A Strong Sustainability Framework for Digital Preservation of Cultural Heritage: Introducing the Eco-Sufficiency Perspective

Evangelia Paschalidou 1, Charlotte Fafet 2 and Leonidas Milios 3,*

1 Independent Researcher, 56625 Thessaloniki, Greece; evapaschal@gmail.com
2 Bouclier Bleu France, 75003 Paris, France; cha.fft21@gmail.com
3 International Institute for Industrial Environmental Economics, Lund University, PO. Box 196, 22100 Lund, Sweden
* Correspondence: leonidas.milios@iiiee.lu.se

Abstract: The intensifying effects of climate change are becoming one of the main threats to cultural heritage, posing risks of degradation or destruction. Climate change is bringing complexity and uncertainty to ensuring the resilience of cultural heritage, and among risk mitigation measures digitalisation is regarded as a promising tool. However, the infrastructure required for the digitalisation process exerts significant pressures on the environment contributing to climate deterioration. To address these issues, this contribution developed a strong sustainability framework for the preservation of cultural heritage through digitalisation, for minimising environmental impacts and maximising the potential of preservation. To construct the framework, a literature review was conducted on efficiency and sufficiency concepts and existing approaches to sustainability of digitalisation in cultural heritage. To test the potential application and feasibility of the framework in driving environmental sustainability efforts within cultural heritage organisations, the case study of the Finnish Heritage Agency was analysed. The results showed that the understanding of the sustainability of digitalisation is not fully developed. Strong sustainability is hardly applied in practice, even though an inherent tendency for sufficiency especially in the appraisal stage was identified. It was highlighted that extensive stakeholder networks are required for advancing the sustainability of digital preservation. Ultimately, re-examining current practices and realigning stakeholders would be required for addressing the current challenges.

Keywords: cultural heritage preservation; digitalisation; eco-sufficiency; sustainability; sustainable digitalisation; climate change risk mitigation

1. Introduction

Heritage means something inherited, and often refers to material or immaterial items which have historical, cultural, symbolic, social and/or aesthetic values [1,2]. A distinction is often made between tangible heritage, which are material elements such as historic cities, collections, archives, natural landscapes, and technological achievements, as opposed to intangible heritage which includes immaterial aspects like knowledge, skills, traditions, craftsmanship, beliefs, social practices, and values [3]. Cultural heritage implies a sense of belonging and can be interpreted as a shared bond within a community. Therefore, it is often an important component of a community’s identity but also a driver of the economy [4,5].

Through the transformative socio-economic developments that occurred in the late 20th and early 21st century, a need for protecting cultural heritage emerged and led to the creation of the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage List, which now counts more than a thousand sites judged important to be preserved for their “outstanding universal value” [6]. Due to its vulnerability to multiple threats, including natural and climate-related disasters, cultural heritage was also integrated
introduction to international disaster risk reduction frameworks such as the Hyogo Framework for Action and the Sendai Framework for Disaster Risk Reduction 2015–2030. In particular, climate change impacts on natural and cultural heritage were emphasised during the 29th Session of the World Heritage Committee in Durban in 2005 [7].

Climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as “any change in climate over time either due to natural variability or as a result of human activity” [8]. According to the Framework Convention on Climate Change (FCCC) and IPCC, human activity is a key driver of climate change as it directly or indirectly modified natural climate vulnerability mostly through the emissions of greenhouse gases [9]. Among the observed effects and impacts of climate change are the increase in frequency and intensity of climate extreme events such as storms, floods, and droughts but also longer-term effects such as sea-level rise and increased temperatures [10,11]. As a consequence, climate change has become in recent years one of the main threats to cultural and natural heritage, as it can cause the degradation or loss of tangible heritage as well as intangible heritage (e.g., due to people’s displacement or modified cultural practices or traditions due to climate stressors) [10,12,13]. For instance, even if the global mean temperature remains stable for the next two millennia, 6% of the UNESCO sites would be affected by sea-level rise [14]. Not only sites but also buildings and objects would be affected by climate change-related risks, which are creating new stressors as well as emphasising or accelerating already existing natural (climate-related risks, geohazards, etc.) and human-induced risks (mass tourism, air pollution, urbanisation) [15–18].

1.1. Risk Management of Cultural Heritage

With the current threats affecting cultural heritage sites as well as the ones exacerbated and/or created by climate change, studying risks is important for finding measures that can reduce their likelihood or consequences. Risk is commonly defined as the likelihood of a hazard multiplied by its consequences [19,20]. Potential risks affecting cultural heritage have been taken into consideration notably through practical guides or policy documents established by international organisations such as the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and UNESCO [21,22].

Even though risks are often context-specific, some main trends and deterioration processes can be highlighted and described. First, cultural heritage sites are exposed to natural conditions such as humidity, temperature, wind pressure and soil characteristics leading to natural deterioration processes which include natural decay of materials as well as erosion processes related to weather events, insects, and vegetation. Natural deterioration processes lead to chemical, physical and biological degradations of the materials that compose buildings as well as their components (including objects and artefacts) that are considered cultural heritage assets [21]. These degradations may be emphasised or accelerated by different types of risks which can sometimes be complex to comprehend. Indeed, risks vary from sudden to slow-onset events (e.g., hurricane versus erosion) and can affect directly or indirectly heritage sites (certain events can lead to secondary risks e.g., a fire can directly destroy some parts of a cultural heritage asset while the fluctuation of humidity caused by this fire can also cause damages to the cultural heritage asset). Furthermore, cultural heritage assets can be affected by large-scale risks (e.g., an earthquake) as well as microscale risks (e.g., biological degradation caused by pests) [20,21].

The potential effects and impacts of climate change on tangible heritage are multiple, and include for instance: corrosion of materials such as limestone due to unusual weather patterns and intensification of rainfall; structural damage and collapse of heritage buildings due to the increase of extreme weather events such as heavy wind; destruction of cultural sites situated on a seaside environment due to coastal erosion; deterioration of building facades due to thermal stress such as thaw and frost, or due to atmospheric pollution; deterioration of surfaces (e.g., paintings, frescos) due to exposure to wetting and drying that results in the crystallisation and dissolution of salts; and for some materials, such
as wood, climate change and rise in temperature are likely to lead to a more frequent proliferation and to the migration of new parasites [7,23,24].

