Sustainability of Digital Libraries: A Conceptual Model

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Abstract. Major factors related to the economic, social and environmental sustainability of digital libraries have been discussed. Some research in digital information systems and services in general, and digital libraries in particular, have been discussed to illustrate different issues of sustainability. Based on these discussions the paper, for the first time, proposes a conceptual model and a theoretical research framework for sustainable digital libraries. It shows that the sustainable business models to support digital libraries should also support equitable access supported by specific design and usability guidelines that facilitate easier, better and cheaper access, support the personal, institutional and social culture of users, and at the same time conform with the policy and regulatory frameworks of the respective regions, countries and institutions.

Keywords: digital libraries, sustainability, social sustainability, economic sustainability, environmental sustainability.

1   Introduction

Sustainability "creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations."[1]. However, achieving sustainability in all its three forms, viz. economic sustainability, social sustainability and environmental sustainability, is a major challenge because often measures taken for achieving one form of sustainability affect the other forms of sustainability. This paper discusses all the three forms of sustainability in the context of digital libraries. It then identifies some factors that have implications on each form of sustainability. Examples of some current research are used, not exhaustively to review the developments in the specific fields per se but to illustrate the cases, for the economic and social sustainability issues of digital libraries. Similarly the paper draws upon some current research in green IT and cloud computing to illustrate some issues of environmental sustainability that are relevant for digital libraries. Based on these discussions this paper, for the first time, proposes a new model for sustainable digital libraries, and a theoretical framework for study and research in this area.

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[1] http://www.epa.gov/sustainability/basicinfo.htm

2   Sustainability of Digital Libraries

Sustainable information refers to resources that facilitate integration of all the three parts of sustainable development –   social, economic and environmental sustainability,   and it contributes to the strengthening of the processes in which society is transformed according to the ideals of sustainable development [1]. Overall,   the concept of sustainability has not been researched well within the mainstream information science in general and   in the context of   digital libraries in particular [1,2].

In order to study the sustainability of digital   libraries, it is necessary to identify the challenges that are associated with the design, delivery, access and use of digital information.   Again, the issues of sustainability can be considered in the context of the major factors influencing the lifecycle of information – from creation to management, use/re-use, and disposal (when required, for example disposal of analogue information resources and also disposal of computing infrastructure and equipment in the context of digital libraries) [3]. In the context of digital libraries,

- the target for the economic sustainability is to ensure cheaper, easier and better access to digital information. The success can be achieved by building   a sustainable business model as well as taking measures for reductions in the creation, distribution and access to information; and also by taking measures for reductions in the user time and efforts for contextual discovery, access and use of information;
- the target for the social sustainability is to ensure equitable access to information in order to build a better (well informed) and healthy society; the success can be achieved by measures to increase the accessibility and   usability as well impact of digital libraries in every sphere of life and society; and
- the target for the environmental sustainability is to ensure reductions in the environmental impact of digital information; the success can be achieved by reducing the greenhouse gas (GHG) emissions throughout the lifecycle of digital libraries.

These factors are interrelated, and none should be considered in isolation.   For example, rapidly changing ICT infrastructure and information   design to deal with digital content and data will have implications for all the three forms of sustainability of digital libraries: (1) on the economic sustainability because of the increasing   costs, increasing levels of efforts or specific needs for ICT equipment for access to information, etc. (2) on the social sustainability because of changes in the level of equitable access,   and effects on the users' work and culture, and perhaps causing more social exclusion,   and (3) environmental sustainability in terms increase in the GHG emissions due to quick changes in, and disposal of,   the ICT infrastructure, and so on. Furthermore there are a number of external factors that form the foundations of digital libraries, such as the emerging ICT infrastructure and policies; changing web, social networking and mobile technologies; intellectual property rights (IPR), privacy and security issues, etc. Often these factors play a significant part in each area of sustainability and thus affecting the overall sustainability of digital libraries.

Some past research have indirectly touched upon different forms of sustainability of digital information services. For example, a number of   alternative business models for information have been studied in the context of e-books and e-journal subscrip-

tion models in libraries, and also in the context of open access models (see for example, [4]). Similarly there have been many evaluation studies focusing on the impact of digital library services. A significant amount of research has taken place in the broad area of user studies   as well as   digital literacy, social inclusion, etc. in the context of digital libraries (for a review see [5]). Recently Chowdury [2,6-8]   has discussed the environmental aspects of digital information systems and services. However, to date very little research has been done addressing all the three forms of sustainability and the factors that influence the sustainability of digital libraries, their implications as well as their interrelationships in the context of digital library development [3].

