Chapter 8
Sustainability in a Digital Context

Keywords Sustainability of ICT · Sustainability through ICT · Digital artifacts

This Chapter's Learning Goals

- You know about the potentials of digitalization for sustainable development.
- You know why ICT operations can act as an enabler of sustainability.
- You know the role of sustainable ICT.
- You know about the sustainability of digital artifacts.

8.1 The Sustainability Potential of a Digital Society

Technological progress has always shaped the lifestyles, cultures, and communities of mankind. Since the first wave of industrialization that rolled from Europe across large parts of the world in the late eighteenth century, the nature of its effects on the well-being of society has been ambivalent. Correspondingly, scholars have long been concerned with the question of how the well-being of society and its individuals change in the face of technological progress, and how its ambiguity may be resolved (e.g., Ashton, 1948; Crafts, 1986).

The pressure and responsibility to find answers and provide guidance on how the technological progress may promote the transformation to a sustainable society have never been greater than today. After all, never before in history has progress accelerated at the current pace: not only is technology developing exponentially, but the extent to which technologies are shaping people's working and private lives is increasing as well (e.g., Adedoyin et al., 2020). Today, innovative technologies show a great potential to promote environmental protection, sustainable production and consumption, and social well-being for many.

- Collecting and sharing data at the local, regional and international level can reveal great potential for optimization, especially with regard to ecological aspects.

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- The potential of the novel technologies in companies and organizations is in the first place to increase the efficiency of their processes. These efficiency gains may lead to an increased sustainability of the operation and products.

Technology, especially the provision of up-to-date data and information, has great potential to improve sustainability on an individual level, as well, e.g. through better informed consumption decisions. There are a variety of apps promoting the sharing of products or services such as car sharing, tool lending/ sharing, or food surplus distribution platforms. All of these if effective can reduce waste and redundancy.

Despite the complexity and diversity of today's technological innovations, the majority of innovations build on one key resource: data. Data is the "new oil" of our century (e.g., Sorescu, 2017). Thus, data has a correspondingly central role in transforming society into something more sustainable (UN, 2014). Among politicians and academics, a specific term is currently emerging for a vision of society in which data and data-driven technology is primarily mobilized for the transformation to sustainable society. The goal is to maximize social welfare and individual well-being: Society 5.0 (e.g., Cabinet Office, 2016). Expanding the idea of Industrie 4.0, the vision of Society 5.0 is that innovative technologies will now be exploited to promote for social, economic, and ecological sustainability. The aspiration for a Society 5.0 is in line with the 17 UN SDGs as sustainability and the well-being of individuals are an equally central component. For example, while SDG 12 ("Responsible Production and Consumption") specifies the direction in which efforts should be guided, in a Society 5.0, data and technology would be part of the goal's specific advancement: e.g., data provides information on the carbon footprint of products, where unnecessary production waste occurs, and what wages are paid along the value chain, data-driven technologies optimize production processes in terms of energy efficiency and waste management. The unique potential of data in addressing the SDGs is reflected in the lively research interest surrounding this topic. In the report "A World That Counts" (2014), the UN explicitly called for the mobilization of data to promote sustainable development.

Risks and Ethical Considerations in a Data-Driven Society

The transformation of a society into Society 5.0 requires one key ingredient: data. The UN sees data as "the lifeblood for decision-making and the raw material for accountability" (UN, 2014, p. 2). The importance of data for technological progress is as broad as its potential applications for socio-ecological sustainability, e.g., for operating technologies such as smart grids and autonomous navigation systems, for containing pandemics, and for quantifying poverty and living conditions. This central role of data poses various challenges, among others:

- **Violation of Privacy Rights.** Dangers include the general violation of the individual's right to privacy. The misuse of data can have extreme societal impact, as the data-driven manipulation of the 2016 US election known as the Cambridge Analytica scandal highlighted (Cadwalladr, 2018). In this context, though, a violation of privacy does not only happen with regard to data that has been disclosed voluntarily. Algorithmic analysis also facilitates the generation of new insights about individuals by combining existing data sets. For example, social media activity patterns can lead to conclusions about mental illness or sexual orientation without this information having been specifically shared by a person.

