6 The Notion of System

The notion of *system* is an important notion in all sciences, each of them studying its own kind of system. Thus physics studies physical systems, biology biosystems, and sociology studies social systems. Since about 1950, research ([7], [9], [65]) has strived for and contributed to the development of a general systems theory, also called *systemics*, which focuses on the characteristics of systems across the barriers between scientific disciplines. This systems approach is important for enterprise ontology since we have to deal with at least three distinct kinds of systems: social systems (as will become clear, the essence of enterprises), conceptual systems (information or knowledge systems), and technical systems (ICT systems). Not only is it necessary to profoundly understand these kinds of systems in isolation, but also to understand their interrelationships in a thorough way.

6.1 The Distinct System Notions

When studying the way in which the notion of system is used in the distinct scientific disciplines, it appears that there exist two quite different system notions, which we will refer to as the teleological and the ontological system notions. The *teleological system* notion is concerned with the function and the (external) behavior of a system [11]. The teleological system notion is adequate for the purpose of *using* or *controlling* a system. It is therefore the dominant system notion in the social sciences, including the organizational sciences. As will be revealed in the next chapter, the teleological system notion is actually identical to one of the model types that are applied to systems: the *black-box model*.

So, the *ontological system* notion is the only true system notion[9]. In the author's opinion, the most crisp and precise definition is the one provided by Bunge [11]. He starts by distinguishing between aggregates and systems. Both are collections of items. In an *aggregate*, the items are not held

[9] In this chapter the term "ontological" is used in opposition to "teleological". Although it is not in conflict with the richer notion of ontology in the rest of the book, the reader should be aware of the slightly restricted use.

together by interaction bonds, in a *system* they are. A system therefore has unity and integrity, whereas an aggregate lacks these properties. An example of a concrete aggregate is a random sample of a biological population. An example of an abstract aggregate is a set. The basic and indispensable property of a system is that the elements influence each other. The existence of just a relationship between the elements is insufficient. So, for instance, the well-known Periodic System of Elements from chemistry is not a system according to our definition. Examples of concrete systems are human bodies, the earth, and computers. A system may be said to have a definite composition, a definite environment, and a definite structure [11]. We add, that a system has a definite production. By this we mean what is brought about by the elements of the system once they are activated through their structural links. Usually, the effect of the production of a system is considered to be a change of its state. The notion of the state of a system appears to be ambiguous, however. We therefore introduced the notion of world in Chap. 4, and we distinguish between the system world and the object world of a system. The state of the *system world* reflects the influences among the elements by means of their structural relationships. The state of the *object world* reflects the effects of the production acts that are performed by the elements of the system.

More precisely, the *ontological system* notion is defined as follows. Something is a system if and only if it has the following properties:

- *Composition*: a set of elements of some category (physical, social, biological, etc.).
- *Environment*: a set of elements of the same category; the composition and the environment are disjoint.
- *Production*: the elements in the composition produce things (e.g., goods or services) that are delivered to the elements in the environment.
- *Structure*: a set of influence bonds among the elements in the composition, and between them and the elements in the environment.

Clearly, this definition defines a type of thing (like the type car or the type tree), which means that concrete things may conform to this type or not. Anything that conforms to the defined type may rightly be called a system; anything that does not conform to the type is not a system. To elaborate this point, we consider it confusing to say that one can view anything as a system. That would be like saying that one views a bird as a mammal: it makes no sense, since a bird is not a mammal. Another aspect we like to emphasize is the inclusion in our system definition of the environment. It may sound counterintuitive to do this, since the behavior of the system then becomes dependent on the particular environment that is chosen. For the teleological system notion it would indeed be unnecessary, if not incorrect, to do this. For the ontological system notion, however, it is fully correct; one cannot do otherwise. because there is interaction between (the elements in) the environment and (the elements in) the composition. To top that, the structural influence bonds between the elements in the composition and the elements in the environment through which their interactions take place, is inherently part of the operation of the system.

In order to elaborate the ontological system notion, we take enterprises as an example, while following the lines of thought in [11]. An enterprise is a collection of socially linked human beings. The brains of these individuals are parts of them but do not qualify as members or components of a social system because they do not enter independently into social relations: only complete human beings can hold social relations. Likewise, brains are a biological system, but the molecules in the neural cells do not qualify as components of a biological system; they are physical systems. In other words, we need to introduce the notion of proper element of a system, and, corresponding to it, the notion of system category. The *proper elements* of a system are those parts of it that are able to be engaged independently in mutually influencing relations. The type of these relations determines the *category* to which the system belongs. Thus, the *composition* of a social system is a set of social individuals (human beings[10]), whereas the composition of a biological system is a set of cells and the composition of a physical system is a set of physical particles. Next, the *environment* of a system is the set of proper elements from the same category that are not contained in its composition but that act on or are acted upon by elements of the composition. Third, the *structure* of a system is the set of mutually influencing relations, as determined by the system category, among the system's components as well as between them and the proper elements in the environment. Finally, the *production* of a system is defined as what is brought about by the elements in the composition and transferred to the elements in the environment as the result of the interactions among the elements in the environment and the elements in the composition. We conceive the result of a production act as a particular change in the state of the system’s object world.

