Digital Preservation through Digital Sustainability

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ABSTRACT
The concept of digital sustainability introduces a holistic approach on how to maximize the benefits of digital resources for our society. The nine basic conditions for digital sustainability also provide a contribution to potential solutions to the challenges of digital preservation. Elaborateness, transparent structures, semantic data, distributed location, an open licensing regime, shared tacit knowledge, participatory culture, good governance, and diversified funding support the long-term availability of digital knowledge. Therefore, in this conceptual paper, we explain the links between digital sustainability and digital preservation in order to increase the impact of both. We conclude by presenting the political agenda of the Swiss parliamentary group for digital sustainability.

Keywords
Digital sustainability, digital preservation, open source software, open data, open standards, linked open data

1. INTRODUCTION
The discussion on sustainable development started at a global level in 1987 when the United Nation's World Commission on Environment and Development, led by Gro Harlem Brundtland, published the report "Our Common Future" [59]. Today, sustainable development represents a vision more relevant than ever, perhaps the most prominent example being the United Nations' Sustainable Development Goals, launched in 2015 [45] [55].

Most literature on sustainable development focuses on natural resources, human rights, and economic development. However, more recently, sustainability has also become a topic in digital preservation, software engineering, and information systems research. For example, the Blue Ribbon Task Force on Sustainable Digital Preservation and Access in 2010 presented a comprehensive report on the economic challenges of providing sustainable access to digital information [49]. Maintenance of software is hindered because of technical debt of its architecture leading to the insight that sustainability of software systems is important for their resilience, adaptability, and durability [3]. Therefore, several software engineering researchers have recently released a 0.5 version of their Karlskrona Manifesto for Sustainability Design of software [4].

Our holistic notion of digital sustainability covers digital information as well as software systems. The initial idea was briefly introduced in a recent conference publication [51]. An in-depth conceptual working paper derives the nine basic conditions for digital sustainability from sustainability studies, knowledge management, digital information, and innovation literature [52].

In the following article, we link the nine conditions for digital sustainability with examples from the field of digital preservation since this presents a highly relevant stream of research for our knowledge society.

2. BASIC CONDITIONS FOR DIGITAL SUSTAINABILITY
The basic conditions for digital sustainability include legal, technical, organizational, and financial requirements we consider necessary for the creation and use of sustainable digital artifacts. While the first four conditions address the digital artifact itself, the latter five target the surrounding ecosystem (Table 1). This illustrates an important aspect of the concept of digital sustainability: We find that it is not only the characteristics of digital resources that are relevant for its sustainability, but also the community of people and organizations involved in the digital resource. It is therefore essential for our concept of digital sustainability on the one hand that suitable properties of the digital asset are ensured, while on the other hand maintaining a sound ecosystem that continuously updates and grows the digital artifact.

Table 1: Basic conditions for digital sustainability

Conditions regarding the digital artifact:	1	Elaborateness
	2	Transparent structures
	3	Semantic data
	4	Distributed location
Conditions regarding the ecosystem:	5	Open licensing regime
	6	Shared tacit knowledge
	7	Participatory culture
	8	Good governance
	9	Diversified funding

2.1 Elaborateness
Digital resources create immediate as well as long-term value to society through their elaborateness. For instance, data quality requires characteristics such as accuracy, relevancy, timeliness, completeness and many more characteristics [57]. Within software development, modularity of the source code is crucial. If the code is modular it can easily be enhanced by programmers because it is not necessary to completely understand the source code in order to improve and enhance it [30].

Quality of data plays a significant role within digital preservation. On the one hand, libraries are often confronted with errors in documents and their metadata [2]. Within the documents there are often typographical errors, scanning and data conversion errors, as well as 'find and replace' errors.

Metadata quality is defined by characteristics such as accuracy, comprehensiveness, consistency, flexibility and many more, some obviously with competing properties [33]. The growing volume and digitization quality of digital assets, steadily increasing the demands for data storage, pose another challenge in preserving data quality [13]. While, in the early days, preservation targeted full information capture of media by archiving microfilm and alkaline paper, today technology facilitates the digitization of analog material in a high quality. Therefore, preserving data quality is also a question of financial resources [54].

2.2 Transparent Structures

In addition to the elaborateness of a digital artifact, its technical openness of content and software is essential for digital sustainability. Digital artifacts can be best used and further developed if their inner structures are transparent and well-documented. For example, access to the source code facilitates the re-use of open source components, saving substantial development costs [21]. Alternatively, open standards such as the Open Document Format (ODF) are developed through a participatory process within a standardization body (in the case of ODF, the "Organization for the Advancement of Structured Information Standards", OASIS [8]), fully documented and made publicly available, as well as being integrated into various software tools such as LibreOffice [19]. An open standard allows the development of software implementing the standard, grants low-cost (or even free), universal access to the standards, and assures that the standard has been developed using a participatory approach [14]. The architectural transparency of software and content thus allows verification by any technically skilled person, thereby reducing errors and increasing trust in digital artifacts. Therefore, transparent structures are another basic condition for digital sustainability.

