system changes. When one event inevitably leads to another event, we talk of an *activity*. An activity takes time. The state of a system at a particular moment is a result of previous events. The definition of state thus includes the *memory* of the system. All relevant historical information is stored here. To describe the state, we must provide an overview of the value of the properties of all of the elements at that time.

Sometimes not just the values of the properties but also the relationships between the elements can change over time. In this case, there is talk of a *changing structure*. With an *unchanging structure*, we must be aware that a structure can *appear* not to change. When the relationships continuously change with a definite cycle-time and we continue to take measurements at a determined point in that cycle-time, then the structure appears to be unchanged to the observer. Due to the chosen interval between measurements, the system appears to have an unchanged structure.

It can even be the case that a number of elements are removed from or replaced in the system. This changes the content and thus the structure because a number of relationships also change. In such cases we must not only provide a description of the value of the properties but also of the content and structure at that time.

Managers are primarily concerned with systems that must fulfil a function in their environment; that is, make a contribution to a greater whole. Some functions can be fulfilled by unchanging *static* systems, such as a suspension bridge or a pillar of the bridge, or a system of roads. Within such a system we find elements and relationships but no events. At least, that is not the intention. To fulfil other functions, events and activities must take place within the system. Those are time-dependent systems in which processes occur.

Beware: the terms *static* and *time-dependent systems* refer respectively to the absence or presence of a process in the system. Changing or unchanging refers to the structure of the system, for example:

- Car motor: unchanging structure, time-dependent system
- Company: changing structure, time-dependent system
- Map: unchanging structure, static system (i.e. not a process)
- Stamp collection: changing structure, static system.

Time-dependent systems often need various supplies from the environment, such as energy, materials, and ideas, etc., in order to fulfil their specific functions. Some systems, such as companies, fulfil their function in the environment by delivering products or services as required by the environment. Generally, in such systems we can differentiate between:

- Input
- Throughput
- Output.

The simplest depiction of such a system to which we will repeatedly refer is displayed in Fig. 2.2.

This image is based on the flow of matter.

The flowing elements may or may not have their own identities, e.g. cars on a production line or oil in a refinery. It is essential to define exactly what it is that flows. In the case of the car factory, we can regard the raw materials that must be transformed into cars as flowing elements just like the received orders that are converted to fulfilled orders for cars. In the first case, we are concerned with raw material flow, and in the second case with the "information material" flow. The matter that flows is indicated next to the process arrows. So our simplest scheme of a car factory with respect to the materials would be represented as in Fig. 2.3.

In a system where a process occurs, we can distinguish between the *permanent* elements and the *temporary* elements. Only for the latter can we talk of a flow

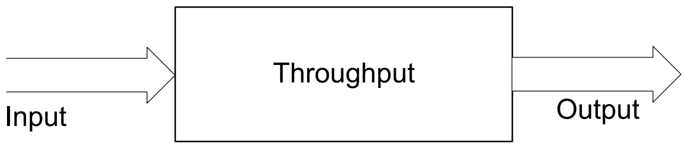


**Fig. 2.2** Simplest scheme of a time-dependent system (based on the flow of matter)

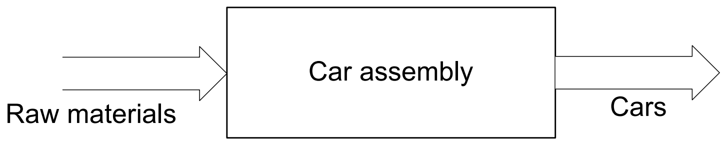


**Fig. 2.3** Simplest scheme of a car factory

time. These temporary elements are continuously supplied to the system where they are transformed by various activities during the throughput to become the output demanded by the environment, plus eventually waste. These activities collectively form the process. The permanent elements fulfil functions in that process.

### *2.3.2 Process*

**Definition**

A *process* is a series of transformations that occur during throughput which result in a change of the input elements in place, position, form, size, function, property or any other characteristic.

The way in which the activities are performed, their respective sequence, etc., is determined by the properties of the permanent and temporary elements and by the relationships that exist among the permanent elements and with the temporary elements.