3   Economic Sustainability of Digital Libraries

As stated earlier in the paper, the target for the economic sustainability is to ensure cheaper, easier and better access to digital information through a sustainable funding model. Thus for digital libraries, economic sustainability can be achieved by:

1. Building a sustainable business model supporting the economic, technological and manpower   resources for the design, delivery and management for cheaper and easier access to digital content and data in order   to meet the present and future   needs of the user community, and
2. A sustainable model for providing   the economic,   technological as well as intellectual   support for preservation of digital   content and data.

   Although it has been talked about in several publications, economic sustainability of digital libraries still remains a challenge requiring further research and studies [9].

3.1   A Sustainable Business Model for Digital Libraries

While some digital libraries are based on commercial models,   i.e. they require payment or subscriptions for access, many digital libraries have appeared over the past decade or so that are free at the point of use. Such digital libraries are   funded by:

1. governments,   e.g. the US National Science Foundation providing support for the National Science Digital Library, or the National Library of Medicine as part of the US National Institute of Health providing funds for PubMed;
2. specific countries/institutions or consortia for example, various EU countries providing support for Europeana, or specific institutional repositories; and
3. charities, e.g. the Wellcome Library funded by the Wellcome Trust.

   However, sustainable funding is still a major issue for many digital libraries. A recent report on the funding of Europeana notes that it has raised €2.1 million since 2008 from Ministries of Culture & Education across Europe but it is becoming   increasingly difficult to get further commitment from governments and institutions. The report points out that   Europeana has a funding gap for 2011**,** 2012 and 2013 of €1.2 million[2].   Most other digital libraries face a similar funding crisis.

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[2] `http://pro.europeana.eu/documents/844813/851970/Funding+Gap+`
`Paper.pdf`

The open access (OA) movement that emerged in the early 1990s with the establishment of the open archive known as arXiv.org (formerly xxx.lanl.gov) gave a significant boost to digital library development. However, a sustainable business model for open access has yet to appear. Developments through the green route to open access that is based on self-archiving of research papers, has given rise to thousands of institutional repositories but its uptake has been slow due a variety of reasons ranging from the lack of a sustainable funding model for institutions, lack of interests from publishers and authors in participating in the process, the complex workflow and copyright clearance process, duplication of efforts, and so on. Huge amounts of discussions and debates are currently going on around the world on this. Moreover, different institutions follow different practices for creation of institutional repositories. A recent survey of the funding and deployment of institutional repositories [10] notes that:

- institutions that mediate submissions incur less expense than institutions that allow self-archiving,
- institutions that offer additional services incur greater annual operating costs than those who do not, and
- institutions that use open source applications have lower implementation costs but have comparable annual operating costs with institutions that use proprietary software.

The gold route to open access has also suffered from a sustainable business model. Recently the UK government has taken a radical step by accepting the Finch Report [11] and making recommendations based on this through the UK Research Councils (RCUK) for implementation of a model with article processing charges (APCs) to support the gold route to OA. The report and RCUK OA policies recommend APCs as the main vehicle for supporting open access. It is proposed that the UK Research Councils and other public sector funding bodies should establish more effective and flexible arrangements to meet the costs of OA. The Finch Report recommends a funding of £50-60 million per year to support OA to research publications in the UK.

3.2 Long-Term Access: Digital Preservation

Sustainable digital preservation is a societal concern and transcends the boundaries of any content domain, and therefore all parts of society such as the national and international agencies, funders and sponsors of data creation, stakeholder organizations, and individuals have roles in achieving sustainability [13]. However, the DPimpact Study [12] noted that the memory institutions had very limited funding for digital preservation. According to Dobreva & Ruusalepp [14], the economic and social sustainability of digital preservation has not been a major area of digital preservation research. The EU SHAMAN project [15] proposed an Enterprise Architecture-based approach that enables the accommodation of digital preservation concerns in the overall architecture of an organization with the justification that although the preservation of content is not a main business requirement, it is required to enable the actual delivery of value in the primary business. Overall a sustainable funding model for digital preservation has yet to appear.

