Sustainable digitalisation through different dimensions of openness: how can lock-in, interoperability, and long-term maintenance of IT systems be addressed?

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ABSTRACT

Lock-in, interoperability, and long-term maintenance are three fundamental challenges that need to be addressed by any organisation involved in development, use and procurement of IT systems. This paper clarifies fundamental concepts and key dimensions of openness and provides examples of work-practices and recommendations for achieving sustainable digitalisation through addressing the fundamental challenges. Specifically, there are three main contributions. First, the concepts open standard, open source software, and open content are clarified and elaborated. Second, the associated three dimensions standard, software, and content are elaborated through examples of how different combinations along the dimensions can enable and inhibit sustainable digitalisation when IT-systems are developed and procured. Third, work-practices used by public sector organisations in specific projects for development and procurement of IT-systems are elaborated with the view to discuss how the three fundamental challenges are being addressed and provide guidance for how organisations can achieve a sustainable digitalisation.

Author Keywords

open standard; open source; open content; lock-in; interoperability; long-term maintenance; IT systems

ACM Classification Keywords

D.2.7: Distribution, Maintenance, and Enhancement
D.2.12: Interoperability
K.5: Legal aspects of computing
K.6.3. Software Management

1. INTRODUCTION

In a recent keynote address the president of the Open Source Initiative (OSI) elaborated on the evolution of openness in the software domain over three decades and highlighted a number of challenges related to (intentional or unintentional) misunderstandings of core concepts which are fundamental to open source and open standards [44].

The purpose of this paper is to clarify fundamental concepts and key dimensions of openness in the software domain and through illustrative examples from specific projects undertaken by public sector organisations illuminate how current work-practices and recommendations can achieve a sustainable digitalisation by addressing the fundamental challenges lock-in, interoperability, and long-term maintenance of IT-systems.

According to Aliprandi [1], the "main goal of an interoperable system is to facilitate interaction between different software applications and to enable sharing and re-use of information among non-homogenous systems." Further, in order to avoid lock-in and an undesirable dependency of specific proprietary technology when an organisation undertakes public procurement, the importance of expressing requirements for interoperability (instead of compatibility) has been stressed as follows in previous research: "compatibility with proprietary technologies should be explicitly excluded from public procurement criteria and replaced by interoperability with products from multiple vendors" [20]. Concerning long-term maintenance of digital assets and longevity of systems, previous research shows that many systems need to be maintained for several decades [29]. Further, previous research also stresses that representation of data over long life-cycles beyond the life-cycle for any specific software application is of particular importance for long-term maintenance of data [28].

Previous research commissioned by the Swedish Competition Authority [31] identified significant lock-in caused by references to closed IT-standards and "found that many IT-projects in the Swedish public sector refer to closed standards which cannot be implemented in open source software" [32]. Further, the same study identified widespread practices amongst public sector organisations to request compatibility (instead of interoperability) with specific proprietary technologies, products and trademarks, something which inhibits interoperability. In addition, the study also illuminated that amongst public sector organisations there is a widespread lack of practices that

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account for requirements related to fundamental needs for long-term maintenance of data and systems [31].

The paper presents three main contributions. First, three fundamental concepts for sustainable digitalisation are clarified and elaborated, namely: open standard, open source software, and open content. Second, the three associated dimensions standard, software, and content are elaborated through illustrative examples of how different combinations along the three dimensions can enable and inhibit sustainable digitalisation when IT-systems are developed and procured. The three dimensions can be conceptualised as an 'openness cube' and the three fundamental challenges lock-in, interoperability, and long-term maintenance are analysed through illustrative examples. By elaborating and illuminating the three dimensions of openness and implications of their combinations, the paper provides an important contribution that fills a gap in the existing body of knowledge. Third, publicly available recommendations and work-practices used by public sector organisations in specific projects for development and procurement of IT-systems are elaborated with the view to discuss and provide guidance for how organisations can achieve sustainable digitalisation by addressing the three fundamental challenges (lock-in, interoperability, and long-term maintenance). Specifically, novel recommendations are presented related to the challenges lock-in, interoperability, and long-term maintenance.

2. RESEARCH APPROACH

The research approach for this study is based on a systematic analysis of published sources (peer-reviewed literature and policy documents), and previously collected documentation from a number of projects undertaken by different public sector organisations in Sweden.