Many people, particularly those who adhere to the teleological system notion, like to call the production of a system its purpose. We like to make a clear distinction, however, between function and purpose. Every de-

[10] Throughout the book we consider human beings to be the only possible social individuals. So, we disregard primates and other highly developed mamals, as well as all artificial intelligent agents.

signed system has a *function* (this point is elaborated in Chap. 8). Through its function, a system is able to support some other system, which uses the function. On the other hand, *purpose* is a relationship between a system and a stakeholder. For example, my purpose in using the function of my car could be to go to a symposium. As another example, consider the system of blood circulation in the human body. In explaining it, a teacher may very likely say that it is the purpose of the heart to pump the blood around, such that it can exchange things with other parts of the body, like exchanging oxygen and carbon dioxide with the lungs. We consider such an explanation as a typical anthropomorphic explanation: only because we, human beings, can have purposes, we transpose this idea to other things without even thinking about the appropriateness of doing it. From the ontological point of view, this is erroneous; fortunately, there is also no need to do it. It is perfectly satisfying to say that the heart pumps because it is somehow predetermined to pump, and that the effect of the pumping is that the blood flows through the veins, and so on. The very notion of pumping is something a heart does not know of! What the teacher should say is that it is the function of the heart to pump etc. Although this is in fact drawing an analogy, because the human heart is not a designed and engineered system, it does no harm.

6.2 Formal Definition of Ontological System

The composition, the environment, and the structure, are collectively called the *construction* of the system. The construction of a system can thus be described by enumerating the elements in the composition and the environment, as well as the relationships in the structure. Figure 6.1 illustrates the construction of a system. The composition consists of the gray-colored elements; the environment consists of the white-colored elements. The gray line that separates the composition and the environment is called the *boundary*. The black elements are external; they do not belong to the system because they do not have influencing bonds with elements in the composition. The lines represent the structural bonds between elements. Only the bonds among the internal elements and the bonds between these elements and elements in the environment belong to the structure of the system. Therefore, the black elements are external; they do not belong to the system because they do not have influencing bonds with elements in the composition. The composition, together with the structural bonds between its elements, is called the *kernel* of the system.

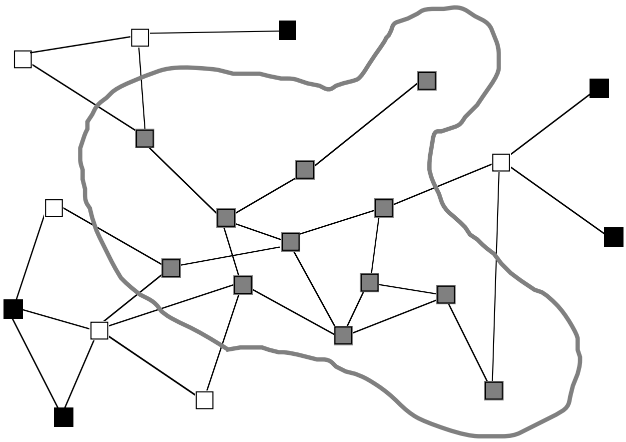

Fig. 6.1 The construction of a system

An identical but more precise formal definition of the construction of a system, following [11], is presented below. In this definition, two special symbols are used:

$\prec$ means "is part of";

$\rhd$ means "acts upon"; x acts upon y if and only if x influences the behavior of y; if both $x \rhd y$ and $y \rhd x$ hold, we say that x and y interact.

Let σ be a *system* and Γ a class of things, called the *category* of σ. Then, the *composition* C of σ is defined as

$$C(\sigma) = \{x \in \Gamma \mid x \prec \sigma\},$$

the *environment* E of σ is defined as

$$E(\sigma) = \{x \in \Gamma \mid x \notin C(\sigma) \wedge \exists y{:}\ y \in C(\sigma) \wedge (x \rhd y \vee y \rhd x)\},\ \text{and}$$

the *structure* S of σ is defined as

$$S(\sigma) = \{<x, y> \mid (x \rhd y \vee y \rhd x) \wedge (x, y \in C(\sigma) \vee (x \in C(\sigma) \wedge y \in E(\sigma)))\}.$$

Another notion that is often ill-defined is the notion of subsystem. Intuitively, a subsystem encompasses only a subset of the composition of a system, but that is not a precise expression, of course. On the basis of the system definition above, we are able to provide an equally precise definition of the notion of subsystem notion, as provided below.

Let there be a system σ_1 with the construction < $C(\sigma_1)$, $E(\sigma_1)$, $S(\sigma_1)$ > and a system σ_2 with the construction < $C(\sigma_2)$, $E(\sigma_2)$, $S(\sigma_2)$ >. Then system σ_2 is a *subsystem* of system σ_1 if and only if

$C(\sigma_2) \subseteq C(\sigma_1)$
$E(\sigma_2) \subseteq (C(\sigma_1) \setminus C(\sigma_2) \cup E(\sigma_1))$
$S(\sigma_2) \subseteq S(\sigma_1)$

The collective activity of the elements in the composition and the environment is called the *operation* of the system. Thus, one could also say that the operation of a system is the manifestation of its construction in the course of time. It encompasses both the productions as performed by the elements in the composition and the interactions through the structural bonds. The operation of a system can be described by specifying (for every element in the composition) the action rules that guide or prescribe the activity of the element.

The definition provided applies to *homogeneous* systems, i.e., systems in exactly one category. However, the most interesting systems are not such simple homogeneous systems but complex combinations of homogeneous systems, called *heterogeneous* systems. For example, a human being is a heterogeneous system, composed of at least a physical system, a chemical system, and a biological system. These systems are related to each other in a layered nesting [11]. It means that the chemical system builds on the physical system and that the biological system builds on the chemical system. Likewise, a car is a heterogeneous system, composed of at least a mechanical system, an electrical system, and a chemical system. The way in which a collection of homogeneous systems constitutes a heterogeneous system is not trivial and not simple. This holds, in particular, for enterprises. It is obvious that an enterprise is a heterogeneous system, consisting of several homogeneous systems. But how, exactly? What kinds of partial systems should we distinguish? We will address these questions in Chap. 13.

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