Even though disaster risk management has been incorporated into preservation and conservation techniques and principles, climate change is bringing a new dimension of complexity and uncertainty to ensure the resilience of cultural heritage [25]. In this context, existing strategies for the whole disaster risk management cycle (preparedness and mitigation, response, recovery) should be reinforced in addition to the implementation of climate integrated cultural heritage management strategy and targeted actions [13,18]. Managerial and structural adaptation measures include dedicated funding and insurance schemes, regulations, and governance procedures, and fostering knowledge and learning opportunities (e.g., awareness and communication campaigns, education through training and drills) to bridge climate change science and cultural heritage communities to increase collaboration [18,24,26]. Among preservation measures, digitalisation is regarded as a promising tool that can “enhance access to cultural heritage and the benefits which derive from it” according to the Faro Convention [26–28]. Indeed, more and more advanced Information and Communication Technology (ICT) and image processing tools allow both a form of digital preservation of heritage and the possibility to remotely discover or explore an artefact or a site through the development of virtually generated versions of it, usually in three-dimensional and interactive visualisations [27].

1.2. Digitalisation and the Environmental Impacts of Information and Communication Technologies (ICT)

The digitalisation of cultural heritage offers indeed a unique opportunity for the preservation of a virtual copy of the material object in standard quality over time that would enable the continued use and appreciation of its cultural value for future generations. However, the digitalisation process is relying upon extensive material (hardware) and immaterial (software) ICT infrastructure which directly and indirectly contributes to environmental pressures and the intensification of climate change [29].

ICT equipment is enabling both the preservation and the dissemination of digital content, so it is indispensable for all essential processes that fulfil digital preservation purposes, from securing safe storage of the digitised or born-digital content to sharing and providing access to the end-user. In this respect, ICT equipment comprises the whole communication network, meaning the data services or core network for the electronic distribution of data (e.g., data centres’ computational power and hardware) as well as the extended end-user’s network (e.g., laptops and servers) to connect to it [30]. However, the actual ICT system required for digital preservation is hard to define precisely, especially the extent of the enabling infrastructure and the resources and energy consumption needed, as well as its environmental impacts. This is why the adoption of a life-cycle perspective is required to address both resources (e.g., scarce minerals) and energy use throughout the production, use and disposal phases of ICT equipment [31,32].

In the production stage, the direct impacts of ICT equipment mainly derive from energy-intensive processes linked to resources’ mining and refining [33]. The extraction of raw materials, including scarce metals (gold, indium, palladium, silver, etc.) as well as rare earth elements (tantalum, magnesium, etc.) leads to resource depletion [34]. Moreover, the extraction process of these materials requires excessive use of chemicals, and the mining industry is highly dependent on fossil fuels, contributing tremendously to carbon dioxide emissions [29]. Major impacts occurring during the mining and refining processes include biodiversity loss, contamination of soil and water in the surrounding areas, and emissions in the atmosphere [35,36]. Consequently, the ‘embodied energy’—the upstream energy demand of the material composition of the product—is largely contributing to the overall environmental impacts of ICT equipment.

In the use phase, direct effects can be found in the ICT infrastructure and cloud-computing, due to the energy demand of the computing and networking equipment as well as the cooling needs of data centres [35,37].
Ultimately, ICT equipment is forced to replacement due to either technological or software obsolescence, which in the context of digital preservation is dictated by the digital assets’ safety and preservation standards [37]. Therefore, ICT equipment exerts further pressures on the environment at its end of life, especially considering that only 17.4% of the total electronic waste produced was reported as officially collected for treatment in 2020 [38]. The rest was disposed of in landfills, burnt, or illegally traded mainly for extracting the precious metals from ICT components, leading to the production of highly toxic substances, and usually treated under hazardous conditions [39,40].

The mitigation focus of ICT impacts has mainly been on the energy consumption and the extended energy demand implications from the optimisation, virtualisation, or substitution processes in other sectors, e.g., in transportation [31,35]. Thus, the preferred path for mitigating the resource and environmental impacts of ICT is to increase technological efficiency as it will lead to energy and material resources savings, and thus reduced environmental impacts [31,41]. It is argued, however, that perpetual technological fixes by increasing constantly the energy and resource efficiency of ICT, cannot reach sustainability in the long run [42].

Increasing the efficiency of ICT implies having more service/work produced per unit of ICT equipment. For example, for the same computational outcome, only half of the energy would be needed if the processing efficiency doubles [43]. However, the ICT sector (products and services) keeps growing on a global scale and this translates directly to an increase in the total resources consumption. Therefore, it remains uncertain whether efficiency improvement alone could outpace the sector’s growing impacts [41].

Energy consumption of ICT has been continuously increasing over the past years, from 3.9% of the global electricity demand in 2007 [44] to 4.6% in 2012 [45]. Recent estimates point out that the sector could reach 13% of the global energy consumption by 2030 [46]. Moreover, the IEA [47] predicts exponential growth in data usage, with global internet traffic expected to double by 2022 to 4.2 zettabytes per year (4.2 trillion gigabytes). This suggests that despite technological efficiency improvements in the ICT sector, energy and resource consumption will keep increasing. The reasons for this can be better understood with insights from the ‘rebound effect’ and ‘resource decoupling’.

The rebound effect means that the technological efficiency improvement of a process or product is not followed by a decrease in its demand. On the contrary, demand bounces back, counteracting much of the efficiency gains [48]. Consequently, reducing energy consumption through efficiency increases cannot be guaranteed because of potential rebound effects [41,49,50].

On the other hand, understanding the decoupling of resources and negative environmental impacts per function of ICT is deeply attached to the broader economic system [31,41]. For instance, there is a discrepancy between the current technical value of ICT growth and its economic measuring—an example of this could be the prices of smartphones which have remained steady over the past ten years despite significant computational efficiency increases [51]. Moreover, the value of digital services is underestimated since they are not charged per data unit but rather at flat rates [41]. Such actions may counteract the resource-saving effects of efficiency increases by driving an increase in total consumption [31].

Consequently, a complementary approach is needed beyond the widely applied technological fixes of ICT efficiency, and emerging literature is suggesting the introduction of a sufficiency perspective [31,41].