- **Accountability of Algorithms.** Algorithms lack transparency and accountability. Generally, self-learning algorithms aim to optimize certain outputs according to predefined criteria. However, how exactly an algorithmic model optimizes an output according to these criteria, and how those criteria may automatically change over time, is mostly a black box. This lack of insight leads to ethical challenges, especially when algorithmic outputs have real-world consequences, e.g., when outputs are used to make decisions about lending, recruiting personnel, or controlling self-driving cars. The lack of transparency and accountability is further a constraint because algorithmic outputs may be socially discriminating, e.g., when a targeting process assigns too much statistical weight to an individual's zip code, members of precarious neighborhoods with low incomes could easily be assumed to have a propensity to commit crime.
- **Accountability of Digital Artifacts.** Just like algorithms themselves, their digital counterparts, the digital artifacts, are used every single day all over the world for a plethora of different tasks and jobs. Most of them, especially executable digital artifacts (i.e., software) lack transparency and thereby accountability. It is possible to analyze such an artifact and find out, albeit usually with a considerable amount of effort, what exactly it is doing by retro-engineering it. However, without access to its source code, it is almost impossible to say for sure what it is not doing and will never do. In the end, this means for the average consumer using most commercial products they have few options other than to trust blindly. This trust, however, can be and has often been abused by criminal individuals and above-the-board corporations alike.
- **Biased Data.** Data are the driver of technological progress and pose a particular threat to social sustainability. Biases in data sets can arise because prevailing biases in society are correctly measured and thus unreflectively included in the data set. Prevailing social biases may include stereotypes, racism, and unequal treatment. Consequently, data-driven outputs are optimized for those groups that have already been prioritized during data collection, e.g. white males. A scandal in 2015 involving Google provides a vivid example: A designated function in the Google Media Library automatically tagged images with their content in order to facilitate the search. The corresponding algorithm was probably trained with a data set in which black people were underrepresented. As a result, several black people claimed to have been recognized by Google as gorillas.

Hence, in any “society 5.0” that intensively uses digital technology and data, there must be accountability and transparency. This needs to be done either by increasing the accountability and transparency of the products we use or by switching to already accountable and transparent (open source) products in the first place.

Real-World Example: Digitalization Using the Internet of Things and Remote Servicing Reducing the Environmental Impact by EcoLab

EcoLab is the global leader in water, hygiene, and energy technologies and services. EcoLab's products and services help its customers keep their environment clean and safe, operate efficiently, and achieve their sustainability goals.

By using Internet of Things (IoT) technology with sensors that collect and analyze data on water consumption and/or hygiene products it is possible to use resources much more efficiently. This leads to lower resource consumption, as they are only used when needed, and consequently to a lower environmental impact of the operation.

In addition, EcoLab plans to introduce remote maintenance using digital technologies such as virtual or augmented reality to reduce trips by 50% and thus reduce CO_2 emissions.

Source: www.ecolab.com

In the following sub-chapters, the impact of the ever-growing presence of information and communications technology (ICT) on sustainability is discussed. Sustainability in the digital domain is traditionally viewed from two points of view: ICT as an enabler of sustainability, that is sustainability **through ICT**, and sustainability **of ICT** operation. Furthermore, a third, often neglected, type of digital sustainability: the sustainability of **digital artifacts** will be discussed.

8.2 Sustainability of ICT

Operating ICT has impacts like operating any kind of device does. Like any other device, ICT hardware has to be produced, maintained, and recycled and, eventually, disposed of. While in this regard, a server farm is not fundamentally different from a factory full of juice extractors, there are significant differences in the details:

- While simpler, e.g., mechanical machinery can be used for decades before the need for replacement and disposal arises, things look different for most ICT products. Usually, ICT hardware has a life cycle of a few years depending on its area of operation. While an electronic cash desk in a small store might be used for 5–10 years before it is considered outdated and replaced, things might already look different with a cloud-based point of sale used in a store chain or a laptop or desktop computer in a typical corporate office with life cycles closer to 3–5 years. While there certainly are computer systems that have been running for decades, they constitute a tiny minority considering all ICT-powered hardware in use worldwide.

- Non-ICT-powered machinery mostly consist of several types of materials that must be separated and recycled separately at the end of the machine's life cycle. However, compared to the amount and types of materials used in ICT, most of those recycling processes are simple and cost-efficient. Due to the number and types of materials used in ICT hardware and the fact that it is miniaturized whenever possible, recycling turns into a cost-intensive process. This is the main reason why year after year millions of tons of ICT hardware scrap are shipped to countries with weak or developing industries for recycling, sometimes illegally. Away from tight regulation and oversight, ICT hardware is often simply burned to get access to some of the materials it contains, with catastrophic consequences:
  - For the health of the workers having to perform these jobs, often without any equipment or protection
  - For the workers' families who are often forced to live on-site due to lacking alternatives
  - For the dumping and burning sites that are increasingly saturated with poisonous residues from years of burning and melting materials and have meanwhile become an ecological hazard themselves, poisoning groundwater reservoirs and surrounding ecosystems.
- ICT hardware relies on materials that are energy-intensive in their production, destructive to human health and ecosystems, short in supply on a global scale. Examples include silicon dioxide, quartz, hafnium, tantalum, palladium, boron, cobalt, tungsten, chrome, nickel, beryllium, platinum-group metals, indium, the list is almost endless. In addition to these rather electronics-specific materials, ICT products contain the usual mix of plastics and synthetics, making recycling even more complicated and cost-intensive.
- ICT hardware depends on software to operate them, which gives this kind of products an additional lever when it comes to improving sustainability. Instead of redesigning or even swapping out the entire product, ICT products can be updated or even upgraded by changing the software part of the product. Upgraded software can lead to results such as better energy efficiency, lower hardware requirements, lower material fatigue, etc.

