



Invited Review

Sustainable Operations

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ABSTRACT

The field of “Sustainable Operations” and the term itself have arisen only in the last ten to twenty years in the context of sustainable development. Even though the term is frequently used in practice and research, it has hardly been characterized and defined precisely in the literature so far. For reasons of clarity and unambiguity, we present terms and definitions before we demarcate Sustainable Operations from its neighboring topics. We especially focus on the interactions between economic, social and ecological aspects as part of Sustainable Operations, but exclude the development of a normative ethics, instead focusing on the use of quantitative methods from Operations Research. Then the broad subject of Sustainable Operations is structured into various areas arising from the typical structure of an enterprise. For each area, we present examples of applications and refer to the existing literature. The paper concludes with future research directions.

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1. Introduction and definitions

Sustainable development has become widely spread since the Brundtland report (Brundtland, 1987), especially due to Agenda 21, which was established in order to put the ideas of the Brundtland report into action. A great research field emerged, including normative aspects of the factors of a system’s sustainability and the implementation of such norms with qualitative and/or quantitative concepts. In the course of this, Sustainable Operations emerged, which rather focuses on the implementation and interactions of given policies than on developing the corresponding (ethical or natural scientific) norms. However, the notion of a sustainable operation has hardly been characterized and defined in the literature so far, and therefore the term is used in different contexts. It should be noted that often, even each of the words, “sustainable” and “operations” are used differently. Traditionally, the term “sustainability” comes from ecology but nowadays it is also used in the sense of the triple bottom line concept (Elkington, 1998) and therefore equally referring to environmental, economic, and social systems. Many authors interpret “Sustainable Operations” in the sense of sustainable actions (Gimenez, Sierra, & Rodon, 2012; Simaens & Koster, 2013). However, others consider the term “operations” in the sense of Operations Research (Tang & Zhou, 2012). Furthermore, the phrase “Sustainable Operations Management” is frequently used (Gunasekaran & Irani, 2014; Kleindorfer, Singhal, & Van Wassenhove, 2005; Walker, Seuring, Sarkis, & Klassen, 2014),

which in our eyes is only part of the more general concept of Sustainable Operations. We therefore start with some formal disambiguations in order to distinguish Sustainable Operations from neighboring topics.

The adjective “sustainable” is used to describe a system and we restrict ourselves to using this adjective in connection with some kind of system. Thus, we first have to define “system,” which is already difficult as a look at sociology shows (Luhmann, 1984; Parsons, 1971). Without dwelling on systems theory, we use the following definition of a system.

Definition 1.1 (System). A set of elements having a mutual, functional relation to each other, which can thereby be delimited from their environment, is called a system.

Note that the environment mentioned in this definition refers to the surroundings of the set of elements but not to the environment in the sense of “nature.” We may distinguish between open systems and closed systems. In the former, the environment can interact with the elements and can affect the elements. In a closed system, such an interdependence does not exist. For example, the (ecological) system of a forest can be interpreted as the area in which the trees grow, including all living and non-living beings permanently located in that area. Then, for example, humans and the atmosphere are part of the environment, having interactions with the system. Closed systems are mostly used in theoretical considerations. An example of a closed system could be a miniature biosphere in a glass (though one could question whether there is really no interaction with the environment). In the following, we will focus on open systems.

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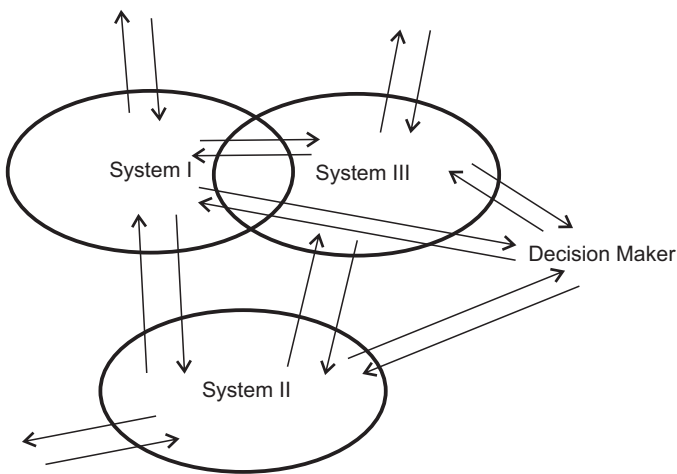


Fig. 1. Interactions of systems with their particular environment.