Open standards and open file formats are particularly important for digital preservation. While there are various definitions and lists of criteria characterizing long-term preservation formats, all of these include "open specification", "transparency", or "openness" as one of their requirements [38]. Researchers on digital preservation thus agree that "open standard" is a crucial criteria for any content to be made long-term accessible [56].

However, having the data in an open format is but one side of the coin. Appropriate software is always necessary to read the documents. While some file formats are pretty straightforward to read (e.g. plain text) other content, such as structured documents, images, video, music, or Geographical Information Systems (GIS,) is stored in highly complex standards. Their technical specifications might be openly available, as is the case with the Microsoft document standard OOXML. However, the extensive documentation of such standards (OOXML specification is approximately 7000 pages [8]) indicates the effort required to implement such a file format. Only a few - if not only a single corporation (the one who has drafted the specification) - will be able to program an implementation, often resulting in proprietary software. Those software products become an object of control for a single company, thus decreasing the sustainability of development. Therefore, the availability of an open source implementation of an open standard is required to support a file format in the long term.

2.3 Semantic Data

In order to make the vast amount of digital resources accessible from an information management perspective, it is highly beneficial to enrich the data with metadata [24]. Structured semantic data makes complex digital artifacts machine-readable [7] and also more easily comprehensible to humans by adding meaningful information about the data [18]. Various semantic platforms such as DBpedia [1] [7] and Wikidata [53] [49] have emerged in recent years, providing knowledge graphs in order to make large volumes of digital information accessible to humans and machines.

Within the digital preservation literature, for example, the Digital Preservation Recommender (DiPRec) system [20] addresses the issue of structured information of digital assets through Linked Open Data (LOD). This approach applies the semantic Web and linked open data paradigms in order to "transform the web from a pool of information into a valuable knowledge source of data". The importance of metadata for records keeping was already pointed out by the Open Archival Information System (OAIS) reference model [28] and the ISO standard 16363 on "Audit and Certification of Trustworthy Digital Repositories". They both provide thorough conceptual guidance on sustainability of digital preservation systems.

2.4 Distributed Location

The redundant storage of information in different locations decreases the risk of it being lost as a result of hardware crash or other accidents. Ideally, digital resources are replicated and stored in a decentralized way through peer-to-peer technology like the Bitcoin Blockchain [43] [15] in order to maximize independence from any single storage provider.

Within digital preservation, institutional repositories enable educational organizations to provide access to assets of an institution, such as research results and educational resources. However, the long-term availability of the service is a challenge, as continuity depends on the way the information systems are managed by the particular institution [23]. A successful approach was introduced in the beginning of 2000 when David Rosenthal and Vicky Reich launched LOCKSS (Lots Of Copies Keep Stuff Safe) at the Stanford University Libraries [39]. Since these early days of the Internet this open source platform provides continued access to scientific journals based on peer-to-peer technology [44].

2.5 Open Licensing Regime

As explained above, in addition to the conditions of digital artifacts, there are essential properties of its ecosystem that ultimately influence digital sustainability. Part of this is the legal framework playing a crucial role for digital artifacts.

Text, images or software are by default protected by intellectual property rights [40]. While this mechanism is the basis for many business models, it hinders the use of these digital assets and thus decreases their potential for society as a whole. Only if content or source code is explicitly published under an open license – such as the Creative Commons [26] or an open source license [47] [46] – is that digital resource available to all without restriction. The notion of legal public release of digital assets dates back to the 1980's when Richard M. Stallman drafted the GNU General Public License [50]. About two decades later, this principle of freely available digital assets was transferred to content such as open educational resources [10] and open data [32]. A generalized definition of 'open' is provided by the Open Definition, which states "Open means anyone can freely access, use, modify, and share for any purpose" [1]. An open licensing regime enables the unrestricted use and modification of digital assets and thus forms a basic condition for digital sustainability.

As far as digital preservation is concerned, open licenses are highly practical for the storage of digital materials e.g. by libraries. Usually, there is a conflict of interest between the copyright holder, such as the publisher and e.g. the national

library charged by the public to preserve digital heritage [27]. While there are certain circumventions, such as the "fair use" approach [17], cultural heritage institutions benefit substantially if scientific output is published under an open access regime [31]. This resolves all intellectual property restrictions by granting long-term access without any legal limitations.

2.6 Shared Tacit Knowledge

Using and enhancing digital resources requires specific skills and experiences on how to interpret and modify the technical structures. In knowledge management theory, such uncodified experience is called 'tacit knowledge' and enables individuals and groups to understand and apply technologies and create further knowledge [35]. While digital resources do not diminish through usage, they do need to be updated and adapted continuously to reflect the changing environment. Thus, knowledge about certain technologies is best preserved through collective intelligence [6], meaning tacit knowledge about the digital resource should be spread as widely as possible.