Content, structure and process are thus inextricably bound together by an indissoluble tie and must therefore be studied together. This book will primarily examine industrial systems, systems with processes that are clearly focused on a particular goal. The activities are individually linked by information flows, the information that is required for the execution, at the right time, right place, right manner and in the right combination of the right activities. The activities in such a process are mostly performed by subsystems, each of which has its own determined function in the process and makes its own contribution to the process. Through that process, the system fulfils its function in its environment. The fulfilment of that function in the environment is the system's *goal*. Each element and each subsystem delivers its own contribution in the process towards realising the system's goals. In a well-organised, technical system, no element can be removed without reducing the total function fulfilment of the system. A car without wheels or without petrol cannot fulfil its function.

Doubling the number of elements such that when one is removed the other takes its place (redundancy) is sometimes necessary to reduce risk. The second element is therefore not superfluous because the goal of the system is to also reliably fulfil the systems function. When a certain element stops functioning in a living system (in vivo), this function is sometimes taken over by other elements.

### 2.3.3 Behaviour

A time-dependent system will display certain behaviour within the period in which the system is being studied. Therefore, the researcher must take the time period into consideration when studying the system. To what extent does the researcher wish to make future predictions about the system? What is his time-span? We denote this with the term *phase system* (De Leeuw 2000).

There are thus three possible subdivisions of a system:

- *Subsystem* is a group of elements, e.g. a department
- *Aspectsystem* is a group of relationships, e.g. the interpersonal relationships in a company
- *Phase* system, the time span within which a system is observed, e.g. within a period of one month.

At the very start of cybernetics, RosenBlueth et al. (1943) defined “behaviour” as “any change of an entity with respect to its surroundings”. They declared this behaviouristic approach to be the examination of its output and the relation of this output to the input. They contrast this to the “fundamental approach”, in which the structure, properties, and intrinsic organization of the object are studied, rather than the relationship between the object and its environment. The term “any change of” must be clarified with respect to that “relationship”.

To achieve this, the definition of in ‘t Veld (2002) of “any change” is considered. He defines the behaviour of a system as “the way in which the system reacts to internal and external conditions, to certain inputs and their transformation”. He relates behaviour to the “state” of the system. “The state at some point in time of a system with a given structure is a set of values that together with the input signal at that point in time unambiguously determine the output signal”. He considers the set of values the result of input signals from the past. A value must belong to a “property” of the system.

The term “unambiguously” complicates the interpretation of this definition. Apparently the state of the system is not fully described by the values of its internal properties but must also include the values of external properties, which may influence the internal properties (by means of input signals). The conclusion is that the state of a system must reflect both the internal and external conditions. Consequently, there are two sources by which a property value may change: the system itself or an external source (another system or the environment).

A change of the state is therefore a consequence of a change in the set of property values or a change in the input signals.

We define behaviour in the following way:

*Behaviour is the property of an element that describes the way in which the state of the element together with its input results in output.*

According to this definition, an element has two major properties: state and behaviour. The behaviour cannot be expressed by a simple value, but must somehow express the way in which the state will change.

When we can completely predict the output from a known input, then the behaviour is *completely determined* (deterministic). When chance plays a role and the output is only predictable with a measured probability, we refer to the behaviour as being *stochastic.* A system is in a *steady state* when it displays behaviour that is completely determined and repeatable in time, whereby the behaviour in one interval is similar to the behaviour in another interval. In the case of stochastic behaviour, this means that the probabilities must have a determined value.

Mathematically, we could suggest that the probability distribution of the possible states is constant. This is the case, for example, for an electric clock. However, the behaviour of a system can also change with time: so-called passing or *transient* behaviour. The probability distribution of the possible states in that case is not constant. A system that displays signs of growth or decline, expansion or reduction has transient behaviour and is often referred to as a transient system. Such a system often displays one-off reactions that cannot be repeated; for example a child's first steps and his/her reactions to this event.

## 2.4 Goal, Function and Task

In the previous text the terms goal, function and task were mentioned in passing. A clear distinction between insight into and the coherence of these terms is essential for thinking in terms of processes and systems. Many people have problems when they go to apply these terms to a concrete situation.

Function and task are often confused in common parlance. When we want to design or analyse systems it is imperative to make a clear distinction between these two terms. Malotaux (1997) distinguishes this by making a distinction between:

| Task | Function |
|---|---|
| What the element does | Its purpose |
| The actual work | The (unintentional) effect of it in the greater whole |

Malotaux defines the terms "function" and "task" as follows.

### Definition

The *function* of an element (object or subject) is that which is brought about by that element towards satisfying a need of the greater whole. In short: the desired contribution of a part to a greater whole of which it is a constituent.