4   Social Sustainability of Digital Libraries

Broadly speaking social sustainability may be defined as the maintenance and im-provement of well-being of current and future generations [16]. However, the concept of well-being can be defined differently in different contexts ranging from the equity of access to essential services for healthy lifestyle and well-being, to democratic and informed citizenship, to promotion and sharing of positive relations and culture, and so on. Many indicators of sustainable development have been proposed (see for example, [17,18]), but broadly speaking for digital libraries the main goal of social sustainability is to ensure equitable access and use of digital information in every sphere of life and society. Access is a rather broad term here that includes all the ac-tivities related to discovery, access and use/re-use of information for day-to-day busi-ness, pleasure, well-being, knowledge and understanding, and so on. A number of parameters are associated with the social sustainability of digital libraries that have direct or indirect influence on equitable access, such as:

1. HIB (human information behavior) and IS&R (information seeking and re-trieval) issues;
2. Information and digital literacy issues;
3. Accessibility and usability issues including access to ICT and internet, digi-tal library software and interface issues; and
4. Policy and legal issues.

4.1   HIB and IS&R Issues

HIB and IS&R have remained the two most widely researched areas of information science for the past few decades giving rise to several models in information science in general (for details see, [19-21]) and in the context of digital libraries in particular [22,23]. These models discus various personal, contextual, social, cultural and tech-nological issues that influence access to, and use of, digital libraries.

As discussed in the previous section, open access has become a major agenda among governments and research funding bodies. However, still there are some major cultural issues that need to be overcome in order to make it a success. For example, one may argue that the Finch Report [11] and RCUK OA policies (discussed earlier) based on the APCs, may create a situation where publication of a research paper may be decided not only by the quality but the affordability of the authors and institutions to pay the APCs of a target journal. Furthermore, national research assessment exer-cises like the REF in UK, ERA in Australia, are still very much guided by the assess-ment of quality of research in journals and conferences with high impact factors. These assessment measures may affect the social sustainability of open systems.

Although it is generally recognised that open access research outputs get more ac-cess, and therefore more citations, there is still a lack of evidence as to how open access output compare with ranked commercial journals and conferences in terms of their long-term research impact. This remains a major factor affecting the social sus-tainability of open access information and open scholarship, that will have implica-tions on the social sustainability of digital libraries. So, a number of parameters

interplay towards the social sustainability of digital libraries, and to date no systematic research has taken place to study these parameters and their inter-relationships.

4.2   Information and Digital Literacy Issues

Like human information behaviour, information literacy has also remained a major area of research in information studies. There are other related areas of research like digital literacy, digital divide, social inclusion, etc. Access to, and effective use of, digital libraries can be significantly affected by poor information and digital literacy skills of people [5]. A November 2012 BBC news[3] reports that 16 million people in Britain, i.e. about one in four, or one in three in the adult British population, do not have the basic Internet skills. It may be safely assumed that this is not an isolated case and many countries in the world have comparable, or even worse, information and digital literacy skills causing social exclusion. In the context of digital libraries, social exclusion may be caused by a number of factors ranging from the lack of adequate access to ICT infrastructure and services, to lack of digital and information skills that are the pre-requisites for successful access to, and use of, digital library services.

4.3   Accessibility and Usability Issues

Access to, and effective use of, digital libraries can be significantly affected by digital divide that is often manifested by [24]:

- the social divide which is characterized by the difference in access between diverse social groups
- the global divide which is characterized by the difference in terms of access to the Internet technologies, and
- the democratic divide which is characterized by the different applications and uses of digital information in order to engage and participate in social life.

There are different indicators for assessing these different manifestations of digital divide, and these are not only prevalent in the developing world, but also among various communities within the developed nations. For example, more than a third of the US households do not have a broadband connection yet, and only about two-thirds of the 27 EU countries have a broadband connection at home [24]. So, the vision of the Europeana digital library, to provide digital information and culture to everyone in Europe, still cannot be fully utilized because two-thirds of the EU homes do not yet have a broadband connection. The situation in the third world countries is even worse.