Conduct of the literature analysis was informed by widely used recommendations [50] and emphasised coverage of relevant literature on the topic, and so was "not confined to one research methodology, one set of journals, or one geographic region" [50]. Initially, scientific databases were used for searching high quality papers which included an extensive search for sources in relevant journals and conference proceedings. Besides use of keywords and citations (both forwards and backwards) for identification of sources, the search also involved systematic browsing. The search for papers published in journals and conference proceedings was supplemented with extensive search for relevant policy documents. This search was informed by the researchers' own exposure to, and direct involvement in, various experts groups and policy initiatives at national and EU levels.

The previously collected documentation stems from an underlying study [31] that draws from analysis of project documents from IT projects undertaken by 22 large governmental agencies and 24 municipalities. In total, relevant parts of project documentation from more than 80 IT projects have been thoroughly analysed and reported [31]. In this study, the report from the underlying study [31] and several of the relevant sources from the 80+ IT projects have been revisited and analysed in order to conceptualise and present illustrative examples. The systematic analysis also considered recommendations concerning use of open standards, open source software, and open content that are made publicly available in different countries. Data collection and analysis is also supplemented with experiences and observations by the researchers' own participation – in different roles – in different projects, workshops, seminars, and expert groups during which use of open standards, open source software, and open content have been analysed and scrutinised.

3. ON STANDARDS, SOFTWARE, AND CONTENT

ISO (International Organization for Standardization) defines a standard as a "document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" [22].

Standards are often associated with a number of desirable effects, of which promotion of interoperability is one. For example, it has been claimed that "Standards are designed to promote the interoperability of products and systems by enabling different parties to develop technologies that can be used together." [15]

An open standard is a standard which is provided on royalty-free terms [12,23,38,49] and such a standard can be implemented in software provided under all[1] open source licenses[2] without restriction, whereas closed standards are provided on RAND (or other) terms which are inherently problematic (both from a community and legal basis) for open source projects [36,44]. RAND ('Reasonable And Non-Discriminatory') terms inherently incompatible with the open source definition[3] and previous research that investigated closed standards found that conditions for use of those standards could not be clarified in order to allow for implementation in software [29,30]. Hence, there are

[1] For example, an open file format standard can be implemented and provided in software that is provided under the BSD 3-Clause license (a permissive open source license) that lacks specific patent clauses, and also in software that is implemented and provided in software that is provided under the GPLv3 (a copyleft) license that contains strong patent clauses without additional restrictions.

[2] The Open Source definition which is maintained by the OSI [41] constitutes the foundation for assessing if a proposed license is recognised by OSI as an open source license.

[3] The incompatibility between standards for which organisations have declared standard-essential patents and the open source definition has been elaborated by the current president of the OSI [36,44].

significant risks associated with use of closed standards provided on RAND terms as "conditions for use are unclear" [29]. Specifically, previous research shows that the W3C standard SVG is an open standard, whereas the ISO standard JPEG2000 is a closed standard [29]. Further, it should be noted that an open standard [13] can be implemented in software that is provided under other terms (e.g. as proprietary software, software-as-a-service, public domain software[4], etc.).

A number of countries have stressed the importance of open standards for promoting interoperability and innovation [43] and some countries (e.g. the Netherlands and the U.K.) have adopted various policy initiatives for mandating use of open standards in public sector organisations [38,49]. Further, the Swedish National Procurement Services has published a list of open standards [23], which all can be referenced as mandatory requirements in public procurement [32]. Open standards that are included in this list can be implemented and distributed under different licenses for proprietary software and under all OSI-approved licenses for open source software (OSS).

Previous research has stressed the importance of open standards from a number of different perspectives [4,16,20,24,25,28,47]. For example, the importance of open standards for interoperability and as a driver for innovation has been elaborated as follows: "With the standards like TCP/IP, http, html etc. and the establishment of the world wide web there was a base available, agreed and globally implemented, which enabled and fostered innovation in an unprecedented way. The standards guarantee connectivity and interoperability in an open infrastructure. No constraints, no royalty fees to pay. This has become an open road for innovation. And a major driver for growth – both on the global scale but also regarding the many small and medium sized enterprises everywhere that prosper because of the internet and because of implementing the standards." [16]

For a standard that is provided under RAND terms it follows that a patent owner has agreed with the specific standardisation organisation to provide their patents which impinge on the standard on RAND terms and is bound by an offer from a prospective licensee to negotiate a license on reasonable and non-discriminatory terms. For example, a number of organisations have declared to ISO that they control standard-essential patents which impinge on the technical specification of the ISO standard for the file format TIFF/EP [29].