In summary, ICT products are harder to recycle than the average household consumer product due to their composition and their relatively short life cycle. Therefore, new approaches promoting more sustainability of ICT products are needed. These are for example, use software upgrades to make existing products more sustainable in their operation to prolong their life cycle, employ clean design of ICT products to enable reuse, and ease the recycling and reuse of the materials used in the products.

8.3 Sustainability Through ICT

The influence of **ICT products** on the sustainability of systems goes beyond their operational footprint and can be observed in different aspects:

- Introducing ICT into almost all steps of production and delivery of products or services mostly happens with the goal to improve efficiency, e.g. less fuel usage through more precise injection of fuel, less time loss through flexible route planning, less waste material through better tailored cutting. Whenever efficiency is improved and, consequently, less resources like material or hardware operating time is needed or the life cycle of a product is prolonged, sustainability is increased.[1]
- Apart from increasing efficiency in already existing systems, ICT products have the potential to create new systems that would have been impossible before the introduction of ICT. The opportunities of, for example, digital distance learning, the possibilities of a modern office workplace or platforms enabling sharing of goods or services all can have a large impact on sustainability. In the same vein, a well-streamed collection of eGovernment services can save tons of papers, make on-site visits unnecessary, enable the easier collection and sharing of data, etc. By separating services from the physical movement and manipulation of material, ICT has a large potential to influence the sustainability of a system.

The variety of ICT products is growing and new applications are being rolled out in virtually every aspect of our economy and society. On the one hand, the increased use of ICT tools solves many a problem of the pre-ICT era. On the other hand, however, consequential problems arise, such as the increased consumption of energy and resources, the sometimes unrealistically growing expectations of the problem-solving capacity of ICT, or the fact that access to ICT resources is still very unevenly distributed globally. Unfortunately, one could not expect corporations to deliver a report on these topics with total openness and honesty. That is why the listed dimensions are rather meant to give users of digital artifacts an approach and nudge to think about the characteristics of the digital artifacts they are using or plan to use. After all, the decision which digital artifacts to use could not only have societal impacts in the future but very much shapes the choices a corporation makes from when developing strategies and ways of doing business.

8.4 Sustainability of Digital Artifacts

Our journey towards a digital society means that more information is being transformed from analog to digital format. Consequently, an increasing part of our lives depends on information saved in files and decisions made by software, which

[1] Unfortunately, this is sometimes offset by the rebound effect, which for simplicity is not considered here.

itself comes in the form of code saved in files. Both kinds of digital data—information (e.g., text, pictures, videos, audio recordings) and software (source code or any sort of compiled code)—can therefore be classified as **digital artifacts**, independent of their concrete function.

Digital artifacts differ from their physical data storage artifacts in a number of ways:

- Digital artifacts are not self-contained since they cannot be accessed without the help of a technical device and another digital artifact. To access the digital version of a report, book, or any form of text we not only need the digital artifact itself, but additionally a device capable of running an operating system, the operating system itself, and some sort of application, able to read and interpret the information stored in the digital file. This means that the digital file itself loses its usefulness unless it is surrounded by an entire ecosystem of other artifacts, tangible (the device), virtual (the operating system, all applications) and even social (people creating all these artifacts following the same rules and standards). While traditional artifacts often need to be embedded in a societal ecosystem, too (e.g., adhering to the same rules of language, writing, figures of speech, or pictorial depictions), the preconditions for successfully accessing and interpreting a digital artifact are considerably higher.
- While traditional artifacts can clearly be assigned to the category of material objects, this is both correct and incorrect for digital artifacts. None of them would exist without their physical manifestation (the information carrier) and their existence is limited by the limitation of their physical representation, e.g. the size limitations or the lifetime of the data carrier. At the same time, the material representation of a digital artifact has no practical value by itself. The latter is only revealed when combined with other digital artifacts and their potential to translate the characteristics of a physical object to, for example, an emulation of a printout shown on a screen.
- Due to their existence in the material and at the same time virtual world, digital artifacts cannot not only be reproduced at very lost cost and with no quality loss, but this reproduction can also take place over large distances using a virtually endless variety of other carriers over radio connections, fiber optic cables, satellite links, etc., without any loss in quality.
- Digital data carriers have quite limited lifespans (from a few years to a few decades), compared with the long periods of time knowledge needs to be preserved. Naturally, the lifespan of a data carriers depends on many factors, e.g. the quality of the material, frequency of usage or storing conditions, and therefore can vary in individual cases.
- In addition to the data carriers themselves, data carrier formats have changed many times since computers were first used to store data: cardboard punch cards, paper tape, magnetic tape, magnetic disk, optical disks, flash-drives, etc. However, even if you had an operational data carrier from 40 years ago and a still functional floppy drive to successfully read out the data, you still could not access the stored information without much ado. The software needed to operate the