1.3. Objectives of the Research

The aim of the research is to develop a strong sustainability framework for the preservation of cultural heritage through digitalisation, that minimises the environmental impacts of ICT used in cultural heritage preservation processes and maximises the potential of preservation for the longest possible time with the minimum accepted loss of quality and/or content. The rationale of the research lies in the necessity to digitally preserve
cultural heritage, especially in light of the increasingly detrimental environmental risks connected to the observed direct and indirect effects of climate change. However, the process of digitalisation actively contributes to climate change pressures which in turn intensify the need for preservation. To address this discrepancy, the research seeks to ameliorate this adversely reinforcing situation by introducing a sustainability approach to the process of digital cultural heritage preservation that would contribute the least to climate change.

To achieve this objective, literature was reviewed pertaining to the concepts of efficiency, sufficiency and the existing approaches to sustainability of digitalisation in cultural heritage preservation. Taking stock of the current practice and synthesising the literature findings, a strong sustainability framework was developed and applied to a case study to test its feasibility and potential to drive sustainability efforts within cultural heritage organisations. The case study selected for this research was the Finnish Heritage Agency (FHA), which has adopted a sustainability agenda and acts under a general mandate for increasing its sustainability efforts as a part of the Finnish public authorities.

2. Method

The research was developed in two distinct phases. Initially, the research focused on setting up an appropriate sustainability framework that would grasp the processes of the digital preservation of cultural heritage as best as possible and introduce the necessary elements for optimising its anticipated performance in terms of sustainability outcomes. This first phase was based on a literature review of the existing knowledge regarding strong sustainability approaches of ICT and digital preservation processes in the cultural heritage scientific field. Then, the research applied a case study approach to explore the feasibility, implementation potential, and anticipated outcomes of the sustainability framework, which was theoretically constructed in the previous stage of the research. The case study ultimately would enable the validation of the framework and would offer further insights for potential practical improvements. The results of the literature review are presented in Section 3 and the results of the case study analysis are presented in Section 4 of this article. The research steps are illustrated in Figure 1.

Figure 1. Flowchart of the research. CHOS = Cultural Heritage Organisations; FHA = Finnish Heritage Agency; AIS = Archives and Information Systems; DP = Digital Preservation.

2.1. Literature Review and Theoretical Framework

A literature review was carried out with the dual aim of providing an orienting context to the study as well as the theoretical foundation for creating the analytical framework [52]. Academic peer-reviewed articles, monographs and reports were sourced from widely used academic search engines (e.g., Scopus, Google Scholar). To retrieve relevant content in line with the objectives of the research, appropriate search terms were used in different combi-
nations, including: ‘cultural heritage’, ‘digital preservation,’ ‘digitalisation’, ‘strong/weak sustainability’, ‘(eco-)efficiency’, and ‘(eco-)sufficiency’. With the snowball method, additional literature was sourced from the bibliography found in the relevant articles [53]. The most closely related article identified was that of Pendergrass et al. [32] introducing the ‘Environmentally Sustainable Digital Preservation Framework’, in which the relations between the environmental impacts of ICT and the digital preservation of cultural heritage are presented. This article constituted the basis for developing the theoretical concept of the research, which was later enhanced by additional literature insights, especially through the notion of sufficiency—something that was lacking in the Pendergrass et al. [32] approach. Therefore, the literature review was expanded to include factors affecting the sufficiency approach for digital preservation of cultural heritage. The literature findings were then synthesised with an elaborated version of the Pendergrass et al. [32] framework, resulting in a revised framework for strong sustainability of digital preservation that was applied in the case study and used for the analysis of the collected data.

2.2. Case Study Selection

Conducting case study research is recommended for understanding and investigating in depth the empirical occurrence of the studied material in contemporary events with no control over them [54]. In the case of novel approaches where previously substantiated evidence is limited, an exploratory rationale is also recommended [55]. Moreover, the case study method has been commonly used in literature for investigating sufficiency-related approaches in business strategy or as a business model for organisations (e.g., [56,57]). Appropriate selection criteria were formulated and applied to selecting a fitting organisation for the case study. Specifically, the organisation must have fulfilled the following criteria: (1) the organisation’s operational objectives must satisfy the definition of cultural heritage; (2) demonstrate active engagement in digital preservation with current or future projects; (3) show a tendency towards environmental sustainability, stated publicly in their core mission strategy.

After a preliminary search in cultural heritage networks and going through various European Union (EU) and UNESCO projects to access a pool of cultural heritage organisations that have been active in the digital preservation of their collections (or are about to initiate such activities), a first-round of communications was held with organisations willing and available to collaborate. Two potential cases were identified, however, after more in-depth discussions one of the two was found not to fulfil the third criterion stated above. This led to the selection of the Finnish Heritage Agency (FHA) as the case study organisation, and more specifically its Archives and Information Systems (AIS) department. The selected case facilitated the research by giving broad access to several willing interviewees and having a well-organised and clearly structured online presence, providing efficient communication and access to data for analysis.

The case study chosen for this research is in accordance with Yin’s [54] rationale of conducting a single-case study when the case to be studied is considered an extreme or rather unique one. The FHA was—by the time the case suitability search was conducted—the only public organisation that has taken, and was publicly communicating, such environmental sustainability considerations, even though these were not mandatory in legislation. The FHA, as a public organisation, is shaping its strategy according to the fulfilment of the societal needs and purpose that cultural heritage serves. Their work is promoting “sustainable development and common well-being” [58] and they are linking cultural heritage to sustainable, democratic and inclusive societies, while sustainability is explicitly acknowledged and related to cultural heritage and digitalisation [59].

2.3. Data Collection and Analysis

The research was conducted qualitatively and was based on stakeholder interviews and document analysis. To obtain a more holistic and in-depth understanding of the case study, the research approach employed multiple analytical embedded units, as rec-
ommended in the literature [54,60]. The units of analysis considered for documenting the practice within the AIS department included (1) interviews of AIS staff coupled with internal iterations of the Pendergrass et al. [32]—derived ‘self-questionnaires’ for assessing environmentally sustainable digital preservation within the organisation (Appendix A), and (2) interviews with various actors relevant to the activities of the AIS department (eventually mapping their associated interrelations).

A total of twenty semi-structured interviews (Appendix B) were conducted to gain empirical data regarding the digital preservation of cultural heritage processes and any related sustainability activities. The semi-structured format of the interviews allowed for a flexible discussion and in-depth insights from the interviewees’ inputs [52].