We consider this concept of a system especially from an economic point of view (e.g., economic systems or companies), from an ecological point of view (e.g., ecological systems or biotopes), and from a social point of view (e.g., social systems such as families or the workforce of a company). Other systems explicitly mentioned by Brundtland (1987) (the conclusion of chapter 2) include political systems, production systems, technological systems, and administrative systems. Furthermore, this very general definition of a system also includes completely theoretical systems as well as physical systems, mental systems, etc., although they will not be considered explicitly in this paper.

Definition 1.2 (Sustainable System). A system is called sustainable if the environment influences the system in such a way that it can exist permanently.

The “permanent existence” of a system is not to be understood in a strict sense, but rather in the sense of a very long time horizon. A very strict interpretation would e.g. to not allow for any sustainable systems on earth, as the earth will very likely be destroyed by falling into the sun in 8 billion years (Schröder & Connon Smith, 2008). Yet, influences of the environment need to be considered not only in a static way, but also in the sense of all future effects that might be caused by today’s influences.

Obviously, a closed system (which is not doomed by itself) is always sustainable as there are no effects from the environment that could harm the existence of the system. In general, we will assume that human interactions (i.e., the decision making process) are in the environment of any system under investigation. If the decision making process was included in the system, there would only be possible a descriptive analysis of the potential sustainability of the system (the chicken or the egg dilemma). This distinction is important in order to distinguish between the anthropogenic influences on a system and the characteristics of the system itself. Note that men may still be part of the systems that we analyze, but not the decision making process. In Fig. 1, we can see that more than one system can be analyzed at the same time. Furthermore, the systems may but need not overlap, and interactions between the systems, which are denoted by arcs, are prevalent.

Based on the above definition, a system is therefore sustainable if the environment

1. Only adds as much (harmful) things within a period of time to the system as can be absorbed by the system within this time, and

2. Only removes as much (essential) things from the system within a period of time as can be renewed by the system in this time.

In the discussion on strong and weak sustainability (see Neumayer, 2003; Ott & Döring, 2004), this definition should be classified as a concept of strong sustainability, even though we directly connect it to the triple bottom line. Let us transfer these theoretical definitions to some applications.

The concept of sustainability appeared first in the forestry sector, when wood was scarce at the beginning of the 18th century. The then-proclaimed maxim “only lumber as much wood as can grow again” was supposed to make the (ecological) forest system sustainable. In this context, the environment of the forest system is the set of human beings exerting an influence on the system by lumbering, but potentially also by planting trees.

As already mentioned, we focus on economic, environmental and social sustainability, i.e., the sustainability of corresponding systems. Since the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, from which the Agenda 21 also emerged, these three areas are seen as equally important pillars of sustainable development (the Triple Bottom Line, 3BL). It is assumed that the sustainability of one of these three systems can only be achieved by way of the sustainability of the other two. For example, the earth’s ecological system is influenced by the economy and by the social system, i.e., the latter two are within the environment of the earth’s ecological system. Similarly, the economy and society are influenced by nature. Of course, the interdependency of economic, ecological, and social systems also exists for smaller systems. For example, a small company can be seen as an economic system as well as a social system, both interacting with the (regional) ecological system and a decision maker, e.g., from the company’s management, should keep these systems sustainable. However, we may see that some decision processes do not influence systems from all three areas. For example, workforce scheduling has a great impact on the economic system “company” and on the social system “staff,” but the decision process has little interaction with environmental systems. So let us take a closer look at the sustainability of systems from the three areas.

An enterprise operates sustainably in the economic sense if it solely lives on its returns, but not on its substance. In general, it is the goal of all businesses to act economically sustainably. Accordingly, business administration as a whole deals with enabling economically sustainable business and moreover maximizing profit. A company or a public enterprise living solely on the sale of premises and real properties owned by the company or the public enterprise is certainly not sustainable. Obviously, such a pure focus on the economic interest of an enterprise defines ecological and social systems to be in the environment of the economic system and neglects their sustainability. We categorize economic systems based on three major groups of decision makers coming from business (including trade associations), public institutions, and non-governmental organizations. With this, important economic systems to be considered in this paper can be subsumed as

1. Companies, conglomerates, specific industries.
2. Public institutions (e.g. municipal authorities), economic regions, countries.
3. Non-governmental organizations (NGO, e.g. the Red Cross).

In contrast to economic and social systems, the issue of sustainability in ecosystems is much discussed in public. A major focus is on the consumption of scarce resources, such as wood, oil, coal, water, and rare earth minerals, which “regrow” (in part) extremely slowly. The impairment of a local or global ecosystem by emissions or other influences is included here as well. We categorize ecological systems by

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