floppy drive has never been written for today's operating systems, as there is no need for it. Writing new software could prove to be very costly or even impossible as the source code and documentation for old digital artifacts, if not published openly, is often lost when the corporation that wrote it goes out of business or merges with another corporation.

- Documentation—for data formats or any other topics—is not written in a vacuum but embedded in a social environment with implicit social rules, assumptions, and tacit knowledge even the authors of the documentation might not be consciously aware of. Since this tacit knowledge is not explicit, it must be shared within a community to be evolved and to survive the ravages of time . Such a community can be a worldwide association or a small team of programmers. However, the smaller and the less open a group, the higher are the probabilities that at a certain point in time knowledge is not shared anymore and disappears, rendering an unknown number of digital artifacts useless. E.g., a documentation for a magnet audio tape player from the 1950s or 60s might instruct you to "insert the tape in the player," because at that time it was perfectly clear how this is done, but you might struggle today not having this knowledge.
- Final characteristic relates to the fact that digital artifacts can be perfectly reproduced at a low cost. However, such reproductions are not necessarily perfect and can also be subject to random changes, thus underscoring the highly transmutable nature of digital artifacts.

Protecting digital artifacts against these various threats does not only demand an awareness of potential threats but constant, considerable efforts to keep the stored information accessible by copying it to fresh data carriers or converting it to more current data formats. Furthermore, it needs to be kept accessible to a broad community thereby keeping the vital tacit knowledge alive. Considering the enormous amounts of information created in the past and the staggering volume of information being created nowadays, this can quickly become a quite costly process that only larger organizations or corporations are able to afford (Fig. 8.1).

The ten criteria sustainable for digital artifacts (Stürmer et al., 2017) describe the basic conditions for sustainable digital artifacts and their contribution to sustainable development in a digitized society by keeping access to knowledge and tools as open as possible. They are separated in three groups addressing different aspects of the topic. The first group describes the digital artifact itself, followed by a description of the ecosystem the digital artifact exists in and finally a last criterion linking it to global sustainability.

8.5 Indirect Impacts of Digital Artifacts

Although digital artifacts are merely sequences of bits with the values 0 and 1, they can hold economic value same as other commodities. Their value stems from the fact that digital artifacts can serve as means to satisfy a need or desire, can therefore have practical value meaning their application can have very real consequences in the

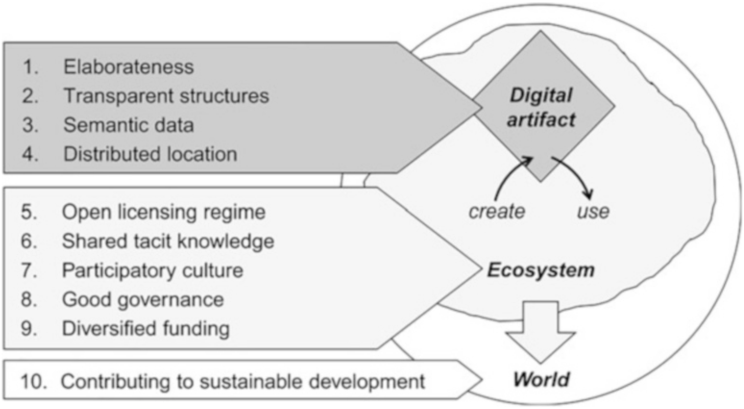

Fig. 8.1 Criteria of sustainable digital artifacts (Stürmer et al., 2017)

analog reality. In contrast to many other commodities, however, digital artifacts are not subject to wear and tear and are inherently non-rival. Moreover, since they can be replicated at very low cost, their availability is practically endless. Therefore, the use of a digital artifact by other people does not impair my own use of the same artifact. Individuals cannot be excluded from making use of a certain digital artifact and the use by one individual does not exclude another person from using them, which makes digital artifacts de facto a common-pool resource. This leaves the question, why somebody should be willing to pay a price for a resource that can be replicated and distributed at almost zero cost.