The interviews were complemented with document analysis, meaning the use of public or private documents relevant to the subject of the study, made available during or after the interviews by the persons involved. Reports, presentations, articles, organisation documents for internal or external communication and web pages were necessary to complement the research since not much academic literature exists on the respective sustainability strategies and network structure in Finland. This method is also aligned with the exploratory nature of the research design and the need for an in-depth and accurate understanding of the interrelations among the actors [52]. Document analysis was conducted along the interviewing stage, feeding back to the interview in an iterative way.

The collected data were structured and analysed qualitatively under the respective axes of the theoretically constructed sufficiency framework (see Figure 4 in Section 4). The analysis focused on empirical evidence about the organisation’s understanding and current practice in relation to the sustainability of digital preservation and sufficiency.

Finally, the collected data was triangulated [52], to the degree possible, by comparing the different sources from the interviews, publicly available documents, and academic literature.

3. Towards a Strong Sustainability Framework

There is little evidence in literature regarding the mitigation of environmental impacts from the use of ICT equipment in decisions taken during digital preservation of cultural heritage. Pendergrass et al. [32] have elaborated on the only sustainability framework available (so far), the ‘Environmentally Sustainable Digital Preservation Framework’, which is factoring the environmental aspects of ICT use in the field of cultural heritage throughout the full life cycle of the equipment used in the process, and along the three main stages of digital preservation: (1) appraisal; (2) preservation; and (3) accessibility of the cultural artefacts. This framework enables environmental sustainability to be consciously incorporated into the fundamental processes of digital preservation in order to go beyond the technological fixing measures that are only reducing apparent environmental impacts [32,61]. Therefore, a ‘paradigm shift’ in the digital preservation processes of appraisal, permanence and accessibility of the digital content is required for “reducing the amount of the digital content preserved, while reducing the resource-intensity of its storage and delivery” [32] (p. 177).

As current mitigation efforts of ICT related environmental impacts are dominated by an efficiency-increasing approach, the additional measures proposed by Pendergrass et al. [32] for reducing the amount of digital content and aiming at a ‘good enough’ quality of digital preservation could be better understood through the notion of ecological (eco-)sufficiency or simply sufficiency. In the following sections, the notion of sufficiency is thoroughly scrutinised and a revised ‘strong’ sustainability framework for the digital preservation of cultural heritage is presented.

3.1. Beyond Efficiency, towards Sufficiency and Sustainability

The notion of sufficiency is firmly based on natural laws and processes, for instance on the second law of thermodynamics (i.e., the linear flow of matter-energy throughput from low to high entropy) [62], on the concept of planetary boundaries [63], or on the scarcity of Earth’s finite resources [64]. The biosphere establishes the bio-physical boundaries within
which all human socio-economic activities develop, and surpassing these boundaries leads to detrimental effects on the capacity of the planetary ecosystem to regenerate itself. Despite that, the current rate of resource consumption globally has outpaced the Earth’s regenerative capacity by 1.75 times [65], while established boundaries on biodiversity loss, climate change, and the global natural nitrogen cycle have been exceeded [63]. In this context, production and consumption activities cannot disregard this reality any longer, but rather should be aligned with the bio-physical absolute limits of resource use [66].

From a strong sustainability perspective, the limitation of resource use must be absolute. Strong sustainability assumes that the human or human-made capital (e.g., financial capital, technology, human skills, infrastructure) cannot replace the natural capital (elements and processes) due to its intricate interrelations that provide unique ecosystem services, and thus, don’t allow for their artificial substitution [67,68]. On the other hand, the unlimited substitutability of capital—also described as weak sustainability [69,70]—and the pursuit of increased value extracted per unit of natural resources are supporting continuous efficiency gains, largely by technological means [67,71]. However, as explained under Section 1.2, pursuing a reduction in material/energy throughput by more efficient use per unit results in a risk of rebound effects, with financial savings being put back into consuming greater quantities and increasing the material-energy flow [56,64,72].

Nevertheless, sufficiency and efficiency are not mutually exclusive, and the two can coexist as long as efficiency occurs within a sufficiency context without undermining the absolute reduction goals, and any efficiency gains are not reinvested in increasing total production and consumption [56,73].

3.2. Understanding Sufficiency

The notion of sufficiency lacks clarity in the literature [74,75]. It has been approached as an “idea, a self-management principle or a social organizing principle” for sustainability [76] (p. 7), among the different scientific disciplines [75]. In addition, sufficiency has been discussed in different contexts, from an economic organisation’s strategy regarding both the production and consumption sides [57,71], to a consumer’s perspective regarding consumption patterns [57,73]. However, when discussing sufficiency from the broader perspective of resource throughput and economic activity, a common ground is its conceptualisation in opposition to efficiency [74,77]. Although efficiency is commonly understood as a production-side strategy for doing something better or more, sufficiency is understood as doing or consuming something less, limiting resource consumption, restricting, or sacrificing profits [56,77,78].

For enabling sustainable change, efficiency strategies should be applied from within sufficiency ones, without triggering rebound effects [56,78]. According to Heikkurinen et al. [73], this can be attained (in a business context) only if the sufficiency strategies are extended to the consumers so that the total economic activity is reduced. In order to approach the production side as well, the entire supply chain (i.e., all producers, not just individual cases) should address overproduction. However, it is widely acknowledged that reducing economic activity highlights a paradox in the current economic growth system [61,72]. It is argued that for such a ground-level change of a sustainable economy to be initiated from the private sphere, the intervention and support from the public sphere (i.e., citizens and government) would be necessary [79].

Although efficiency seeks the highest output per resource use, sufficiency pursues the reduction of the total resource consumption “by emphasizing ‘enough production’ (…) where ‘enough’ refers to the sufficient fulfilment of human needs” [56] (p. 2). Therefore, a sufficiency approach is driven by the satisfaction of a need [80]. Conceptualisations of ‘needs’ have been attempted by different and various disciplines and are commonly referring to something that is in shortcoming [61,76], for instance, from physiological needs [81] to the collective necessities for human development [82]. In the context of sufficiency, ‘needs’ are important to be distinguished from ‘wants’, that are surpassing the upper limits of the sensory perception of need [83]. The notion of ‘wants’, from an economic perspective, is
referring to the desire of acquiring something that depends on the ability (i.e., resources) to have it [61].