Further, it is claimed that many of the disputes between companies caused by declarations of standard-essential patents that firms do to standard-setting bodies relate to "the commitments that firms have made to standard-setting bodies during the standard-setting process." [27] This may be unsurprising, given that "firms may make significant investments in research and development, manufacturing, training and marketing, relying on the promise of broad interoperability across a product category (a situation often referred to as lock-in)." [5]

Open source software is software made available under a software license which has been approved by the OSI, see further OSI [41]. Practitioners, researchers, and representatives for the OSI have presented categorisations of OSS licenses and central to "most (if not all) categorisations is that there is a clear distinction between permissive OSS licenses and those that have a copyleft effect" [18]. The recognised OSS licenses have different legal effects and depending on specific preferences amongst stakeholders involved in a given OSS project, different licenses may be preferred for a specific OSS project. Previous research which analysed 200 widely used OSS projects shows that "the vast majority of the 200 investigated OSS projects are provided under a clear minority of all open source licenses recognised by the OSI" [18]. Specifically, the study shows that "there are only 9 different licenses that are used by 5 or more of the top 200 projects (where several of these are different versions of a license)" [18]. Further, it was found that "licenses with strong copyleft are most widely used in the selected OSS projects and the majority of OSS projects (55%) use such licenses." [18]

The Open Definition establishes "principles that define 'openness' in relation to data and content" [39] and recognises a set of licenses that conform to the definition [40]. The Open Definition 2.1 is established in the open definition project that is maintained by Open Knowledge International. The Open Definition is inspired by the establishment of the Open Source Definition that has been established by the OSI as a foundation for determining if a license shall be approved and thereby recognised as an open source license. Similarly, the open definition project has been established by Open Knowledge International in order to recognise licenses which conform to the open definition. Amongst the licenses that conform to the Open Definition 2.1, there are three of the Creative Commons Licenses: CC0, CC-BY-4.0, and CC-BY-SA-4.0 [40].

4. COMBINING THREE DIMENSIONS OF OPENNESS

Different combinations of how standards, software, and content are provided are presented in Table 1.

The three associated dimensions standard, software, and content are elaborated through illustrative examples of how different combinations along the three dimensions can enable and inhibit sustainable digitalisation when IT-systems are developed and procured. The three dimensions can be conceptualised as an 'openness cube'.

[4] The difference between open source software and public domain software has been elaborated by the current president of the OSI [37].

The relationship between standards and their implementation in software is a complex one that imposes a number of policy, legal and socio-technical challenges [8,9,10,20,29,44]. When a technical specification of a standard is implemented in software and is recognised as a 'reference implementation' of the specification it can be used as a definitive interpretation of the standard's specification. If a reference implementation is developed by an OSS project that provides software under a software license that is recognised by OSI as an open source license it follows that the implementation of the technical specification of the standard constitutes an 'OSS reference implementation'.

For a long time, it has been common practice for many OSS projects to implement a technical specification of a standard in OSS. For example, many IETF and W3C standards are being implemented in OSS projects. However, the extent to which a specific implementation of a specific specification actually is broadly recognised as an 'OSS reference implementation' may vary, and the governance of the OSS project may be more or less related to the specific standardisation organisation that governs the standard at hand. More recently, some traditional standardisation organisations have initiated OSS projects in order to enhance their way-of-working for developing and maintaining standards. For example, ETSI [11] has taken initiatives to establish an OSS project for implementing one of their standards under the Apache 2.0 license [35]. Even if the developed OSS does not replace the documented technical specification of the ETSI standard, the developed OSS may provide significant value to ETSI members and beyond if the OSS possesses production quality and also is considered as an OSS reference implementation. Further, the OSS project may also provide very useful contributions to the further development and clarifications of the technical specification of the ETSI standard, even though the intention with this ETSI initiative is to supplement (and not replace) development of the specification of the ETSI standard [35].

There are different experiences concerning use of different approaches for using reference implementations in the process of developing standards. For example, it has been argued that "no implementation is ever completely bug-free, so finding and fixing a bug in the reference implementation essentially changes the standard." [2] Further, based on experiences with IETF standardisation it has been argued that the reference implementation approach can constitute a useful supplement to a technical specification even if use of reference implementations may lead to interoperability challenges: "there may be two independent implementations that each work against the reference implementation but not against each other.