Usability of digital libraries is often affected by the user needs and expectations that are set, often wrongly, by the search engines. In a usability study of the Europeana digital library it was noted that young users' information needs and search strategies and expectations were quite different from those of more matured users [25]. The study further noted that many younger users wanted to be able to download,

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[3] http://www.bbc.co.uk/news/technology-20236708

annotate and share digital objects. The latter is a   relatively new phenomenon which is caused   by the recent proliferation of the easy-to-use search engine services that have created a different set of expectations, especially amongst the younger users.

4.4   Policy and Legal Issues

Digital library development is influenced by several policy issues. For example, the recent policies of various research funding bodies with regard to open access can have a significant impact on the economic and social sustainability of digital libraries. Research and funding bodies and institutions in many countries now support the motto of open access and encourage researchers to self-archive their published research papers, some even make it compulsory. For example, the public access policy of the US National Institute of Health (NIH) states that:

> **"**all investigators funded by the NIH submit or have submitted for them to the National Library of Medicine's PubMed Central an electronic version of their final, peer-reviewed manuscripts upon acceptance for publication, to be made publicly available no later than 12 months after the official date of publication."[4]

Wellcome Trust have also introduced a   similar open access policy that:

> "requires electronic copies of any research papers that have been accepted for publication in a peer-reviewed journal, and are supported in whole or in part by Wellcome Trust funding, to be made available through PubMed Central (PMC) and Europe PubMed Central (Europe PMC) as soon as possible and in any event within six months of the journal publisher's official date of final publication"[5]

The   newly introduced OA policy of the European Commission[3] stipulates that as of 2014, all research papers   produced with funding from EU Horizon 2020 will have to be freely accessible to the public. The process of self-archiving has given rise to several specialized open access repository services like PubMed Central, and has given rise to institutional repositories at many specific institutional levels. However, the overall take up of self-archiving has been slow because of   a lack of consistent policy issues and some legal   challenges.

The gold OA model has been adopted by many journals whereby they have introduced article processing charges (APCs), and there are now some hybrid journals that follow both the subscription and APC-based open access model. Some funding bodies have introduced inclusion of APCs within their research funding models. For example, the OA policy of the Wellcome Trust states that the Trust, where appropriate, will provide their research grant holders with additional funding, through their institutions, to cover open access charges. The European Commission recommends the following two options for open access[6]:

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[4] http://publicaccess.nih.gov/policy.htm

[5] http://www.wellcome.ac.uk/About-us/Policy/Policy-and-position-statements/WTD002766.htm

[6] http://europa.eu/rapid/press-release_IP-12-790_en.htm

- Gold open access where research papers will be made immediately accessible on-line by the publisher and the researchers will be eligible for reimbursement of the APCs from the Commission; or
- Green open access where researchers will make their research papers available through an open access repository no later than six months after publication (or 12 months for articles in the fields of social sciences and humanities).

A number of social, institutional and cultural issues are involved here. For example, it is not clear how the APC model of gold OA will be implemented, and similarly how the self-archiving of research papers will be adopted by the academics and researchers across all the education and research institutions and disciplines.

Access to, and use of, digital information is very much hindered due to the inappropriate, and often stringent, intellectual property rights (IPR) and complex digital rights management (DRM) issues. This was identified in several studies (see for example, [26,27,28]). Considering the various recommendations of the Hargreaves Review [28], the UK Government commissioned a feasibility study that recommended the development of a *Copyright Hub* to serve a number of functions including [29]:

- Information and copyright education;
- Registries of rights;
- A marketplace for rights - licensing solutions; and
- Help with the orphan works problem.

The report concluded that a number of issues existed with copyright licensing making them unfit for the digital age [29]. However, it will be interesting to see how the new IP laws influence the publishing industry and digital libraries.

5   Environmental Sustainability of Digital Libraries

Digital libraries are based on a variety of ICT infrastructure that run various information systems and services and the overall lifecycle of a digital library. ICT have a profound impact on the environment causing about 2% of global greenhouse gas emissions (GHG) emissions [7,8]. The information services sector, by virtue of making extensive use of ICT infrastructure and equipment make a significant amount of GHG emissions. In 2010 Google's overall consumption of electricity was reported to be 2.26 million MWh [30]. This is equivalent to emissions from about 11 power stations in Britain [7]. Another estimate shows that about one billion Google search is conducted every day, and thus even on a conservative estimate, one billion grams or 1,000 tonnes of CO_2 (carbon dioxide, a measure used to show GHG emissions) is emitted only for Google search every day [31]. This does not include the client-side ICT and energy usage figures. It is estimated that the Internet consumes between 170 and 307 GW (GigaWatt) of electricity which is equivalent to 1.1–1.9% of the total energy usage of humanity [32]. The HE institutions (HEIs) in the US produce 121 million tonnes of CO_2 in a year which is equivalent to nearly 2% of total annual