Jungell-Michelsson and Heikkurinen [84] provided the first systematic literature review on the concept of sufficiency and concluded that sufficiency is acknowledged both as a means and an end in the transition towards more sustainable societies. In terms of consumption, sufficiency is conceptualised as a moderation strategy of individual consumption and requires a certain extent of behavioural change. It is claimed to require socioeconomic transitioning towards more a equitable intra- and intergenerational distribution of wealth. On the production side, sufficiency is depicted as a call for a paradigm shift in business logic and alternative imaginaries for future socio-economic organisation.

3.3. Strong Sustainability Framework for Digital Preservation of Cultural Heritage

For developing a strong sustainability framework for the digital preservation of cultural heritage, an inclusive interpretation of sufficiency, as expressed in literature, was combined with the measures outlined in the ‘Environmentally Sustainable Digital Preservation Framework’ elaborated by Pendergrass et al. [32]. Inclusivity is understood as the combination of both sufficiency and efficiency strategies in digital preservation, including: (1) a stricto sensu sufficiency strategy, that establishes the context within which the following two are understood; (2) an efficiency strategy; and (3) a context-specific version of efficiency, the digital preservation-efficiency (discussed in more detail in Section 3.3.3).

3.3.1. Sufficiency Strategy

From a strong sustainability perspective, a sufficiency strategy is defined narrowly as reducing the matter-energy throughput in absolute terms but retaining the necessary digital preservation processes in proportion to the purpose of a cultural heritage organisation. The target of absolute reductions in throughput depends on the nature and/or the mission of the organisation, which, in the case of cultural heritage, is usually a non-profit organisation assigned to serve the public benefit through a high-value purpose [76]. Particularly, such an organisation fulfils a public need by ensuring the preservation of the cultural memory and heritage for the future generations, and by making available this content to the public to meet its need of reconnecting and creating meanings of the past and its relevance in the world. Therefore, the uniqueness or quality of irreversibility of these values are setting the temporal and resource limits of the necessary actions to be pursued [76].

Consequently, during the appraisal stage of the cultural heritage material, a decrease in absolute numbers of cultural heritage objects can be pursued. Selection of the material is generally guided by international and national legislation (e.g., national Antiquity Acts or Decrees) outlined in more detail by the collecting policy of each cultural heritage organisation. With the measures elaborated by the framework of Pendergrass et al. [32] the number of cultural objects can be further controlled, if not decreased, by (1) collecting strictly objects within the cultural heritage organisation’s policy, (2) digitising only the material for which it is explicitly necessitated (e.g., at risk), (2a) according to users’ needs or (2b) asked to (e.g., tiered or on-demand digitisation), (3) deduplicating the same object that may be found across many collections or organisations by increasing the interoperability and enriching the digital object meta-data, and (4) re-appraising the preservation choice of the object regularly, with possible indicators such as the metrics of its use and its changing value in time. In this respect, the value of the digital cultural heritage object is essential for the sufficiency strategy, i.e., the value extracted by the public from its engagement with the cultural heritage content. Such values span from aesthetic, historic and anthropologic to social and spiritual, for the past, present and future generations [6], and determine the necessity to preserve or not a cultural artefact.

3.3.2. Efficiency Strategy

Efficiency strategies can and should be coupled with sufficiency strategies for advancing sustainability [73]. For cultural heritage, this means that for the same amount of digital
preservation outcome, fewer materials and less energy will be needed, as long as these savings are not adding to the total consumption of digital cultural heritage. Efficiency measures are characterised as easy and fast to apply (‘stopgap measures’) in the Pendergrass et al. [32] framework. Measures such as (1) technological efficiency, (1a) including software; (2) energy efficiency through scheduling, especially (2a) in fixity; and (3) clean energy use; are the ones included in our theoretical framework and can be applied to all the different stages of digital preservation.

3.3.3. Digital Preservation-Efficiency Strategy

Since the production of cultural heritage digital content is not expected to slow down but rather to accelerate through the proliferation of digital solutions, the majority of the ‘paradigm shift’ measures from Pendergrass et al. [32] focus on managing the volume of data as well as the level of its preservation quality. The volume of data and the preservation quality are determined by industry best practices and specific standards (e.g., ISO 16063).

In this context, efficiency would mean that for the same digital preservation quality, fewer resources are needed. However, by lowering the quality of the digital preservation outcome, the energy and materials input could decrease even further. This could constitute another type of efficiency strategy for data-related activities (such as digital preservation) that could be referred to as a ‘digital preservation-efficiency’ strategy.

In the appraisal stage of cultural heritage artefacts this could be implemented by (1) choosing formats that are ‘lighter’ or of ‘lower quality’—in terms of possible actions allowed—and therefore, decreasing the volume of data, or by (2) customising default choices in the workflows (e.g., disk imaging) [85].

In the preservation and accessibility stages, most measures elaborated by Pendergrass et al. [32] are developed under broader strategies for lowering the energy/material intensity of digital preservation processes such as conducting them in sampling, less frequently, on-demand, or tiered according to the value and uniqueness of the cultural heritage objects [32]. Specifically, in the preservation stage, measures include (3) applying a ‘good enough’ level of digital preservation that corresponds to the determined percentages of acceptable loss of digital cultural heritage material and quality; (4) establishing ‘tiered approaches of the preservation resources’ in respect to the value of the content (i.e., more effort and resources go into material that is deemed to be more valuable). When it comes to fixity checks and their frequency, actions include (5) performing less frequent and less complete fixity checks of the digital cultural heritage objects to the extent that this is aligned to the risk mitigation model of the cultural heritage organisation, which can save a considerable amount of energy. Moreover, by (6) performing larger fixity checks upon an indicative sampling of the copies of the cultural heritage objects, complete fixity checks may be avoided or delayed, but the greater risk of quality loss, in this case, is acknowledged.

Further, the file format migration policy can be (7) adjusted to the risk assessments of format obsolescence of the cultural heritage organisation, while (8) the file format migration can be customised (instead of keeping the software management system’s settings). If possible, this could be set on demand when access to the material is requested (also under the accessibility stage), or selectively for some of the material (e.g., input to the preservation system) and not in bulk.

Rather challenging is the number of redundant copies maintained by cultural heritage organisations since every extra copy does significantly increase the resource demands of digital preservation. In the framework of Pendergrass et al. [32], the copies’ redundancy falls under the (9) guidance of the risk mitigation model of the organisation (e.g., contrary to standards of highest quality preservation that may suggest that 6-7 different copies be kept in different geographical locations), and of (10) tiering according to the value of the object.