Combination #	Standard	Software	Content	Illustrative examples
1	**open**	**open**	**open**	The PDF/A-1 standard is implemented in the OSS application LibreOffice 5.4.4.2 which can be used to create a PDF-file that is provided under the open content license CC-BY-SA 4.0.
2	**open**	**open**	closed	The PDF/A-1 standard is implemented in the OSS application LibreOffice 5.4.4.2 which can be used to create a PDF-file that is provided under traditional copyright.
3	**open**	closed	**open**	The PDF/A-1 standard is implemented in the proprietary licensed application callas pdfaPilot 7 which can be used to create a PDF-file that is provided under the open content license CC-BY-SA 4.0.
4	**open**	closed	closed	The PDF/A-1 standard is implemented in the proprietary licensed application callas pdfaPilot 7 which can be used to create a PDF-file that is provided under traditional copyright.
5	closed	**open**	**open**	N/A[5]
6	closed	**open**	closed	N/A[6]
7	closed	closed	**open**	The PDF/A-2[7] standard is implemented in the proprietary licensed application callas pdfaPilot 7 which can be used to create a PDF-file that is provided under the open content license CC-BY-SA 4.0.
8	closed	closed	closed	The PDF/A-2[8] standard is implemented in the proprietary licensed application callas pdfaPilot 7 which can be used to create a PDF-file that is provided under traditional copyright.

Table 1. Eight combinations of how standards, software and content are provided

[5] Previous research shows that technical specifications of closed standards which are provided under RAND terms are inherently incompatible with the open source definition and cannot be provided as OSS projects, see [29] for details.

[6] *ibid.*

[7] In acknowledging that no organisation has declared to ISO that they control standard-essential patents which impinge on the PDF/A-2 standard, from analysis undertaken in previous research it follows that PDF/A-2 includes problematic normative references which imply that the PDF/A-2 standard is a closed standard (see [30]). For this reason, it is also not recognised by Kammarkollegiet [23].

[8] *ibid.*

All that said, the reference implementation approach could be useful in conjunction with a written specification, particularly as that specification is being refined." [2] For these reasons, it may be unsurprising that IETF requires interoperable implementations before establishing standards as a strategy for overcoming challenges related to correctness in formal specifications, something which has been stressed in previous research: "for most software standards the formal specification is insufficient and the actual standard may differ from across implementations. Thus, some bodies (such as the IETF) require multiple interoperating implementations before recognising a standard." [20] Further, it has been argued that an OSS reference implementation may achieve the economic effect of an open standard "even without the institutional processes of standard setting, since the reference implementation may act as the formal specification (especially if sufficiently well documented) and be reproduced without economic restrictions by any potential vendor of the technology" [20]. Clearly, an OSS reference implementation of an open standard constitutes an illustrative example of the first (or second) combination in Table 1.

When organisations provide open content and data sets aimed for further processing it is common to provide such sets under terms which conform to the Open Definition 2.1. In the environmental domain, it is common that organisations in different countries provide extensive data sets covering measured temperature for different geographical locations. For example, data sets covering many years of environmental data are provided by the SMHI in the open file format CSV [23] under the Creative Commons CC-BY 4.0 license.

One data set provided by SMHI contains daily air temperature measurements every third hour since 1988 of the temperature in Nikkaluokta[9] (a small village in the North of Sweden). This dataset constitutes an illustrative example of the first (or third) combination in Table 1 (since the CSV file does not contain information concerning which software was used to create the file). Further, a similar dataset containing ground water temperature at various sites in Italy[10] is provided for the years 2003-2015 in the closed file format ".xlsx" and according to metadata created using some version of the software application Microsoft Excel. This dataset constitutes an illustrative example of the seventh combination in Table 1 (since the file format is not an open file format according to [23]).

A research article published in an academic journal that is provided in a closed file format (which may not even be recognised by any standardisation organisation) and in which the content is provided under traditional copyright constitutes a further illustrative example of the eighth combination in Table 1. Alternatively, in case the researchers have chosen to publish their article in a closed file format, but provided their content in the article under an open content license (e.g. CC-BY 4.0) this would constitute an example of the seventh combination in Table 1.