GHG emissions in the US, or about a quarter of the entire State of California's annual emissions [33]. It is estimated that in 2008-2009, HEIs in the UK alone used nearly 1,470,000 computers, 250,000 printers and 240,000 servers; and it is estimated that there would be   500,000 tonnes of CO_2 emissions from this electricity use   [34].

   Some data related to the environmental impact of information services based on print and digital content is provided by Chowdhury [8]. Studies also show that use of modern technologies like cloud computing, can   reduce both the economic and environmental impact of digital information [2]. In the UK, the Joint Information Systems Committee (JISC) is promoting the idea of using the cloud computing technology for providing data and information access services for the HEIs that can reduce the environmental costs of information services, and the ICT infrastructure costs.   Some US universities are also   taking similar initiatives in developing cloud-based systems for managing research data and information [35]. In The Netherlands, SURFnet is also taking several measures to promote the use of cloud computing for higher education and research.

    Thus cloud-based information services can improve the environmental sustainability of digital libraries and information services [2,7]. However,   a number of social and user related issues are also associated with cloud-based information services, e.g., access and management issues related to sensitive data and content, information behaviour of users in relation to remote access to data and content; institutional and user culture and practices in relation to access and use of remote digital content and data, and so on.   To date no research has addressed all of these issues in tandem   in relation to   digital libraries, and specific user communities and contexts [2,7].

6   A Sustainability Model for Digital Libraries

Figure 1 presents a sustainability model for digital libraries. This model can be used to build a general framework for research and development in digital libraries. At the core, the model shows that a digital library connects users with digital content and data by   using appropriate ICT. Recent research (e.g. Chowdhury [2,7]) shows that a cloud-based architecture can help us build green information services with significant environmental, and perhaps some economic,   benefits. Although further research is needed to justify the overall economic and environmental gains from cloud architecture,   based on the current trends, the model proposes a cloud-based architecture for digital libraries for providing access to linked content and data.

   However, a sustainable digital library needs sustainable funding models that support various social sustainability measures and also   meet the environmental sustainability requirements. The model shows that appropriate measures should be taken to achieve each form of sustainability that enhances or supports the other forms of sustainability.   The model also shows some areas of research to attain sustainability.
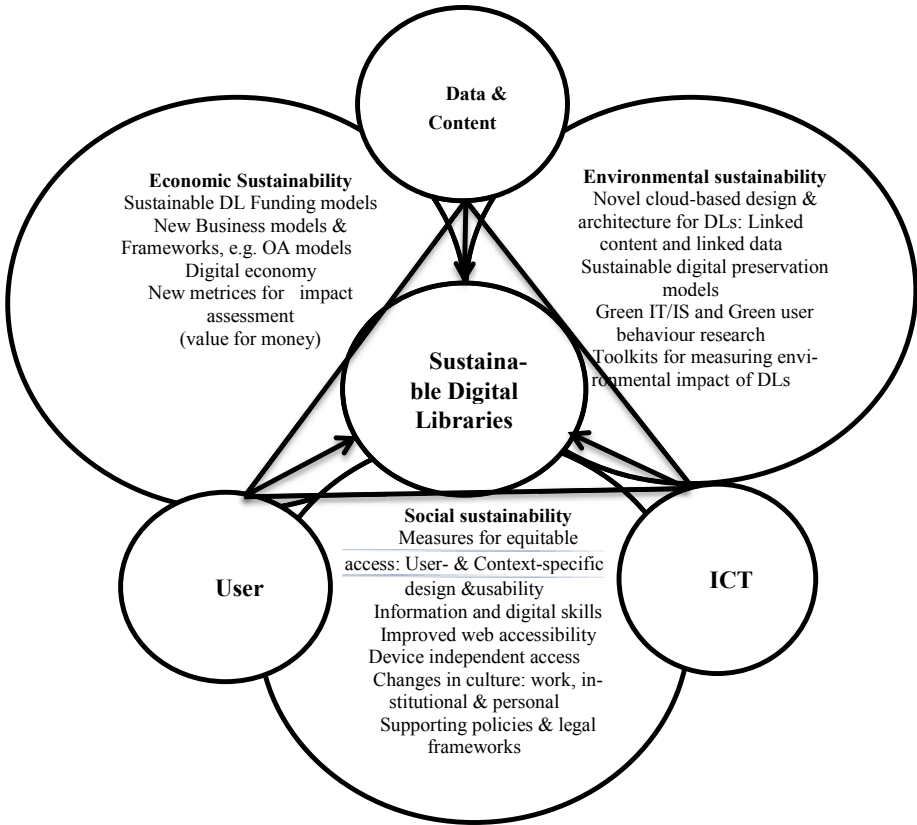
Fig. 1. A Model for Sustainable Digital Libraries