Finally, in the accessibility stage, the quality factor that may be affected concerns the delivery timing, by (11) keeping a tiered access system according to the value or frequency of use of the material. Such systems though may prompt the powering down of that storage
3.3.4. Updated Framework for Digital Preservation of Cultural Heritage

Synthesising the literature findings for a strong sustainability framework, the measures extracted from the framework of Pendergrass et al. [32] were categorized according to the quality of their outcomes under the three above-mentioned strategies for sufficiency, efficiency and digital preservation-efficiency. For the measures to be structured within a sufficiency approach, the component strategies need to emerge from a strong sustainability background, as explained in Section 3.1. This means that the sufficiency strategy should be setting the context for the efficiency and digital preservation-efficiency strategies, and that it should be the one manifesting predominantly and not marginally, as it is also argued by Robra et al. [56]. Indeed, they suggest that marginal manifestation of eco-sufficiency does not satisfy the criterion of being applied as a conscious strategy in an organisation [56]. This theoretical understanding can be conceptualised as a reverse pyramid (Figure 2), where sufficiency should be the broader aim, and manifesting more than the efficiency strategies.

![Figure 2. Hierarchy of the strategies composing the sufficiency approach for the digital preservation of cultural heritage. DP = Digital Preservation.](image)

When this theoretical understanding is applied to the measures presented by Pendergass et al. [32], an updated framework emerges that incorporates the three strategies composing the sufficiency approach on the vertical axis. It thus suggests the order of the measures that should be implemented for advancing a complete sufficiency approach, while the horizontal axis reflects the stages of digital preservation during which this could happen (Figure 3). This novel interpretation of a strong sustainability framework for the digital preservation of cultural heritage, embedded in a sufficiency perspective, forms the original proposal of this contribution. The framework will be applied in a case study in the following section.
The theoretically established strong sustainability approach for the digital preservation of cultural heritage is applied in a real case study to investigate its feasibility, potential for implementation, and structural effects on the functioning of a cultural heritage organisation and its extended network of actors. The case study concerns the Archives and Information Services (AIS) department of the Finnish Heritage Agency (FHA).

The FHA, one of the 13 Agencies operating under the Ministry of Education and Culture of Finland, is the agency responsible for the collection, protection, promotion and study of the Finnish cultural heritage, while providing services to the public [58]. The AIS department provides archive, picture, library, and knowledge management services (i.e., access to information and an image bank), while developing and supporting museum data systems nationally [58]. The complete mapping of the network of actors attached to AIS is presented in Appendix C.

Projects for the digital preservation of cultural heritage have been developed under the Ministry’s initiatives, by disseminating the programme objectives of the Finnish government through its sectoral policies [86]. The foundations of this endeavour were established with the National Digital Library (NDL) project in 2008–2017 [87].

To achieve its objectives, the NDL developed (1) the shared service system, Finna, which is the public platform for accessing all cultural heritage data, and (2) the National Digital Preservation Services (DPS) for cultural heritage, which is the long-term preservation solution offered by the Centre for Scientific Computing (CSC) [87].

In line with the Sustainable Development Policy of the Ministry of Education and Culture, which adheres to the overall strategy of the Finnish government regarding the objectives of sustainable development and carbon neutrality of Finland by 2035 [88], the NDL has established a carbon footprint modelling team and a Sustainable Development Working Group to prepare the new strategy and indicators for sustainability reporting. The 2021–2030 new strategy for sustainable change has been the first among the cultural heritage organisation strategies to acknowledge the ecological footprint of ICT and digital preservation processes, both in terms of energy and material resource consumption.

In the Finnish context, the environmental sustainability of the ICT equipment used for cultural heritage digital preservation is managed by the Centre for Scientific Computing.
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Heritage (CSC), with the National Digital Preservation Services (DPS) assigned with long-term preservation. CSC’s cross-cutting strategy aims at contributing to a green transition by maximising energy efficiency while minimising total environmental impacts [89]. The expansion of data centres and digital services networks, however, is proving to increase the total sum of energy consumption [89]. Along these lines, the environmental impacts of ICT through the overproduction of data and the extensive energy and resources demands of the sector were highlighted in the first of its kind Climate and Environmental Strategy for the ICT sector, adopted by the Ministry of Transport and Communication in Finland [90].

In this context, the digital preservation practice applied by the AIS department was documented, using the updated strong sustainability framework as guidance (Figure 3) and the adapted ‘self-questionnaire’ approach developed by Pendergrass et al. [32]. The results from the interviews and questionnaires are summarised in Figure 4, where the findings are revealing measures that are either somehow applied, considered to be applied, or with limited application due to specific technical standards already in use.

![Figure 4](image_url)

**Figure 4.** Results of the analysis of the measures applied by the Archives and Information Services department of the Finnish Heritage Agency. Green = Measure is applied; Yellow = Measure is not applied but considered for application (planned or in preparation); Red = Measure is restricted.

To interpret the results in Figure 4, two contextual factors should be taken into account: (1) there was a general lack of awareness among the interviewees in the organisations regarding the environmental sustainability of ICT systems that were being developed at that time, and (2) many different professionals were involved in the different stages of digital preservation with varied levels of understanding of the sustainability concept and having their own professional biases, which resulted in differentiated perceptions on the applicability of the suggested measures. It could be observed that all three strategies embedded in the strong sustainability framework (Section 3.3) were evidently manifested at all stages of the process to varying degrees.

First, there is an inherent tendency to **sufficiency**, especially during the appraisal stage. Digitisation occurs in response to demonstrated needs, which can be justified on the basis of legislation, natural degradation of the cultural heritage asset (rescue digitisation), users’ demands, and internal usability (collections, policy, catalogues for exhibition). As for the re-appraisal of the content, it is suggested to occur roughly once a year or only if needed.
However, the interviewees mentioned that de-accessioning did not constitute a major concern yet, since only 1% of the total collection was digitised.

However, the understanding of ICT environmental sustainability in general—and of the sufficiency strategy specifically—is not fully developed within the organisation. Total reduction of digital cultural heritage objects in number is restricted by legal requirements (international, EU and national law) integrated in the FHA’s purpose of cultural heritage preservation, as well as by the contractual agreements between the Agency and the Ministry [86]. De facto sufficiency is induced due to the limited budget and the size of the current collection (18 million images), which lead to the prioritisation and curation of the material to be digitised.