5. ADDRESSING FUNDAMENTAL CHALLENGES IN IT-PROJECTS

This section illuminates how work-practices used by public sector organisations in specific projects for development and procurement of IT-systems impact on opportunities for achieving a sustainable digitalisation. Specifically, work-practices used in specific projects are addressed with respect to how the three fundamental challenges lock-in, interoperability, and long-term maintenance are being addressed. The section presents several recommendations for how organisations can address the fundamental challenges through use of open standards, open source software, and open content.

Findings from a commissioned EU-study show that standards that are set through formal standard setting organisations that "go through a formal development process, they may still contain barriers to implementation by all interested parties, may not be widely implemented by the market, or may not be implemented accurately according to the specifications. This could result in products that despite claiming to implement a standard are not interoperable with other products implementing the same standard." [13] Further, to illustrate barriers the same EU-study highlights as an example the "ISO standard (ISO/IEC 29500) for document formats. The technical specifications of this ISO standard include references to proprietary technology and brand names of specific products. Further, the specification of this ISO standard is not complete (i.e. the technical specification contains references to an external web site (www.microsoft.com) which refers to web pages that are not currently available." [13] In addition, findings from the study stress that determining "the extent to which requiring a standard in a public procurement tender might restrict the competition for the tender, is a challenge of which procurers must be aware." [13]

A comprehensive study of how Swedish public sector stakeholders conduct IT projects shows that there is a widespread practice to refer to standards that lead to lock-in and limited competition in the IT field [31]. Findings from the study show that "a few dominant stakeholders in the market are favoured while smaller stakeholders in the long term risk exclusion. For public sector stakeholders this also contributes to a long-term and often problematic and costly lock-in that can be difficult to unlock." [31]

[9] The data set can be obtained at http://opendata-download-metobs.smhi.se/explore/?parameter=0# by choosing "Lufttemperatur, timvärde" for "parameter" and entering "Nikkaluokta A" at "Sök efter mätplats", and thereafter clicking "Historiska granskade" in the pop-up window.

[10] https://www.europeandataportal.eu/data/sv/dataset/temperatura-delle-acque-sotterranee-montane

Table 2 illustrates specific requirements[11] from projects undertaken by Swedish public sector organisations [31] which include explicit reference to open file format standards that conform to the definition of an open standard according to the EU [12] and the guidelines published by Kammarkollegiet [23] that include a list of open standards that conform to the definition of an open standard according to the EU [12]. As open standards and open file formats can be implemented in software provided under different terms (proprietary, open source, software as a service, etc.) such standards and file formats do not inhibit competition.

Standard and file format	Requirement expressed in specific projects
HTML5	The mobile application shall be developed with HTML5.
XML	Export in XML-format shall be provided as an XML-file per person and agency, and the file name shall be unique and contain the personal identification number and the name of the agency.
CSV	The solution shall be able to access data from Excel and CSV-files.
GIF and PNG	In the e-archive it is possible to convert file to other, in the e-archive, defined formats as follows: … From GIF to PNG
PDF/A-1	The system should be able to convert documents and e-mail to PDF/A (ISO 19005-1:2005) or other long-term sustainable format when documents come in.

Table 2. Examples of specific open standards and open file formats from specific projects.

Similarly, Table 3 illustrates specific requirements from projects that include explicit reference to problematic closed file format standards.

The study [31] presents seven recommendations for how public sector organisations strategically can improve their work-practices when expressing requirements for development and procurement of IT-systems. Two of these recommendations specifically relate to strategies for how an organisation can address the three fundamental challenges: lock-in, interoperability, and long-term maintenance. One recommendation specifically suggests a strategy for addressing challenges related to interoperability and long-term maintenance as follows: "To allow for interoperability and long-term digital preservation, use only open standards and open file formats which have been implemented in software and thus are possible to provide and distribute under different licences (including all licences for open source software)." Further, another recommendation specifically suggests a strategy for addressing challenges related to lock-in: "Refer only to standards included in the guide for open standards published by Kammarkollegiet[12] when specifying requirements for new IT systems, and account specifically, for each reference that a public sector organisation makes to a standard that is not included in the guide, for all risks that the public sector organisation will discriminate individuals and organisations with details of how these references to standards restrict competition."