**Definition**

The *task* (usually tasks) is concerned with what needs to happen or needs to be done in order that the contribution is realised such that the function is fulfilled.

The task is concerned with the actual work, the activities. The function is concerned with the context of the task within the greater whole.

With function, it is the net result on the environment that counts and not *how* the system accomplishes this. It is *not* about the activity itself.

Both terms are in fact extensions of each other, just like the throughput and the output. The task is concerned with the activities that take place within the element or subsystem. The function is concerned with the consequences of these activities in the environment of the subsystem. We think of functions as contributions to a greater whole. As such, we are currently not concerned with the manner by which the subsystem realises this internally. By thinking in this way we keep all our options open for alternative ways of realising this contribution.

Here is a rule of thumb: it is a function when the same contribution can be realised by different means. For example: the *function* to be fulfilled is “producing an electrical current”. A bicycle dynamo can achieve this but so too can batteries. It is thus a function. The *task* of the bicycle dynamo is “to convert the wheel motion into electrical current”, and this is only possible with the bicycle dynamo. The task of the battery is: “to produce an electrical current by means of a chemical reaction”. A function is almost always a verb. A noun is usually a resource. We must *fulfil functions* whereas tasks are *implemented*.

We shall therefore often design a system by first determining the functions that must be fulfilled in the system to realise the system’s goal. In this analytical phase, it is essential to clearly distinguish the functions to be fulfilled, irrespective of whether two functions can be fulfilled by one and the same organ. For example, the wall of a house has different functions, such as partition (visual separation of the inside of the house from the environment, heat insulation, sound insulation) and transmission (supporting the floor above or the roof). Normally, all of these functions are assigned to the one organ, “the wall”. By assigning these different functions to separate organs, we can arrive at surprising new constructions. In particular, when using new materials, this approach can be essential for maximising the usefulness of the new materials. Another example: a hospital’s goal may be formulated as follows: “The healing of patients and/or the easing of their suffering and/or patient reassurance with respect to their perceived suffering”.

This is the function that the hospital must fulfil in society. In general, fulfilling the function in the environment is the goal of the system. To achieve this, various functions must be fulfilled within the hospital, such as diagnosis, treatment, nursing, caring. The question of whether these are functions rather than tasks often arises. The answer to this is again dependent on the question on which the attention is focused. For example, we can view “nursing” in two ways: as an activity in itself (task) or as a contribution to the healing process (function). The function is paired with the desired result. These functions in the hospital can be assigned to separate departments (subsystems). In turn, it is the aim of, for example, the X-ray department to fulfil a function in the hospital, namely to provide the opportunity to perform an internal examination of a patient without resorting to an operation.

Therefore, the tasks of the X-ray department are to take X-rays but also to keep abreast of the technical developments that can contribute to new and better ways of fulfilling that function. The hospital system therefore needs certain functions. To achieve this it creates subsystems that are charged with fulfilling these functions in the hospital system. This means that a variety of tasks (activities) must take place within the subsystem. Seen from the perspective of the total hospital system, subsystems are merely means to realise the hospital's goals.

## Summary

The goal of such a goal-oriented system is to fulfil certain functions in its environment, functions that the environment needs for its processes. Within that system, consecutive processes must occur. In these processes, various process functions are fulfilled for which tasks must be performed. The functions are assigned to certain subsystems. The goal of that subsystem is to fulfil the required function in the system's process. The subsystem becomes a *means* to achieve the system's goal.

Figure 2.4 illustrates our concept of a function. By transforming input into output, *requirements* are being fulfilled to some extent, which is expressed by the *performance*. Requirement and performance are directly related to the goal of the function.

A function is less time-dependent than a task. In the aforementioned X-ray department, many other means and methods have become available in addition to the X-ray taking facility, such as ultrasonic diagnostics. Whilst the function remains the same, the tasks change, and it may be that the name of the department also needs to be changed. Within a time-independent function, we see a continuous shift in task implementation from man to machine, which is brought about by rapidly advancing technology. In offices, we witness a rapid shift from man to the computer, where the function, the contribution to the greater whole, remains unchanged. It is not just because the function is afforded a longer life than the task to be performed that we increasingly take the perspective of functions instead of tasks in the design of technical processes and in organisations, but also because,