7   Conclusion

In order to build sustainable digital libraries, attention should be paid to all the areas viz. economic, social and environmental sustainability. The generic model shows that sustainable business models to support digital libraries should also support easy and equitable access supported by specific design and usability guidelines that facilitate easier, better and cheaper access, support the personal, institutional and social culture of users, and at the same time conform with the policy and regulatory frameworks of the respective regions, countries and institutions. Similarly, the model shows that green IT, green IS and cloud computing will help to achieve environmental sustainability but this should also meet the requirements of the business/funding models and also the social requirements by providing user- and context-specific access to linked content and data. Overall, the model can serve as a starting point for future research and development with a holistic view of digital libraries, and the various factors that have implications on all the three forms of sustainability.

References

1. Nolin, J.: Sustainable information and information science. Information Research 15(2) (2010), `http://informationr.net/ir/15-2/paper431.html` (retrieved August 8, 2011)
2. Chowdhury, G.G.: Building sustainable information services: A Green IS research agenda. Journal of the American Society for Information Science and Technology 63(4), 633–647 (2012)
3. Chowdhury, G.G.: Sustainability of digital information services. Journal of Documentation (accepted, 2013)
4. Houghton, J., Rasmussen, B., Sheehan, P., Oppenheim, C., Morris, A., Creaser, C., Greenwood, H., Summers, M., Gourlay, A.: Economic implications of alternative scholarly publishing models: exploring the costs and benefits. JISC (2009), `http://ie-repository.jisc.ac.uk/278/3/EI-ASPM_Report.pdf`
5. Liew, C.L.: Digital library research 1997-2007: Organisational and people issues. Journal of Documentation 65(2), 245–266 (2009)
6. Chowdhury, G.G.: Carbon footprint of the knowledge sector: what's the future? Journal of Documentation 66(6), 934–946 (2010)
7. Chowdhury, G.G.: An agenda for green information retrieval research. Information Processing and Management 48(6), 1067–1077 (2012)
8. Chowdhury, G.G.: How digital information services can reduce greenhouse gas emissions. Online Information Review 36(4), 489–506 (2012)
9. Collier, M.: Sustainability of digital libraries: economic and business planning. In: Law, D. (ed.) Libraries in a Digital Age: Fundamentals and Latest Thinking. The Biomedical & Life Sciences Collection. Henry Stewart Talks Ltd., London (2012), `http://hstalks.com`
10. Burns, C.S., Lana, A., Budd, J.M.: Institutional repositories: exploration of costs and value. D-Lib Magazine 19(1/2) (2013), `http://www.dlib.org/dlib/january13/burns/01burns.html`
11. Finch, J.: Accessibility, sustainability, excellence: how to expand access to research publications. Report of the Working Group on Expanding Access to Published Research Findings (2012), `http://www.researchinfonet.org/publish/finch`
12. DPimpact, Socio-economic Drivers and Impact of Longer Term Digital Preservation. Final Report (2009), `http://cordis.europa.eu/fp7/ict/telearn-digicult/dpimpact-final-report.pdf`
13. Blue Ribbon Task Force on Sustainable Digital Preservation and Access, Sustainable economics for a digital planet: ensuring long-term access to digital information. Final report (2010), `http://brtf.sdsc.edu/biblio/BRTF_Final_Report.pdf`
14. Dobreva, M., Ruusalepp, R.: Digital preservation: interoperability ad modum. In: Chowdhury, G.G., Foo, S. (eds.) Digital Libraries and Information Access: Research Perspectives, pp. 193–215. Facet Publishing, London (2012)
15. SHAMAN Reference Architecture, EU FP7 Large Scale Integrated project. Final report (2102), `http://shaman-ip.eu/sites/default/files/SHAMAN-REFERENCE%20ARCHITECTURE-Final%20Version_0.pdf`
16. Mak, M.Y., Peacock, C.J.: Social Sustainability: A Comparison of Case Studies in UK, USA and Australia. In: 17th Pacific Rim Real Estate Society Conference, Gold Coast, January 16-19 (2011), `http://www.prres.net/papers/Mak_Peacock_Social_Sustainability.pdf`