Standard and file format	Requirement expressed in specific projects
PDF-formats[13]	It shall be possible to export data to and from the most recent Word, Excel and PDF-formats
Tiff, PDF/A, JPEG	It shall be possible to export pictures in standard formats (Tiff, PDF/A, JPEG) that are suitable for archiving according to the rules for our agency.
PDF-formats (PDF/A-2)	In the e-archive it is possible to convert file to other, in the e-archive, defined formats as follows: … From PDF, the Office package (Word, Excel, PPT) and corresponding formats in Open Office to PDF/A-1a and b, PDF/A-2a and b
Excel-formats	The solution shall be able to access data from Excel[14] and CSV-files.
MS Office formats	Statistical information shall be handed over to <name of the governmental agency> via e-mail once a month in a format that shall be possible to read in a standardised MS Office application.

Table 3. Examples of specific closed standards and closed file formats from specific projects.

In many domains which need to maintain systems and digital assets over several decades it is critical that development and adoption of IT-solutions address requirements for very long life-cycles. In such domains, research shows that OSS is "seen as a strategy for long-term maintainability—as well as minimising the risk of lock-in." [34] Further, the US Department of Defense stresses the importance of OSS for effectively achieving its missions, and in so doing recognises that "there have been

[11] The requirements have been translated from Swedish to English and the names of specific organisations have been anonymised.

[12] The Swedish National Procurement Services at Kammarkollegiet (a governmental authority) provides framework contracts in order to support Swedish public sector organisations in public procurement. As part of their support to public sector organisations, they have published a list of open standards which can be referenced as mandatory requirements when organisations undertake public procurement [23]. Open standards included in this list conform to the definition presented in the European Interoperability Framework (EIF) version 1.0 [12].

[13] It should be noted that PDF is a family of formats, some of which are recognised as standards by ISO. Further, some versions of PDF are open standards (e.g. PDF/A-1) according to the definition used by Kammarkollegiet [23], whereas others are closed standards (e.g. PDF/A-2) according to the same definition as identified in previous research [30].

[14] From analysis of the documentation provided in this procurement project it is apparent that "Excel" refers to some version of a software application which is provided by Microsoft.

misconceptions and misinterpretations of the existing laws, policies and regulations that deal with software and apply to OSS, that have hampered effective DoD use and development of OSS." [7]

In addition to recommendations related to use of OSS, the Department of Defense (DoD) recommends use of open standards with reference to the European Interoperability Framework version 1.0 (EIF version 1.0) when presenting recommendations for helping "U.S. government personnel and contractors implement open technology development (OTD) for software within government projects" [42]. Specifically, the DoD stresses that adopted open standards should "at least" meet the definition of an open standard as defined in the EIF version 1.0 [42]. Use of such open standards is recommended as a strategy for avoiding lock-in, and it is recognised that a standard with "a proprietary extension can be a problem, particularly if it is only implemented by a proprietary program (since this effectively eliminates competition, raising costs long-term)." [42]

There are many OSS projects with associated communities that have received significant interest amongst individuals and organisations over several decades. For example, the well-known (copyleft licensed) Linux project has engaged significant interests from many individuals and organisations over several decades, and the community around the LibreOffice project has attracted interests from individuals and organisations beyond the life-cycle of the company (SUN) that initially launched the project as an OSS project [17].

The creator of the web, Tim Berners-Lee, stresses the importance of using open file format standards as an important aspect of linked data (i.e. data "which is released under an open licence", such as Creative Commons CC-BY) for provision of open content [3].

When public sector organisations conduct projects which include provision of data sets, a variety of different file formats are used. For example, a Swedish municipality that provides financial data in a closed file format states "CC0 1.0 (Public Domain Dedication, No Copyright)" on the website from which the data is made available[15]. In so doing, the organisation confuses the two concepts software application and file format when claiming that the data is made available in "Microsoft Excel (.xls)" format. It should be noted that there is a fundamental difference between the proprietary software application "Microsoft Excel" and the representation of data in the specific closed file format ".xls". Further, there is also a difference between a file format as specified in a technical specification of standard (e.g. ISO/IEC 29500) and its implementation in a specific software application (e.g. Microsoft Excel). In the specific example it is also the case that the municipality makes the data available in a different closed file format (".xlsx"). Concerning terms under which the municipality provides the data set, the use of the phrase "No copyright" is (most likely unintentionally) somewhat misleading since "no legal instrument can ever eliminate all copyright interests in a work in every jurisdiction" [6].

Further, experiences from the UK concerning file formats used for provision of open content show that "datasets are often in comma-separated value (CSV) format or spreadsheets" [46].