The essential qualitative function for the sufficiency strategy is not demonstrated since the engagement of the users with the content is followed up quantitatively (number of downloads) and the quality value is not considered in this metric. Nevertheless, the high standards for meta-data required by Finna can ensure higher accessibility and usability of the material.

The largest share of digital preservation-efficiency measures was observed mainly in the preservation stage. There have been divergent definitions among practitioners of what is a ‘good enough’ level of digital preservation and what could be considered an acceptable level of loss over time (also adhering to technical standards). Depending on the purpose of preservation, the practitioners’ loss acceptance varies in terms of fixity checks, adoption of a tiered approach, or the storage technologies used. The high standards (high-scale efficiency and automated processes) of the long-term preservation strategy provided by the DPS do not allow any flexibility for losses in quality, as well as for less frequent or incomplete fixity checks, tiered approaches in migration, or redundancy of the copies. On the other hand, it is acknowledged from the AIS side that for the measures they can control the level of preservation, some type of tiered approach (e.g., smaller size of image files and on-demand migration) could be considered in view of data storage sustainability implications. Therefore, the digital preservation-efficiency was reported as being to some extent considered internally within the focal department, but its extension was restricted due to interdependencies with the outsourcing service (DPS).

Finally, the measures for the efficiency strategy were consciously applied as the mainstream sustainability approach for the use of ICT throughout all digital preservation stages. European Union directives on energy efficiency covering individual ICT components were followed and some voluntary measures were also applied based on green public procurement, even though not systematically at the cultural heritage organisations’ level. However, the efficiency-increasing measures did not seem to arise from the sufficiency strategy. The driving force behind efficiency measures—at least for gearing energy consumption towards cleaner types—was Finland’s carbon neutrality target for 2035.

5. Discussion

Under the risk of cultural heritage degradation and the potentially irreversible destruction of cultural heritage artefacts due to the increasingly prominent phenomenon of climate change [9], this study examined both in theory and practice how digital preservation could be implemented so that it may ensure the preservation of cultural heritage while limiting environmental impacts inherent to the ICT equipment used for this process, which adversely contributes to climate change. The potential of digital technologies in safeguarding and preserving cultural heritage assets has been firmly established over recent years [91]. However, the immense growth of data in cultural heritage applications, following a general digitalisation trend, is highlighting the relevance of the study in view of the intensification of climate change impacts, resource depletion impacts and the broader rebound effect discussion, as well as cultural sustainability and public participation [92].

So far, the ‘Environmentally Sustainable Digital Preservation Framework’ by Pendergrass et al. [32] has been the only contribution promoting the required interdisciplinarity for systematically linking the environmental impacts of ICT to the digital preservation...
process. This framework enabled the operationalisation of the notion of sufficiency and a strong sustainability perspective, as developed in this study, in a real-life cultural heritage organisation context. On the one hand, the measures for sustainable digital preservation, outlined in our framework, proved to be possible to be arranged according to the sufficiency hierarchy. This aligns with the structure of the inclusive sufficiency interpretation, where any efficiency strategies should be happening within the broader sufficiency context [56].

On the other hand, the sufficiency conceptualisation by environmental economists (i.e., absolute reductions in matter/energy throughput) cannot apply strictly in the cultural heritage field, as it has a constantly increasing content production and it needs to be complemented with a quality perspective. To bridge this gap, the qualitative function of lowering the preservation quality and increasing the value extracted by the engaged public is introduced in the framework. However, with sustainability in digital preservation being just recently introduced in cultural heritage, the qualitative function of preservation is not fully understood—let alone problematised—in the sense adopted by the framework.

Therefore, all three strategies making up the sufficiency hierarchy (Figure 2) are only partially expressed in the documented practice of the case study organisation. With the sufficiency context set in this research as a prerequisite for efficiency strategies, it appears that strong sustainability as defined in literature is hardly applied in practice, even though an inherent tendency for sufficiency especially in the appraisal stage was identified. The digital preservation processes are currently based on monitoring the quantitative growth of the digital collection (e.g., set with annual performance agreements) or on increasing efficiencies to accommodate the digital preservation of a greater number of cultural heritage assets.

The broad application basis of the FHA is supported by the rich and interconnected network that surrounds it (Appendix C) and most crucially through the common public digital interface Finna—a hub for nearly 450 organisations—that offers both the broad outreach and the shared managing of the fundamental digital preservation strategies. In line with Peters et al. [93], it becomes evident that advancing the sustainability of cultural heritage digital preservation requires extensive and immersive partnerships between stakeholders (including the business sector, government, national archives, national libraries and museums, and other cultural institutions), which is even more true in the context of developing sufficiency strategies beyond the ‘traditional’ technological efficiency solutions.

The adoption of a sufficiency approach would be further facilitated by a long-term perspective assumed by a cultural heritage organisation in order to fulfil its dual purpose of preservation and engagement with the coming generations [91]. Moreover, the notion of intertemporal and universal accessibility of cultural heritage further highlights the need for—and importance of—the democratisation of information [92]. Ultimately, adapting to climate threats in both the short and long term poses tremendous challenges for cultural heritage organisations. There is no doubt that difficult decisions would be required concerning what can be protected and what should not and at what cost (cultural, environmental, etc.). What becomes clear is that different approaches—including the inclusive sufficiency approach—would be needed to address this issue, and that could only mean re-examining current practices, realigning stakeholders and adjusting respectively to the challenges and opportunities of doing things differently [24].

6. Conclusions and Future Research Perspectives

This contribution demonstrated how it is possible to integrate strong environmental sustainability principles in the process of digital preservation of cultural heritage. The proposed framework goes beyond mere resource efficiency and introduces elements of sufficiency and digital preservation efficiency. The theoretically derived framework was introduced in the case study of the Finish Heritage Agency, where its strengths and weaknesses were explored, and the implementation potential was assessed. The results of the case study showed that the strong environmental sustainability elements of the framework
have not been fully adopted, however, there is a potential for future considerations of certain elements.