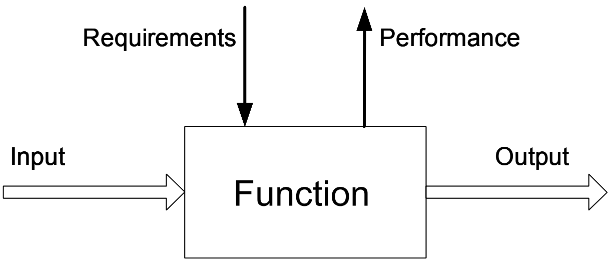


**Fig. 2.4** Simplest scheme of a function

when designing functions, various alternatives remain open in terms of the manner with which (the task) a function will be fulfilled. We then determine which functions are needed within the process and which relationships must be realised. We can, in fact, speak of the design of the functional structure. The process functions form the elements: the relationships between these functions form the structure. In organisation science, the term "functional structure" has had a completely different meaning for some ninety years. To avoid confusion, this book will stick to the classical meaning of the term "functional structure", as derived from organisational science. The former is indicated as "*process function system*" or "system of process functions". In such a system, the relationships between the functions are primarily determined by the process cohesion. Functions change in time more slowly than tasks. In the long run, it is possible that the need for a certain function in the environment can change or even completely disappear. As such, the goal of the system or subsystem that fulfilled this function changes. Should that system wish to continue to exist then it must focus itself on a new goal.

### Question

As practice material for the previous issues addressed, indicate which elements are not correctly represented in the "bakery" system displayed in Fig. 2.5. Why is this and how should it have been incorporated into the scheme?

### Answer

In the scheme displayed in Fig. 2.5 only "prepare dough" and "inspect" are functions. The other elements are not functions.

"Flour" is not a function; it is a flowing element. It does not belong in a process function block but should be placed next to the process arrows. The same applies to "cookies".

"Oven" is not a function but a means of fulfilling the function. The function is "baking".

The "customer" is also the means of performing the function, which is "consuming".

The functions "preparing dough" and "baking" are often collectively placed in one *department*, the "bakery".

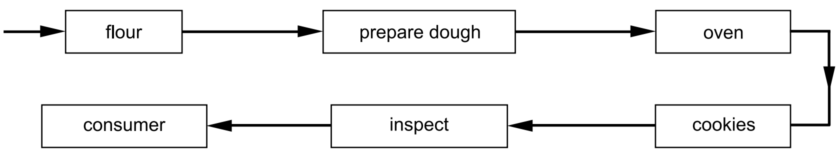


**Fig. 2.5** Question: system of process functions

## 2.5 System and Environment

The system's environment is composed of those elements from the total reality that exert influence on or are influenced by the elements of the system. We now distinguish between open and closed systems. An *open system* is a system whose elements interact with elements from the environment. A *closed system* knows no interaction with the environment; in other words, the system's environment is considered to be empty. This distinction also depends on the manner of consideration. If, whilst studying an open system, we accept for simplicity's sake that no relationships exist with the environment, then we are actually considering the open system to be a closed system for the purpose of the study.

It is also possible that confusion can arise here because, in electricity and hydraulics, the term open circuit implies one where the process flow or the information flow is impeded by an "open" switch or closed tap. When we flip the switch closed then the process takes place and the circuit is closed. In systems thinking, the difference between open and closed systems is completely different. Better terms would be respectively: not isolated and isolated systems.

All systems with an input and output are difficult to study as closed systems. We tend to ignore too many essential relationships. A system that does not have input during the test period but does have output is called a *free system*. An open system has input and output.

### *2.5.1 The System Boundary*

A system is a cohesive whole of elements. In order to distinguish a system from its environment, we need to draw a *system boundary*. The eventual input and output traverse this boundary. In principle, this boundary can be chosen freely. In practice it is determined by the method of consideration chosen by the researcher as being the most adequate for his particular question. We must be careful not to draw this boundary too narrowly. This could lead to the possibility that the cause of the problem as presented falls outside of the chosen system and thus evades detection. If we chose a royal boundary, the whole becomes more complex and unmanageable. Choosing the boundary is a difficult issue. All things are connected and if we are not careful, we may conclude that in order to solve a specific problem in the maintenance department of a firm, we must first change the complete universe. Inexperienced researchers are often inclined to draw a royal boundary. In contrast, experienced researchers often display the inclination to draw too narrow boundaries; Company myopia can be an important reason for this behaviour.

How we define the system to be studied is dependent on the goals that we set the system and the questions to be answered. The (artificial) system boundary is therefore also dependent on both the ability to measure the goals and the various means to achieve these goals.