The importance of using open standards when publishing open content is stressed in national policy. For example, the UK Government strategy for open data states that such data "will be published using open standards, and following relevant recommendations of the World Wide Web Consortium (W3C)" [48].

Considering the eight combinations concerning how standards, software and content can be provided (see Table 1) it follows from the presented recommendations that only two of these combinations are recommended for all organisations that seek to address the three fundamental challenges. The first combination (i.e. open standard, open source software, and open content) is particularly relevant and recommended for many scenarios in all public sector organisations that maintain and provide non confidential data and content for use and re-use. Further, the second combination (i.e. open standard, open source software, and closed content) may be particularly relevant in scenarios when companies seek to ensure that valuable and company sensitive data and content can be maintained and re-used over very long life-cycles which extend beyond the IT-systems that were used to create the content in the first place.

6. DISCUSSION AND CONCLUSION

For many years, standardisation and use of standards have been recognised by public sector organisation to constitute an effective strategy for addressing fundamental challenges related to lock-in and interoperability. In the words of Guijarro [21]: "Public administrations have been very much concerned about the need of avoiding vendor lock-in when procuring IT infrastructure. This concern met a response in the 1980s by means of the standardization. Standardization was a typical response in the 1980s to the concerns related to interoperability and proprietary systems."

The importance of open standards is widely recognised as such standards promote a healthy competitive market, something which has been recognised by the European Commissioner for Competition Policy: "Interoperability is a critical issue for the Commission, and usage of well-established open standards is a key factor to achieve and endorse it." [26] Further, the importance of open standards and open source software are broadly recognised in different domains. For example, in the US military "The

[15] https://catalog.goteborg.se/portal/#view=public&resource=https://catalog.goteborg.se/store/6/resource/75

Army recently partnered with Local Motors to crowdsource new military vehicle designs. The CIA created In-Q-Tel, a venture capital firm that funds tech startups, including open source big data companies like Cloudant and MongoDB." [14] In essence, it is noted that "the defense industry sees what Facebook and Twitter and so many other web companies see: that innovation often comes from openness." [14]

However, in acknowledging that use of standards may have a number of advantages for commercial and public sector organisations it is evident that use of standards may impose significant technical and legal challenges that may inhibit use of open source software [29]. Further, previous research which presents a review of how Swedish public sector organisations express explicit and implicit requirements on the use of different types of IT standards "shows that projects are conducted on the basis of an already locked-in situation with requirements which are based on a strong dependency to different specific technologies and vendors, which affect conditions for conduct. In several cases, the conduct of an IT project will further aggravate an already locked-in situation so that the organisation becomes even more locked-in. This study has not identified any single project where exit costs are calculated in a way so that the original investment is charged. The study has also not identified any single situation in any single IT project in which an organisation actively has taken steps to 'unlock' an already existing lock-in." [31]

Strategic involvement with OSS projects face a number of challenges, and especially for OSS projects that implement technical specifications of standards which implies that there is a need to also engage in standardisation. Previous research shows that it "is important to thoroughly understand how each community works and act according to its 'informal rules'. From a corporate perspective, it is clear that the big challenge is to properly understand this and handle the difficult balance between the shorter-term corporate goal and the longer-term goal of establishing a mutualistic relationship with Open Source communities" [33]. Further, despite reported examples of mutual interaction between developers of standards and OSS projects (e.g. [19]) it is apparent that established work-practices amongst OSS projects may create tension between open source communities and standardisation communities, something which has been extensively discussed amongst participants of OSS projects and traditional standardisation organisations [8,9,10]. For example, it has been noted that a "requirement that all implementations function in a particular way is contrary to every open source license that guarantees complete freedom to create derivative works. The desire of standards organizations to prevent forking of open standards contradicts the requirement of open source licenses that permit any derivative works." [45]

In conclusion, the paper clarifies fundamental concepts and key dimensions of openness and provides examples of work-practices and recommendations for achieving sustainable digitalisation through addressing the three fundamental challenges lock-in, interoperability, and long-term maintenance. Important lessons from analysis of practice shed light on inherent complexities stemming from widespread misconceptions of fundamental concepts related to the three challenges. Further, improved understanding of fundamental concepts, their effects, and how different concepts are inter-related is of key importance for recognising the importance of presented recommendations in order to achieve an improved practice.

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