The strong sustainability framework for digitalisation of cultural heritage presented in this study is not developed in detail regarding the included measures. This could be further elaborated in collaboration with archiving and cultural management practitioners. Further research could be also conducted to integrate the public’s and end-users’ perspectives in the stages of appraisal and accessing of the digital cultural heritage content. To this end, future research may consider various pathways: from a more applicable perspective of tools to communicate and involve directly the end-user with the technical quality decisions (e.g., software to calculate and communicate to the user how much more energy downloading a cultural heritage item in this format will need than a lower one), to a more theoretical level discussion on how and to what extent, humans and human experience have been merged with a technological way of being.

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Appendix A

Table A1. Questions to guide environmentally sustainable appraisal of digital preservation [32], used in the stakeholder interviews.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Born-Digital Content</th>
<th>Digitized Content</th>
</tr>
</thead>
</table>
| Storage size        | • Is the entirety of the digital content within your organization’s collecting policies? Is there some content (e.g., personal or system data) that you should not acquire? | • Do you have a demonstrated need for digital availability of the analog materials?  
• What file format(s) are you generating? Would different formats result in smaller storage demands while satisfying preservation and user needs?  
• Should you digitize material to the highest quality possible, or is lesser quality acceptable? |
|                     | • Is it necessary to capture and maintain a disk image? What are the use cases?  
• Do duplicates exist within the collection? If so, can you deduplicate, using metadata or descriptive pointers in the place of duplicate copies?                                                                 |                                                                                                                                                                                                                  |
| Capture and analysis| • What technology resources are required to capture, analyse, or arrange the digital content?                                                                                                                                 | • What technology resources are required to digitise the analog materials and conduct quality control of the digital surrogates?                                                                                   |
| Reappraisal         | • How regularly should you conduct reappraisal?  
• What procedures are in place for deaccessioning in the event that you deem some or all of the digital content not valuable during reappraisal?                                                  |                                                                                                                                                                                                                  |
Table A2. Questions to guide environmentally sustainable permanence of digital preservation [32], used in the stakeholder interviews.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Questions</th>
</tr>
</thead>
</table>
| Determination of acceptable loss    | • Have you established organizational policies around what constitutes “good enough” digital preservation, and what might constitute acceptable amounts of loss over time?  
• Have you implemented tiered approaches to digital preservation, where resources are allocated according to the value and uniqueness of materials being preserved?  
• Do your digital preservation policies and donor agreements allow enough flexibility for you to engage in sustainable digital preservation? What language is used around the effort and resources spent on preservation over time? Does this language allow for any degree of loss over time? |
| Fixity check methods and frequency  | • How often do you run scheduled fixity checks?  
• Do you run fixity checks during peak or off-peak energy and network hours?  
• Is it necessary to run fixity checks on all AIPs, or is verifying a sample of AIPs adequate to meet organizational needs?  
• Are file-based checksums supplemented by other integrity checks, such as natively checksumming file systems or block/media-level hardware checks? If so, can you responsibly reduce the frequency of file-by-file fixity checks? |
| Storage technologies utilized       | • How many copies are in online vs. nearline or offline storage?  
• On what media do you store digital content? Do these media need frequent replacement? What are the environmental costs of manufacturing, transporting, and disposing of these media?  
• Have you evaluated the environmental impact and energy sources of vendor and cloud services used? |
| File format migration policies       | • Have you developed a local file format policy?  
• Have you customized the file format migration policies of digital preservation systems in use at your organization to ensure that they match your local format policy?  
• For the types of data being stored in your repository, is it necessary to conduct format migrations at the time of ingest? Would format migration at the time of access suffice?  
• Is it necessary to apply file format policies equally to all materials being preserved? Would migration at the time of ingest be appropriate for some material and not others? |
| Number of redundant copies          | • Have you conducted a proper threat model for your AIPs?  
• How many stored copies of AIPs are truly necessary, considering the threats (e.g., internal attack, external attack, natural disaster, hardware failure) identified in your threat model?  
• Is it necessary to retain the same number of copies for all preserved digital content?
Table A3. Questions to guide environmentally sustainable availability of digital preservation [32], used in the stakeholder interviews.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Questions</th>
</tr>
</thead>
</table>
| Digitisation | • Is there a specific or demonstrated need for digitisation of an entire collection? If not, how can you alter the scale of the digitization project to meet user needs?  
• If there is a demonstrated need for digital access to particular items in a collection, what digitisation and access methods will most immediately serve the user while keeping organizational commitment to a minimum?  
• Are you clearly articulating on-demand digitisation policies to users to avoid unnecessary trips to view analog materials? |
| Access storage | • Is it necessary to migrate content to an access copy? If so, is it necessary to do so prior to a request for the content?  
• Are you retaining access copies in a storage system that facilitates media powering down when not in use? |
| Delivery | • If you are storing access copies in a system for delayed delivery, do you have language to indicate this to users?  
• If a user requests born-digital content or content with component files, can the retrieval system bundle this content appropriately?  
• Is there any supplemental documentation you should provide to the user with the content (e.g., how to access a particular file format)? |

Appendix B

Table A4. List of the 20 interviewed stakeholders in this study.

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Department/Position</th>
<th>Format/Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finnish Heritage Agency</td>
<td>Archives and Information Systems</td>
<td>Video call/March 2021</td>
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<td>Finnish Heritage Agency</td>
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<td>Archives and Information Systems</td>
<td>Written Interview Guide/March 2021</td>
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<td>Finnish Heritage Agency</td>
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<td>Written Interview Guide/March 2021</td>
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<tr>
<td>National Library of Finland</td>
<td>Service</td>
<td>Video call/March 2021</td>
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<tr>
<td>Ministry of Culture and Education of Finland</td>
<td>Art and Cultural Policy</td>
<td>Video call/April 2021</td>
</tr>
<tr>
<td>Centre for Scientific Computing</td>
<td>Development Manager</td>
<td>Video call/April 2021</td>
</tr>
<tr>
<td>STTRA Innovation Fund</td>
<td>Circular Economy Specialist</td>
<td>Video call/April 2021</td>
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<tr>
<td>Europeana Foundation</td>
<td>Senior Software Developer</td>
<td>Video call/April 2021</td>
</tr>
<tr>
<td>National Archives of Finland</td>
<td>General Administration Manager</td>
<td>Video call/April 2021</td>
</tr>
<tr>
<td>National Archives of Finland</td>
<td>Development Manager</td>
<td>Video call/April 2021</td>
</tr>
</tbody>
</table>
Appendix C

Figure A1. Network of actors and initiatives around the Finnish Heritage Agency in Finland.


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