A system should form a cohesive whole. In practice, we can therefore only consider a group of elements as a system when their mutual cohesion is greater than their cohesion with the elements in the environment. In order to be sufficiently manageable, the system boundary should be chosen as follows:

- Such that the exchange of the *temporary* elements—such as material or patients or, with further abstraction, data—across the boundary is less than within the boundary. In this case, it should be that the exchange takes place via a number (as small as possible) of permanent elements.
- And/or on the basis of the number of relationships dissected by the boundary. Whether or not we wish to consider a particular element as belonging to the system is thus dependent on whether the number of relationships among the elements already incorporated in the system is greater or less than the number of relationships with the environment. It is not about all conceivable relationships here, only relationships that are considered relevant to the problem.
- And/or on the basis of the energy required for transmission through the boundary. Transmission through the boundary requires more energy than a transmission that takes place within or beyond the boundary.
- And/or such that we are able to clearly formulate the function of the chosen system in the environment. Does the (sub)system have clear emergent properties? The omission or addition of an element can influence this.

The system's boundary is primarily determined by the goal of the study. Within this parameter, we must attempt to choose the system's boundary such that the least number of relationships are severed and the least possible number of temporary elements crosses the boundary.

The latter must, in addition, occur via the least possible number of permanent elements. Always choose the system boundary to occur at a discontinuity in the process.

We are often presented with a number of possibilities in choosing this boundary. Confusion can occur if we choose the boundary that is, unnecessarily, on the royal side; choosing too narrow a boundary means we risk overlooking important aspects. The choice of boundary is often an iterative process.

We usually base the choice on practical considerations. A couple of examples are as follows:

- When we wish to study a family, we can place the boundary around the constituent elements, the family members. We could also include the home help in the system or consider the actual house as an element in the system.
- The strain on an electrical or a mechanical system can be considered either as part of the system or as an output. Some car manufacturers give the engine power in so-called DIN-kW, others in SAE-kW. When measuring the performance in SAE-kW, all aids, such as the dynamo, are removed. When using the DIN measurement, all accessories are present, as in the case of the car. The performance in SAE-kW is therefore always greater than that in DIN-kW. It can be useful to be aware of this difference when comparing cars.

- When researching certain phenomena in a dishwasher we may or may not regard the operator as part of the system, just as we may the dirty crockery.
- When investigating the actual organisation of an X-ray department, we could place the systems boundary at the walls of the department, but we could also include the operating theatre or other departments in the system.

Whether we have chosen meaningful boundaries for the purpose of solving the problem becomes apparent when the results obtained are confronted with reality. It is primarily about making a purposeful choice for the boundary in view of the problem to be analysed.

## 2.6 Some Other Definitions

In Sect. 2.3, *steady state* is defined as the state of a system that materialises when the behaviour of the system is repeatable in time and when the behaviour in one period is similar to the behaviour in another period. The opposite of this is *transient*, passing behaviour. In a closed system, the eventual steady-state equilibrium situation is only determined by the initial conditions. In an open system, an eventual equilibrium situation is actually maintained through a continuous exchange of temporary elements between the system and the environment. It is a dynamic state of equilibrium. *Homeostasis* is the term used to define the overall equilibrium maintained by a living organism. Such an open system can attain time-independent equilibrium independent of the initial conditions. We call this the principal of *equifinality*; that is, the maintenance of a steadfast goal-orientedness based on a dynamic equilibrium under changing conditions.

Finally, the concepts of *wholeness* versus *independence* continue to be important. For the latter, one no longer refers to a system but instead to an *aggregate*.

If each element of a system has relationships with all of the other elements in the system, then a change in the value of a property of a random element causes a change in all of the other elements and thus in the whole system, and so that system is referred to as being a *wholeness.* The coherence of all elements in the system is reflected in the collection of relationships, and therefore in the structure. The extent of coherence is a property of the structure of the system. This is called the *coherence grade.*

### Summary

Depending on the goals set by the researcher, a system is a distinguishable collection of mutually related elements within the total reality. Within the system, a distinction has been made between subsystems and aspectsystems. The following definitions were discussed: state of the system, processes within that system and system behaviour. The difference between task and function was reviewed.

Emphasis was placed on the point that in the systems approach one should think in terms of “functions” being the constituent elements of the system, not the “tasks” or the “means”. Finally, the problem of determining the system boundary was discussed.

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