Making digital resources available long-term requires skills and knowledge on how to properly handle them and correctly interpret the stored information. Therefore, not only the explicit forms - such as recorded data - are necessary for digital sustainability; tacit knowledge is also crucial to be able to maintain and interpret the resources in the long-term. Digital preservation scholars have identified problems when tacit knowledge is lost, including an increased risk of not being able to read and understand the data in the future [48]. This illustrates the critical role of such uncodified knowledge.

2.7 Participatory Culture

Assuming knowledge is being shared among various stakeholders, how should sustainable digital resources be developed further? Experience from open source projects (Linux kernel etc.) or open content communities (Wikipedia etc.) have shown that an active ecosystem leads to significant contributions from outsiders such as volunteers [37] and corporations [58]. Such dispersed communities gather the expertise from an international set of contributors, ideally leading to high-quality peer-reviewed processes of knowledge creation.

Archives and other digital heritage institutions have the potential to benefit greatly from these kinds of crowdsourcing methods. Quality assurance and information gathering processes, as well as assessments, have been testing a number of participatory patterns [12]. In addition, crowdsourcing projects promoted by galleries, libraries, archives, museums, and educational institutions have started to be applied, leading to positive results and empirical insights [9]. For instance, the Brooklyn Museum and other GLAM (galleries, libraries, archives, and museums) institutions made successful experiments with crowdsourcing games (Games with a Purpose, GWAP) where citizens conducted microtasks such as tagging content and validating data [42].

2.8 Good Governance

Nowadays, many digital resources are produced and controlled by corporations. However, centralized control by a single entity might not be an appropriate governance basis for a sustainable digital resource as it becomes directly linked to the organization's continuity. While technology companies and innovative business models are considered part of sustainable digital resources [53], they should remain independent from self-serving commercial interests and control in the hands of only a few individuals. Open source projects integrate the possibility of 'forking', signifying the division of the developer community [36]. Although such events can bring turmoil and wastage of resources, they are a crucial element within open source communities, potentially leading to more sustainable governance structures and more effective collaboration [19]. Thus, good governance among contributors and other stakeholders represents another condition of sustainable digital resources.

In digital preservation projects decisions, often need to be taken on which information is digitalized and made available publicly and which is not [27]. Not all data can be digitally published since the resources of archives are limited and certain sources could result in too much effort. Therefore, publication should follow a careful planning and decision-making process including all relevant stakeholders. Ideally, the selection procedure leads to "well-documented, well-argued and transparent decisions" [5]. Another example indicates the importance of widely supported governance structures: In 2003, the UNESCO Charter acknowledged that digital heritage is essential for our society [29]. Within the charter, a multilevel approach was proposed: Universal strategies, strategies adapted to geographical and national configurations and the involvement of authors, publishers and other relevant stakeholders are required. The development of cultural heritage should not be based on a selection made by a single institution.

2.9 Diversified Funding

While governance may be shared broadly among various stakeholders, ultimately, it tends to be financial capabilities that direct the use of resources. Therefore, diversified funding reduces control by a single organization, thus increasing the independence of the endeavor. There are a variety of funding models available, as explained with the example of open educational resources [16]: the endowment model (interests paid), the membership model (all interested organizations pay a fee), the donations model (voluntary donations), the conversion model (selling of added value services), the contributor-pay model (contributors are charged), the sponsorship model (public relations by corporations), the institutional model (a public institution pays), the government model (a government agency pays), and the partnership and exchanges model (costs are split among various institutions).

Digital heritage work is for the most part funded by public institutions or by some other not-for-profit sources, such as lottery funds [41]. As such, it is presumed to be less prone to commercial exploitation by corporations. Nevertheless, diversified funding of digital preservation projects supports scientific independence and increases public awareness of the societal impact of digital heritage. In order to leverage public funding, incentives should be introduced to motivate private investments into digital preservation activities [11].

3. POLITICAL AGENDA FOR DIGITAL SUSTAINABILITY

As with many initiatives relating to sustainable development, most people might agree upon the goals. However, the question remains how these aims can be implemented successfully.

One approach addresses the policy level in order to advance the attainment of targets relating to digital sustainability. In Switzerland, there is a national parliamentary group lobbying for the concept of digital sustainability[1]. The group was founded in 2009 in order to increase the creation and use of

[1] www.digitale-nachhaltigkeit.ch

open standards, open source software, open content, open data, and open access [34] [22].

Among others, this nonpartisan group of parliamentarians advocates the following issues regarding digital sustainability:

Public funding of digital resources should follow the conditions for digital sustainability. Thus, institutions like the national archive should not only ensure that digital heritage data is stored within open formats, but also that the requisite software is available under free licenses, such as open source software.

Public institutions should prioritize the procurement of open source software. In order to decrease dependencies from proprietary software vendors, public tenders should favor bids offering open source software solutions. Libraries in particular are not yet fully exploiting the potential of open source software, as academics already noted as long ago as 2007 [25].

Research funding should focus on open science principles. Publicly funded research should provide the aggregated results in open access journals and the research data as open data. Furthermore, all software developed during research activities should be published as open source.

Political statements and policy interventions, like the ones outlined above, are helping to promote digital sustainability in the public sector, thereby advancing the notion for digital preservation also.

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