17. Hutchins, M.J., Gierke, J.S., Sutherland, J.W.: Decision making for social sustainability: a lifecycle assessment approach. In: IEEE International Symposium on Technology and Society, ISTAS 2009, May 18-20, pp. 1–5 (2009)
18. Hutchins, M., Sutherland, J.W.: An exploration of measures of social sustainability and their application to supply chain decisions. Journal of Cleaner Production 16(15), 1688–1698 (2008)
19. Wilson, T.: On user studies and information needs. Journal of Documentation, Special publication, 174–186 (2009)
20. Ruthven, I., Kelly, D. (eds.): Interactive information seeking, behaviour and retrieval. Facet Publishing, London (2011)
21. Ingwersen, P., Järvelin, K.: The turn: integration of information seeking and retrieval in context. Springer, Dordrecht (2005)
22. Wilson, T.D., Maceviciute, E.: Users' interactions with digital libraries. In: Chowdhury, G.G., Foo, S. (eds.) Digital Libraries and Information Access: Research Perspectives, pp. 113–128. Facet Publishing, London (2012)
23. Dobreva, M., O'Dwyer, A. (eds.): User studies for digital library development. Facet Publishing, London (2012)
24. Chowdhury, G.G., Chowdhury, S.: Information users and usability in the digital age. Facet Publishing, London (2011)
25. Dobreva, M., Chowdhury, S.: A User-Centric Evaluation of the Europeana Digital Library. In: Chowdhury, G., Koo, C., Hunter, J. (eds.) ICADL 2010. LNCS, vol. 6102, pp. 148–157. Springer, Heidelberg (2010)
26. Chowdhury, G.G.: . Towards the conceptual model of a content service network. In: In: Globalizing academic libraries vision 2020, Proceedings of the International Conference on Academic Libraries, Delhi, October 5-8, pp. 215–220. Delhi Mittal Publications (2009)
27. Chowdhury, G.G., Fraser, M.: Carbon footprint of the knowledge industry and ways to reduce it. World Digital Libraries 4(1), 9–18 (2011)
28. Hargreaves, I.: Digital opportunity: a review of intellectual property and growth. An Independent Report (2011), `http://www.ipo.gov.uk/ipreview-finalreport.pdf`
29. Hooper, R., Lynch, R.: Copyright works: streaming copyright licensing for the digital age. UK Intellectual Property Office (2012), `http://www.ipo.gov.uk/dce-report-phase2.pdf`
30. Albanesius, C.: How much electricity does Google consume each year? PCMag.com (2011), `http://www.pcmag.com/article2/0,2817,2392654,00.asp`
31. Gombiner, J.: Carbon footprinting the internet. Consilience: The Journal of Sustainable Development 5(1), 119–124 (2011)
32. Raghavan, B., Ma, J.: The energy and emergy of the internet. In: Proceedings of the ACM Workshop on Hot Topics in Networks (Hotnets), Cambridge, MA (November 2011), `http://www.cs.berkeley.edu/~jtma/papers/emergy-hotnets2011.pdf`
33. Sinha, P., Schew, W.A., Sawant, A., Kolwaite, K.J., Strode, S.A.: Greenhouse gas emissions from US institutions of higher education. Journal of Air & Waste Management Association 60(5), 568–573 (2010)
34. James, P., Hopkinson, L.: Green ICT: managing sustainable ICT in education and research (2009), `http://www.jisc.ac.uk/publications/programmerelated/2009/sustainableictfinalreport.aspx` (retrieved August 8, 2011)
35. Foster, I.: Research data lifecycle management as a service (2011), `http://www.columbia.edu/~rb2568/rdlm/Foster_UChicago_RDLM2011.pdf`