While the replication and distribution of digital artifacts is almost free of cost, their development is not. This begs the question, why anybody should invest effort in the development of a product that can subsequently be endlessly replicated by anyone at almost no cost. There are two fundamentally different approaches to answer this question:

1. The private model of developing innovative digital artifacts is motivated by the incentive of intellectual property rights granted to the authors or their employer. In return for the effort of developing an innovative digital artifact, the authors or their employer can protect access to their newly developed digital artifact using copyrights and patents. Thereby having an effective tool to lock individuals out from using their digital artifact, they can now dictate licensing or selling prices for their product. The benefit of this model is that there is a strong incentive for innovation. The downside is the lost potential with regard to societal knowledge and under certain circumstances—interestingly enough—loss of innovation. The lock-in strategy has become a widespread strategy in the domain of IT corporations. Following this strategy, the IT corporation not only locks out individuals from using their product without a license, but also strives to lock in the individuals using it with a license. Usually this is done by reducing compatibility and connectivity to an absolute minimum. Taking a common situation in

education, if students have written all their essays and other documents with my software and I have made sure that these digital artifacts may not be edited with any other software or converted to other data formats, I can force these individuals to keep using my software, without having to invest in innovation. The fear of losing access to their own data makes sure that they keep using and paying for my product. The same principle applies when users have all their pictures, videos, social contacts, etc., in one social network with no compatibility or connectivity to others. Even if other, new social networks were better and more innovative, the cost of losing everything and having to start anew is mostly too high for users to make the change. From a technical point of view, there is no reason why you cannot use a Zoom client to enter a Teams call. It is a design decision that separates those two worlds, not for the benefit of its users, but rather with the goal to minimize competition and thereby the need to innovate.

2. In the collective action model, innovation is provided as a public good. The benefit of this model is that society does not experience any loss of knowledge, neither absolutely nor relatively. The downside is that there are less extrinsic incentives for people or corporations to innovate. This might lead to a situation, where no collective action takes place, because those with extrinsic motivations are unwilling to shoulder the effort of developing and maintaining public good and the number of individuals with intrinsic motivation is too low to have an impact. However, research shows that there may be sufficiently high number of individuals with intrinsic motivation, willing to put the effort it, which relieves this model from the collective action problem. In addition, there are business models that do not focus on selling digital artifacts but services around these artifacts, e.g. most Linux distributions or software like OpenOffice or LibreOffice, as will be briefly discussed below.

Digital artifacts have existed for a bit more than half a century, which is less than half a percent of the timespan since humankind started agriculture. Nevertheless, these artifacts already permeate almost every aspect of our lives. It is digital artifacts that enable us to communicate, to perform our work, to get entertained. There are very few parts of our society that are not dependent on digital artifacts and would remain functional without them. This role gives the creator of digital artifacts enormous power over millions of people that are helplessly at their mercy. Nowadays, increasingly, digital artifacts answer questions like: Will the landing gear of an airplane extend or not? Does this person get a loan or not? Is this corporation trustworthy or not? Will this person get the job, the apartment, or the insurance contract? Digital artifacts also increasingly determine what we can or cannot do and how what we do is perceived by others within society. Microsoft's decision to include or exclude a feature in MS Word or MS Excel determines for millions of office workers worldwide, what they can or cannot do.

The Chinese Social Credit System is a perfect example of how data can been collected and then automatically assessed by digital artifacts without or with minimal human interaction. This system is currently unique, but it demonstrates perfectly the power digital artifacts—or rather their creators and controllers—in the form of algorithms or artificial intelligence can have over an entire society. Whoever controls these digital artifacts, de facto controls Chinese society, because if a digital artifact determines that a certain person is to be hired, avoided, promoted, celebrated, or arrested, the person will be hired, avoided, promoted, celebrated, or arrested, no questions asked.

Of course, most countries are not today's China, but all countries are on their way into a digitized society full of digital artifacts and there is no roadmap giving directions. All we can say is that our perception of the world and our decisions are heavily influenced by digital artifacts and control of these digital artifacts gives a selected group of people disproportionate power over large groups of individuals. It is for this exact reason that open access to digital artifacts and knowledge about them are the main focus of sustainability in a digital environment.

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